Iron Bridge

Site 12 Pool Water Quality and Quantity Monitoring Plan

IB Operations Pty Ltd

28 October 2021

662MI-5700-PL-WM-0001

	Site 12 Pool Water Management Plan		662MI-5700-PL-WM-0001
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Status	**DRAFT**		
Author	Sofie Springer	Signature	Click here to enter a date.
Checked	Belinda McCawley	Signature	Click here to enter a date.
Approved	Sean Mcgunnigle	Signature Sean McGunnigle Digitally signed by Sean McGunnigle Date: 2021.10.29 09:46:05 +08'00'	Click here to enter a date.
Confidentiality	**PUBLIC USE (ACCESS TO ALL)**	**Publish on Extranet**	☐ Yes ☐ No
Review Date	Click here to enter a date.		

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Table 1: Site 12 Pool WQQMP Executive Summary

Proposal name	North Star Magnetite Project
Proponent name	Iron Bridge Operations Pty Ltd
Ministerial Statement #	993
Purpose of the EMP	Provide management and monitoring actions for surface water in accordance with the objectives of condition 12-3 and 12-7 of MS 993
Key environmental factor/s, outcome/s and objective/s	**EPA Factor/s and objectives:** Inland Waters **Outcomes:** The Project does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool. **Key Environmental Values:** • Flora, fauna - To maintain the quality of groundwater and surface water so that environmental values are protected. • Hydrological processes – To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected **Key Impacts and Risks:** • Alteration of hydrological processes at Site 12 Pool that lead to degradation of flora and/or fauna habitat • Changes in water quality at Site 12 Pool due to sedimentation and WRD leachate that lead to degradation of flora and/or fauna habitat.
Condition clauses (if applicable)	The proponent shall ensure that the implementation of the proposal within the catchment of Site 12 Pool that is located within the Mine Development Envelope, as delineated in Figure 8 of Schedule 1 and defined by the geographic coordinates in Schedule 2, does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool, through the implementation of conditions 12-3 to 12-7.
Key components in the EMP (if applicable)	N/A
Proposed construction date	May 2021
EMP required pre-construction	Yes ✓ No ☐

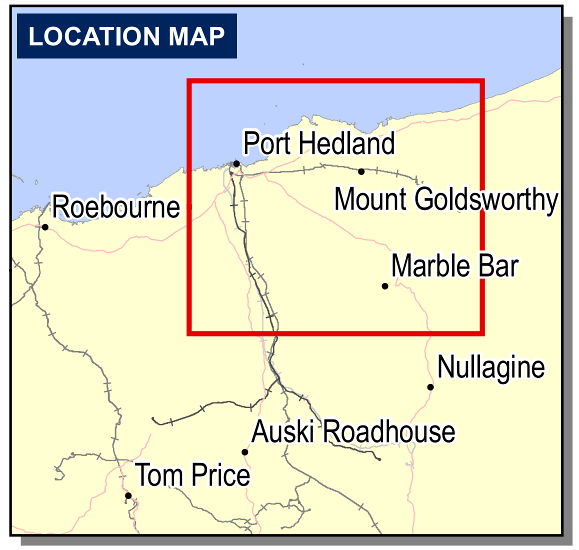
1. CONTEXT, SCOPE AND RATIONALE

1.1 Proposal

The North Star Magnetite Project (the Project) was approved under Part IV of the *Environment Protection Act 1986* (EP Act) by Ministerial Statement 993 (MS) in January 2015. Condition 12 of the MS specifies that a Water Quality and Quantity Monitoring Plan (this Plan) is required to demonstrate that the implementation of the Project within the catchment of 'Site 12 Pool', located within the mine development envelope (MDE) as delineated in Figure 8 of Schedule 1, and defined by the geographic coordinates in Schedule 2, does not have a detrimental impact on the water quality or hydrological regime of 'Site 12 Pool'.

This Plan supersedes the Site 12 Pool Water Quality and Quantity Monitoring Plan (662MI-5700-PL-WM-0001 Rev 0).

The proponent for the North Star Magnetite Project is FMG Iron Bridge (Aust) Pty Ltd (FMG IB). The Project is a joint venture between FMGIB and Formosa Steel IB Pty Ltd (Formosa). The managing entity for the Project is IB Operations Pty Ltd (IBO), a joint venture company between FMG IB and Formosa.



LEGEND

- Infrastructure Development Envelope
- Mining Area Development Envelope
- North Start Extension Disturbance Envelope
- Slurry Corridor Development Envelope
- Water Corridor Development Envelope
- FMG Managed Tenements
- Towns
- FMG Mines
- FMG Rail Alignments

Data Source(s):
Topo; Geoscience Australia
All other data; FMGL, 2020

N

0 10 20 30 40 50
Kilometres

Figure 1
Irgon Bridge Developement Envelopes

Requested By: A. Harris
Drawn By: B. Ralebala
Revised By: sanli
Approved By:
Scale: 1:750,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: 662NS_0000_MP_EN_0158.003_r0

Date: 8/12/2020
Size: A3L
Revision: 0
Confidentiality: 0

Iron Bridge

1.2 Key Environmental Factors

The key environmental factor for Site 12 Pool is hydrological processes and water quality.

The Project activities in the MDE that have the potential to detrimentally impact the surface water quantity and the hydrological regime of Site 12 Pool (which contains habitat for the Pilbara Olive Python), include the following:

- Modification of the upper catchment resulting in decreased flow rates and deteriorating water quality
- Storage of waste material affecting the catchment's runoff characteristics. This can lead to decreased infiltration rates and volumes of runoff into Site 12 Pool. Site 12 Pool monitoring locations are provided in Table 3.

1.3 Condition Requirements

Water quality and quantity monitoring at Site 12 Pool will be undertaken to address the requirements of Condition 12 of MS 993 to ensure implementation of the proposal within the catchment of Site 12 Pool that is located within the MDE does not have a detrimental impact on the water quality of hydrological regime of Site 12 Pool.

To demonstrate this environmental outcome will be achieved, Condition 12-3 requires the following aspects to be included in the Plan:

(1) The location of monitoring sites for monitoring water quality and quantity within Site 12 Pool

(2) Baseline water quality and quantity survey data collected at monitoring sites identified pursuant to Condition 12-3 (i)

(3) Protocols, procedures and frequency for monitoring and evaluating water quality and quantity at monitoring sites required under Condition 12-3(i)

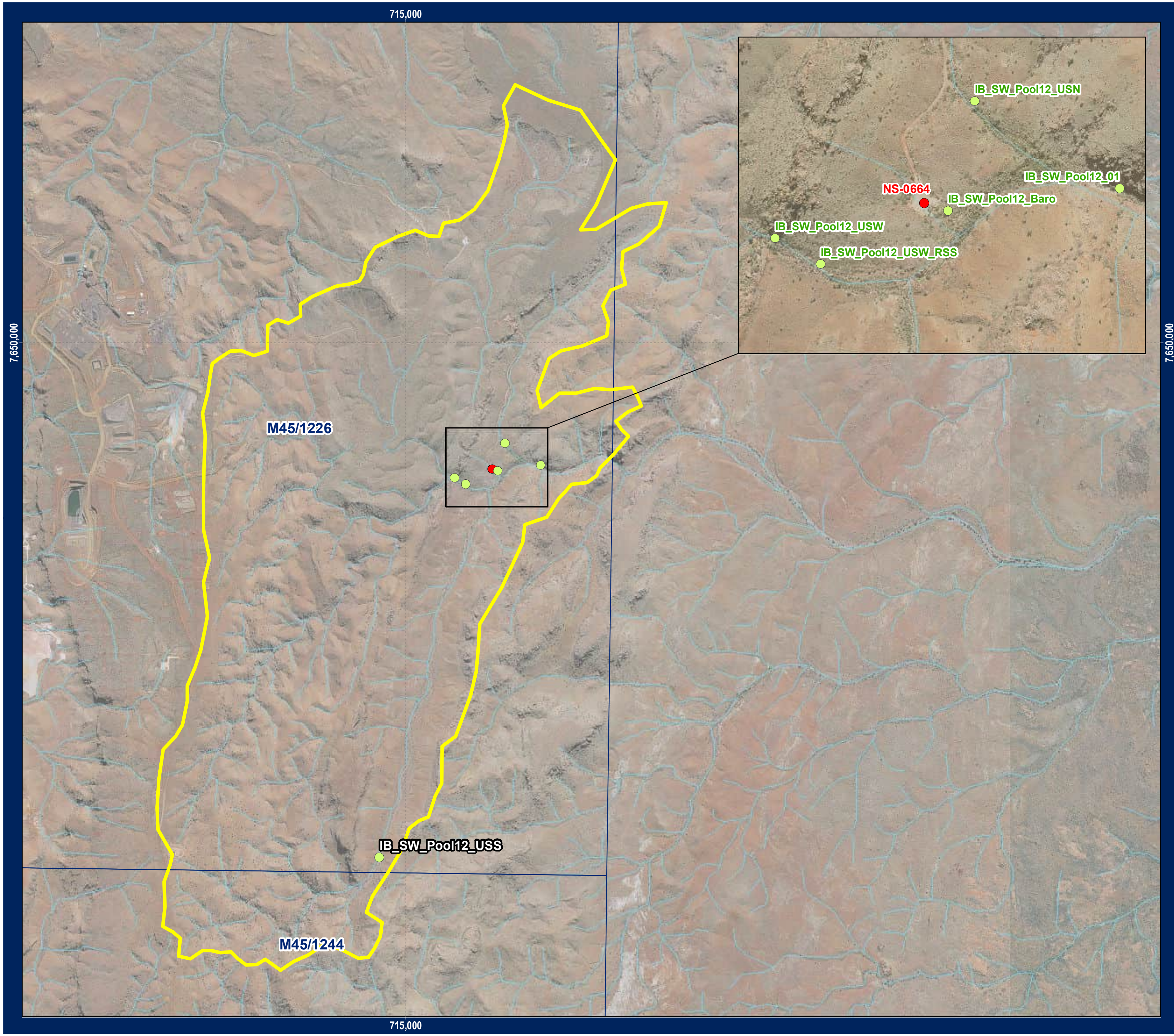
(4) Specified trigger levels for all run-off (including rainwater run-off) from the Mine Development envelope (including pH, total acidity, total alkalinity, dissolved iron), with reference to Managing Acid and metalliferous Drainage (DITR, 2007) and turbidity (including impacts related to increased sedimentation)

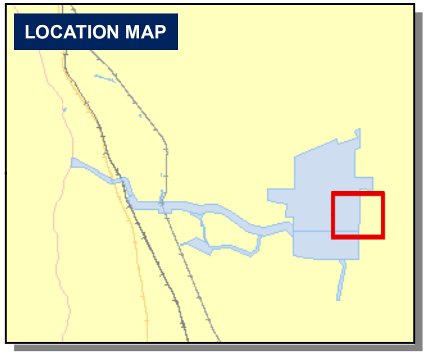
(5) A framework for development of management and contingency actions to be implemented for mitigating changes to the water quality and quantity in the event that any trigger levels referred to in condition 12-3 9(iv) are not met.

This Plan describes the environmental monitoring activities that are required of Iron Bridge Operations (IBO) in relation to surface water resources at Site 12 Pool. Table 2 outlines how this Plan meets the requirements of Condition 12 of MS 993, and where it is referenced throughout.

Table 2: Condition Requirement of MS 993

Conditions	Location in this Plan
12-1 *Prior to the commencement of ground disturbing activities within the catchment of Site 12 Pool that is located with the Mine Development Envelope, as delineated in Figure 8 of Schedule 1 and defined by the geographic coordinates in Schedule 2, the proponent shall prepare a Water Quality and Quantity Monitoring Plan in consultation with the Department of Water, to the requirements of the CEO, to demonstrate that Condition 12-2 has been met*	This Plan addresses these requirements and supersedes Site 12 Pool Water Quality and Quantity Monitoring Plan (662MI-5700-PL-WM-0001 Rev 0).
12-2 *The Proponent shall ensure that the implementation of the proposal within the catchment of Site 12 Pool that is located within the Mine Development Envelope, as delineated in Figure 8 of Schedule 1 and defined by the geographic coordinates in Schedule 2, does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool, through the implementation of conditions 12-3 to 12-7*	The implementation of this Plan will address the requirements of conditions 12-2 to 12-7.
i. The location of monitoring sites for monitoring water quality and quantity within Site 12 Pool. *ii. Baseline water quality and quantity survey data collected at monitoring sites identified pursuant to condition 12-3(i).* *iii. Protocols, procedures and frequency for monitoring sites required under condition 12-3(i);* *iv. Specified trigger levels for all run-off (including rain water run-off) from the Mine Development Envelope (including pH, total acidity, total alkalinity, dissolved iron), with reference to Managing Acid and Metalliferous Drainage (DITR, 2007), and turbidity (including impacts related to increased sedimentation); and* *v. A framework for development of management and contingency actions to be implemented for mitigating changes to the water quality and quantity in the event that any trigger levels referred to in condition 12-3(iv) are not met.*	i. Site 12 Pool monitoring locations are defined in Table 3 and Figure 2. ii. Baseline water quality and quantity data is discussed in Attachments 5 and 6. iii. Monitoring procedures are provided in Attachment 4 iv. Trigger Levels are provided in Section 1.4.4.3 v. Management and contingency actions are provided in Table 3
12-7 *In the event that monitoring required by Condition 12-3(iii), indicates that the trigger levels developed pursuant to Condition 12-3(iv), are exceeded or likely to be exceeded, due to surface or groundwater run-off from within the Mine Development Envelope, the proponent shall:*	
i. Investigate to determine the likely cause(s) of the trigger levels required by condition 12-3(iv) being exceeded; and *ii. If the exceedance is likely to be the result of activities undertaken in implementing the proposal, implement management and/or contingency measures required by condition 12-3(v) and continue implementation until trigger levels required by condition 12-3(iv) are met, or until otherwise agreed by the CEO, and* *iii. Provide a report that describes the investigation required by condition 12-7(i) and measures required by condition 12-3(v) to the CEO within 21 days of identification that criteria required by 12-3(iv) has been exceeded.*	i. Table 3 outlines the investigations required where trigger levels are exceeded. ii. Table 3 outlines what actions are required if exceedances are found to be caused by the Project. iii. Table 3 outlines the reporting requirements of a non-compliance





LEGEND

- Site 12 Pool Catchment
- GOV 50k Drainage
- FMG Managed Tenements
- Site 12 Pool Surface Water Monitoring Locations
- Site 12 Pool Groundwater Bore Monitoring Location

N

0 0.5 1 1.5

Kilometres

Figure 2
Site 12 Pool Existing Monitoring Locations

Requested By: Jayden O'Brien
Date: 29/09/2021
Drawn By: Sang Li
Size: A4L
Revised By: sanli
Revision: 0
Approved By: P. Mastalir
Confidentiality: 0
Scale: 1:30,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: 662NS_0000_MP_EN_0158.002_r2

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1.4 Rationale and Approach

Site 12 Pool is located on a small tributary downstream of a proposed Waste Rock Dump (WRD) at the Project. Condition 12 of MS 993 requires the preparation of a plan prior to the commencement of ground disturbing activities within the hydrological catchment of Site 12 Pool.

It is important to note that the proposed WRD and any potential runoffs will be contained in the upper part of the Site 12 Pool catchment and behind a north-south ridge line that sub-divides the upstream catchment of the Site 12 Pool in several sub-catchments (Plate 1).

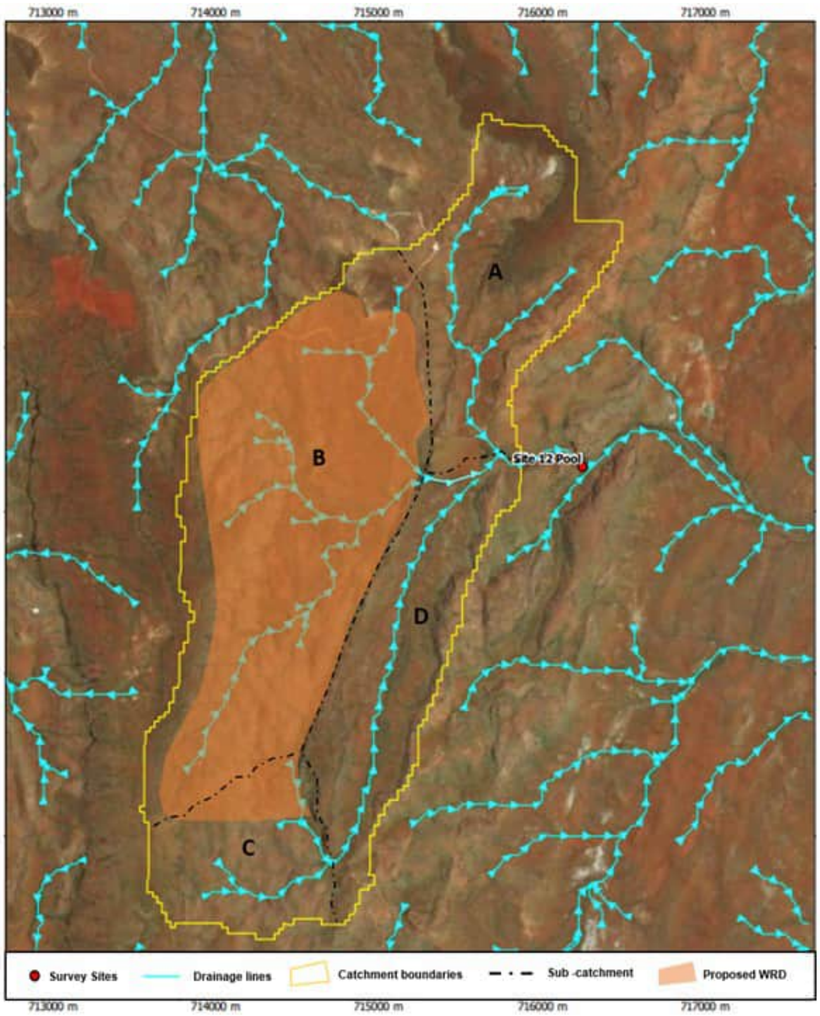

Plate 1: Site 12 Pool Sub-catchments and proposed WRD location (modified from Hydrobiology, 2021)The geological and hydrogeological settings of the Site 12 Pool catchment is summarised below. For further detail, please refer to the Site 12 Pool Hydrogeology Memorandum (FMG IB, 2021a) presented in Attachment 1.

The main geological units within the Site 12 Pool area are the Kangaroo Caves Formation, the Cardinal Formation, and the Corboy Formation comprised of metamorphosed sandstone, siltstone, and shale. These formations are considered sub-vertical as they are located on the eastern limb of the regional Pilgangoora Syncline.

All creek lines within the Site 12 Pool upper catchment and Site 12 Pool lay directly on the fractured bedrock Formations (Plate 2). Groundwater is only found within the weathered fractured bedrock (i.e., Corboy Formation and Kangaroo Caves Formation), and the groundwater levels mimic the local topography, naturally flowing from higher hill terrains (ridge area) to low-lying areas.

Groundwater levels within the Site 12 Pool upper catchment ranged from 340 m AHD at the watershed divide/ridge to 285 m AHD at the NS-0664 monitoring bore, and 279 m AHD further downstream at Site 12 Pool.

The main recharge processes to groundwater are infiltration of rainfall associated with cyclonic events due to the arid climate of the Pilbara region. An analysis of local monitoring bore hydrograph inclusive of daily rainfall records indicate that a minimum of 20 mm/day of rain is required before enough infiltration is generated to recharge the local fractured aquifers within the Site 12 Pool area.

During the dry season, local groundwater levels tend to decrease progressively due to groundwater discharge mechanisms such as seepage into creek beds/pools and evapotranspiration.

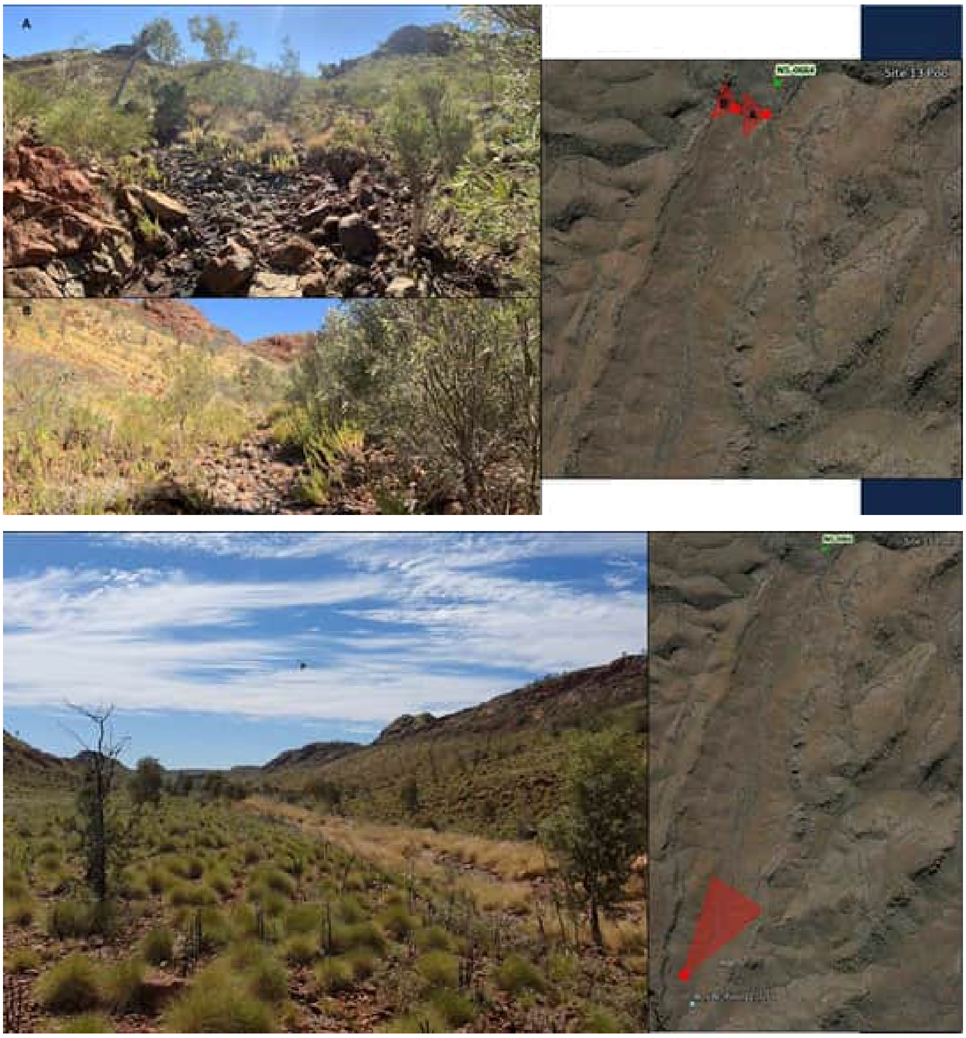

Plate 2: Photos of the upstream catchment of the Site 12 Pool (FMG, 2021)

The purpose of this Plan is to ensure the Project does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool. This Plan supersedes the WQQMP (662MI-5700-PL-WM-0001 Rev 0) approved by the EPA in October 2016.

In preparation of this Plan, monitoring was developed using water quality and hydrological regime investigations undertaken by Hydrobiology since December 2019. The monitoring approach applies a multiple line of evidence approach (ANZG 2018a) to assess whether management goals are achieved, or if a detrimental impact has occurred. In comparison to single line evaluation, this approach gives greater certainty to assessment conclusions, and subsequent management decisions aimed to meet water quality objectives.

Key indicators were selected across the following major groups:

1. Pressure (Drivers): External activities or status that affect water quality
2. Stressor (Direct Effects): Physical-chemical quality elements and non-water quality stressors
3. Ecosystem receptor (Indirect Effects): Biological elements.

Ecosystem receptors are an important line of evidence as they are used to classify the health status of the system, and ultimately determine whether a loss of environmental value/s has occurred.

Stressor lines of evidence (physical, chemical, and non-water quality) provide cause-effect linkages to validate ecological status, use quantitative measures obtained more frequently in an ongoing sampling program, and serve as early indicators to ecological impacts. Additionally, the selection of indicators across the surface water, sediment and biota systems of Site 12 Pool aims to provide a strong basis for meeting the EPA's (2018) objective of maintaining the water quality so that the environmental values are protected.

1.4.1 Environmental Outcomes

The implementation of the Project will not cause a detrimental impact on the water quality or hydrological regime within the catchment of Site 12 Pool located in the MDE.

1.4.2 Baseline Survey and Study Findings (Condition 12-3(ii))

Site 12 Pool is a gorge hosting a chain of small pools over a linear distance of approximately 650 m. Most pools are shallow, with the deepest pool at a maximum depth of approximately 2.5 m. Collectively, these pools are referred to as 'Site 12 Pool'.

Site 12 Pool is a fresh-brackish (<1500 uS/cm), clear (low turbidity), alkaline pool, and water levels and quality are highly seasonal. Site 12 Pool is a magnesium-bicarbonate (Mg-HCO_3) dominated water type with low sulphates (SO_4) (Hydrobiology, 2020, 2021).

Since 2013, monitoring data indicates that water levels in Site 12 Pool are primarily driven in response to rainfall, with pools initially filled by surface water runoff and sustained by groundwater for some time thereafter, before drying out later in the year. Following larger rainfall events, the local fractured rock aquifer can sustain pool water levels for the remainder of the wet season and into the dry season.

Once the local groundwater level drops below the pool elevation, groundwater discharge into Site 12 Pool ceases, and the pool water level will decrease with time due to evaporation until the pool becomes dry, or until a rainfall event replenishes the pool and/or recharges the local groundwater aquifers. Recent observations indicated that the pool completely dried out in 2020 (Hydrobiology, 2021a).

The potential impacts to Site 12 Pool have been informed through the following studies:

- Site 12 Pool Water Quality Monitoring & Hydrological Regime Investigation (Hydrobiology, 2021b)

- Surface Water Monitoring and Aquatic Ecology Survey Baseline Report – Late Wet 2019 /2020 (Hydrobiology, 2021a)
- Site 12 Pool Water Quantity Assessment and Management (662NS-5700-RP-WM-002) (FMG IB, 2021b)
- Site 12 Pool Hydrogeology (662MI-5700-RP-HY-0003) (FMG IB, 2021a).

1.4.2.1 Key Pool Features

The key features of Site 12 Pool were identified through the various baseline studies and were used in the preparation of this Plan to establish appropriate monitoring and management methods. The key features of Site 12 Pool are listed below:

- A bedrock supported natural habitat that lies in a small catchment with typically low rainfall and infrequent high rainfall events largely driven by storm and cyclonic activity.
- Water quality results demonstrate high seasonal variability due to the climatic conditions of the region and temporary nature of the waterbody. The greatest variability recorded occurs following rainfall events.
- Conductivity was typically slightly brackish (1,100-1,300 µS/cm) except during surface water flow events when it would become extremely fresh (<100 µS/cm).
- Predominantly clear (mean turbidity = 2.5 NTU), slightly alkaline (mean pH = 8.5) and a magnesium-bicarbonate ($Ca/Mg\text{-}HCO_3$) dominated water type with low sulphates (SO_4).
- Preliminary baseline data collected between December 2019 and June 2021 indicate that Site 12 Pool is sustained by the local fractured rock aquifers when the local groundwater levels are above the pool elevation and is periodically flushed with fresh surface water flows after rainfall events. The ratio of the Site 12 Pool volume against inflow volume is presented in Site 12 Pool Water Quantity Assessment and Management (FMG IB, 2021b). It takes approximately 2-3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred.
- Represents a larger habitat area relative to other North Star pools, consisting of a series of isolated pools spanning a linear distance of 650 m, and a total estimated area of 1266m^2. Considered likely to have a greater downstream connectivity relative to other pools in the North Star area.
- Most pools are shallow, with the deepest being approximately 2.5 m. The total volume of Site 12 Pool is estimated to be 2,532 m^3 based on an average depth of 2 m. This is a small volume relative to the inflow volume; for example, the 1EY post development estimated inflow is substantially higher (54,198 m^3) (FMG IB, 2021b).

- Recorded water levels were a maximum of approximately 0.6 m above the overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded.

Site 12 Pool is understood to be temporal, running dry for three to ten months of the year (based on a five-year monitoring period). Recent observations indicated Site 12 Pool did not completely dry out between December 2019 and October 2020, likely due to a high rainfall season and a large recharge (cyclonic) event.

Substantial decreases in water levels and the natural drying process of the pool are expected to impact significantly on the ecological health of Site 12 Pool due to evapo-concentration increasing environmental stressors (e.g., salinity) and lower water levels reducing available habitat. Visual observations in the late dry 2019 study indicated there were no fish in Site 12 Pool. However, after a drying event in mid-November 2020 (late dry), the pool retained all three fish species within several weeks of re-wetting in December 2020. These events indicated that the ecological response of Site 12 Pool to natural drying is variable depending on antecedent conditions.

1.4.3 Key Assumptions and Uncertainties

The key assumptions for this Plan include:

- Early Response Indicators adequately detect declining water quality that encompass the range of potential impact mechanisms.
- Ecological parameters adequately detect declining aquatic ecosystem functionality and thereby detect loss of environmental value.
- Seasonal and annual variability in water quality and quantity which result in non-project caused exceedances of Early Response Trigger Levels and Threshold Criteria, are identified by the Early Response Trigger Investigation and validation step of Threshold Criteria (Hydrobiology, 2021b).

The key uncertainties for this Plan are:

- Groundwater flow contribution is variable as the groundwater contribution is linked to the level of the groundwater local fractured rock aquifer. When the groundwater level is above the pool elevation, groundwater discharge will sustain the pool. When the local groundwater level drops below the pool elevation, no groundwater discharge will contribute to Site 12 Pool water levels.
- The baseline surveys provide a representative degree of variability (within and between seasons and years) in the natural system (Hydrobiology, 2021a).

1.4.4 Rationale for Indicators (Condition 12-3(iv)):

Site-specific indicators include water quality and ecological indicators. These are described further in the following sections.

1.4.4.1 Water Quality Indicators

The selected water quality indicators were developed into a monitoring program to use the stressors on the Site 12 Pool system (e.g., salinity, pH) as an early detection for potential detrimental impacts to the ecosystem receptors (e.g., macrophytes).

Water quality indicators were selected from those recommended by Managing Acid and Metalliferous Drainage (DITR 2007), as per MS 993 Condition 12 – 3 (iv), and from the Pressure-stressor-ecosystem Receptor (PSER) Causal Pathway as recommended by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (2018) to be informative of water quality changes that potentially impact environmental values. The selected indicators include conductivity, pH, turbidity, sulphate, total acidity, total alkalinity, dissolved iron, Nitrite & Nitrate (NOx as N).

Seasonal trigger levels for key water quality parameters were calculated from the baseline data to accommodate the high temporal variability anticipated in temporary water systems (ANZG 2018b).

1.4.4.2 Ecological Indicators

Threshold criteria are derived from monitoring ecosystem receptor indicators, identified through changes to water quality in the conceptual impact mechanisms and as indicators of the loss of environmental values. These indicators are diatom communities, macrophyte communities, macroinvertebrate communities and fish communities.

Criteria are qualitatively assessed to accommodate the high natural seasonal variability anticipated in temporary waters, which can impact abundance, and limits the applicability of quantitative assessment.

The rationale for the selected indicators is as follows:

- Algae (diatoms), macroinvertebrates, fish and macrophytes underpin the food web in temporary pools, providing habitat and/or food sources for a diversity of native species include terrestrial or semi-aquatic organisms that may use Site 12 Pool such as reptiles (e.g., Pilbara olive python), avian fauna and amphibians (Halse et al. 2001).
- The selection of these four communities spans multiple trophic levels and phyla which is recommended to capture the variable impact of ecosystems stressors, and detect for example, impacts of bioaccumulation and biomagnification.

- Diatom communities - single-celled algae are effective indicators of ecological change in freshwater systems (Gale 2015). Quantitative sampling using periphytometers placed *in situ* for a defined period measures the capacity for growth, reproduction, and colonisation under current conditions.
- Macroinvertebrate communities - highly studied worldwide as indicators of water quality using a variety of bioindices and predictive models (e.g., EPT, SIGNAL, AUSRIVAS). As for diatoms, the taxonomic groups sensitive or tolerant to declines in water quality is well known and the presence and abundance of these taxa are used to score the water condition of Site 12 Pool.
- Macrophyte communities - effective indicators of ecological change, including monitoring of physical parameter threshold targets (e.g., turbidity blocking photosynthesis of submerged macrophytes or impacts of sedimentation). They are useful indicators of heavy metal bioaccumulation in a waterbody due to immobility, and provide an important habitat and refuge for fauna, especially in shallow waterbodies such as Site 12 Pool.
- Fish communities - higher order organisms with relatively long-life spans. They are useful for visually assessing health including bioaccumulation effects, interannual survivability and reproduction. Evidence of reproduction is sought (i.e., presence of juveniles) to detect sub-lethal effects impacting reproduction or vulnerable size classes.

1.4.4.3 Trigger Level Derivation

The *Managing Acid and Metalliferous Drainage Guidance* (DITR 2007) states that mining activities should not lead to water quality degradation, such that the most conservative of environmental values defined for a water body is compromised. This does not mean that there must be no measurable impacts, but rather that impacts are minimised so that water quality is not degraded to the point where any existing environmental value is lost. Strategies in the *Managing Acid and Metalliferous Drainage Guidance* (DITR 2007) recommends demonstrating the retainment of environmental values by:

- Ensuring that relevant trigger values are not exceeded in receiving water bodies.
- Ensuring that discharge does not result in a statistically significant change in key water quality parameters (no change occurs that is outside the seasonally relevant background concentration plus (or minus) two standard deviations).
- Demonstrating that the discharge will not have ecological impacts on the basis of site-specific ecotoxicological studies.

This Plan presents a three-step trigger assessment approach to align with the relevant guidelines:

1. The **Early Response Trigger Levels**, while seasonal, are not yet refined to encompass the entire (site-specific) high variability in water quality associated with the hydrological cycle (such as first flush events and drying events). Therefore, they are intended to trigger further investigation and not to assess compliance.

2. The **Early Response Trigger Investigation** generated by exceedance of the Early Response Trigger Levels is supported by the *Temporary Waters Guidance* (ANZG 2018b) and involves assessing the water quality against the highly variable hydrological regime (Section 1.4.2). This may result in subsequent refinement of the trigger levels based on site-specific conditions. The outcome of the Early Response Trigger Investigation determines whether the Threshold Criteria is assessed.
3. **Threshold Criteria** is established from the exceedance of Early Response Trigger Levels, no natural hydrological cause identified by Early Response Trigger Investigation, and exceedance of Threshold Criteria. Criteria were developed with regard to the *Temporary Waters Guidance* (ANZG 2018b) and to align with *Managing Acid and Metalliferous Drainage* (DITR 2007). These criteria demonstrate whether the Project has had an ecological impact based on biological parameters reflecting toxicity. The Threshold Criteria are derived from the ecosystem receptor lines of evidence and assess the aquatic ecology. A 'traffic light system' of low, moderate and high-risk criteria is applied where an exceedance of a set number of validated moderate or high-risk criteria is defined as an exceedance and is reportable for purposes of further investigation and compliance monitoring.

Early Response Trigger Levels were developed for the receiving water body which ensures changes to key water quality parameters (as per MS 993 Condition 12) do not occur outside the relevant seasonal background concentration without triggering further investigation. To derive seasonal relevant site-specific trigger values, the median seasonal background concentration plus (and minus for pH) two standard deviations was applied as per the *Managing Acid and Metalliferous Drainage Guidance* (DITR 2007). These were determined to be the most protective compared to values, where available, provided by the *Water Quality Guidelines* (ANZG 2018a).

The trigger levels are interim values and will be reviewed at the completion of the baseline data collection phase. Supplementary monitoring parameters will be collected and analysed in the event of an exceedance of primary monitoring parameters. The supplementary monitoring parameters include:

- Groundwater water levels and quality upstream of Site 12 Pool in bore NS-0664
- Ecosystem health monitoring in Site 12 Pool.

1.4.4.4 Expected Changes in the Intensity, Duration, Magnitude or Geographic Footprint of the Impact.

The Project is expected to comprise approximately 40% of the Site 12 Pool catchment within a WRD, with a footprint of 3 km2. This has the potential to impact the downstream hydrology and water quality of the Site 12 Pool. Impacts to water quality and quantity, and consequently the ecology, may occur due to the following:

- Modification of the upper catchment resulting in decreased flow rates and deteriorating water quality.

- Storage of waste material affecting the catchment's runoff characteristics. This can lead to decreased infiltration rates and volumes of runoff into Site 12 Pool.

These impacts can cause direct or indirect effects which interlink with the natural variability and factors integral to water quality in temporary pools.

Despite the significant reduction in flow, the impact on the scouring ability and total inflow volume to the pools remain largely unchanged. This is due to the relatively small pool volume compared to the inflow volume of the reduced catchment, resulting in small and frequent rainfall events causing Site 12 Pool to fill and overflow, maintaining catchment connectivity.

1.4.4.5 Expected Changes and Rate of Changes at Site 12 Pool

Site 12 Pool hydrology is characterised by relatively large rainfall events at the beginning of the wet season and the associated flushing of water and sediment through the catchment. These highly variable conditions lead to fluctuations in water levels at Site 12 Pool.

Extended periods of little, to no rainfall, is likely to cause evaporation and reduced local groundwater levels, resulting in decreased surface water levels, increased electrical conductivity, increased sulphate, and lower pH levels.

In contrast, significant rainfall events may result in a decrease in electrical conductivity, increased turbidity, increased sulphate and increased dissolved iron. Note that the conductivity may have rebounded to pre-rainfall levels prior to other parameters stabilising.

Rainfall, and consequently run-off, has a varying impact on the water quality depending on when it occurs relative to the wet season and large rainfall events. Minor rainfall in the early or late wet season, infiltrates into the drier soil and has a relatively low impact to the water quality in comparison to similarly sized rainfall that occurs during the mid-wet season where the soil is more saturated. For example, a 21 mm rainfall event in May 2020 had a negligible impact to electrical conductivity, whereas a 31 mm rainfall event in March 2020 decreased the electrical conductivity by more than 60%.

Change in electrical conductivity can be used to guide the expected difference in other parameters. For example, where rainfall has occurred but has caused a small (<1%) change in electrical conductivity, it has likely infiltrated into soil and significant changes to other water quality parameters (e.g., SO_4, turbidity) are not expected to naturally occur. Likewise, where a significant change to electrical conductivity occurs (> 40%) during or following rainfall, significant changes to other parameters (e.g., turbidity) are expected as a result of substantial surface run-off and may be due to the natural seasonal variability.

1.4.4.6 Possible Effects of non-Project Activities

A small amount of disturbance occurred within the Site 12 Pool catchment during Stage 1 of the Project (haematite mining). A small amount of waste oxide material was placed at the top of the catchment, approximately 3.5 km upstream of the pools. Static and kinetic testing was undertaken to determine the potential for waste oxide material to produce elevated levels of acid, salt and metals. These tests demonstrated that the waste from Stage 1 is benign and does not produce harmful leachates.

Given the small amount of waste that has been stored in the WRD (it occupies 2.5 ha in a catchment area upstream of the pools of 775 ha), the characteristics of the material and the distance from Site 12 Pool, it is unlikely that the elevated levels observed in the limited samples taken to date are caused by drainage from the Stage 1 WRD.

2. OUTCOME BASED MONITORING PLAN

This Plan is a requirement of Condition 12 in MS 993. Table 3 details how this Plan focuses on monitoring and evaluating measurable outcomes driven by trigger and threshold criteria, to meet the primary environmental outcome:

There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope (MDE).

Table 3: Provisional Table

EPA Factor/s and objectives: Inland Waters

Outcomes: There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope (MDE).

Key Environmental Values:

- Aquatic ecosystem

Key Impacts and Risks:

- Alteration of hydrological processes at Site 12 Pool that lead to degradation of the aquatic ecosystem;
- Changes in water quality at Site 12 Pool due to sedimentation and WRD leachate that lead to degradation of the aquatic ecosystem.

Outcomes-based provisions

Environmental criteria	Response actions	Monitoring	Reporting

Condition 12-2 The proponent shall ensure that the implementation of the proposal within the catchment of Site 12 Pool that is located within the Mine Development Envelope, as delineated in Figure 8 of Schedule 1 and defined by the geographic coordinates in Schedule 2, does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool, through the implementation of conditions 12-3 to 12-7.

Environmental criteria

Trigger Criterion 1 An exceedance of Early Response Trigger Levels. The values for each parameter are presented in Table 4 of Section 3.1.3

Trigger Criterion 2: Early Response Trigger investigation determines the exceedance is due to Project and not natural causes

Trigger Criterion 3: Ecological parameters meeting moderate or high-risk categories for indicating declining environmental value are validated by expert ecological assessment as not occurring due to natural causes.

Early Response Criteria:

An exceedance of Early Response Levels. The aquatic ecosystem is measured by a set of four ecological criteria (Refer to Table 5 of Section 3.1.3) that are assigned either low, moderate or high risk of indicating loss to the environmental value.

Threshold criteria:

When the designated number of moderate and/or high-risk criteria are met, the Threshold Criteria is determined to be exceeded. Detrimental impact or 'the loss of environmental value' is determined as where the Threshold Criteria is exceeded.

The threshold is:

- ≥2 High Risk Criteria; or
- ≥2 Moderate Risk and ≥1 High Risk Criteria; or
- ≥3 Moderate Risk Criteria.

This approach uses the multiple lines of evidence approach to determine whether a Threshold exceedance has occurred.

Response actions

Trigger Contingency Actions in response to Early Response Trigger Level Exceedance

1. Re-examine water quality results by checking the QA/QC sample result is consistent and ensuring correct calibration of sampling equipment.
2. Resample and reassess to confirm the exceedance. This will also help to establish if the parameter in exceedance is increasing or decreasing in the timeframe since previous sampling.
3. Check Project related operations that have the potential to impact the water quality.
4. Acquire and use current North Star rain gauge data to ensure that the water quality parameter results are being assessed against the correct seasons Early Response Trigger Level (i.e., wet or drying season). Note that seasons vary interannually and the water quality parameters should be compared to the most representative seasons. Early Response Trigger Levels based on rainfall events rather than sampling date.
5. Assess the Visual Inspection results recorded during sampling for indications of causes to changes in water quality and preliminary evidence of ecological impacts (See Appendix D for field datasheet template). For example, check if the *Visual Inspection* notes nearly dry water levels, flood conditions, evidence of increased sedimentation or records of fish death.
6. Acquire and record logger data from the Site 12 Pool water level and water quality data logger and the Site 12 Pool Barometer. Correct the water level for barometric pressure using the barometric data. Assess the water quality relative to the hydrological cycle by plotting the depth, temperature and specific conductivity over time and;
   a. Inspect the conductivity, depth and temperature data against the North Star rain gauge data and the sampled water quality parameters. Evaluate

Monitoring

Method	Monitoring parameters	Frequency[1]	Location[5]
Water loggers	Pool water level & Upstream channel water level	Automatic logging 3 hour for pool and 15 minutes for watercourse. [6]	IB_SW_Pool12_01 IB_SW_Pool12_Baro IB_SW_Pool12_USN IB_SW_Pool12_USW [2] IB_SW_Pool12_USS
	Groundwater level	Automatic logging 3h	NS-0664
Field measurements	Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Turbidity, Temperature	Monthly from Nov to Apr, Quarterly from May to Oct, and/or event based[1]	IB_SW_Pool12_01 IB_SW_Pool12_USN IB_SW_Pool12_USW_RSS [2] IB_SW_Pool12_USS
			NS-0664
Grab water samples for laboratory analysis	TSS, TDS, TOC, DOC Nutrients (Total Nitrogen, Total Phosphorus, Nitrate+Nitrite (NOx as N), Total Kjeldahl Nitrogen: TKN, Ammonia/Ammonium)[9]	Monthly from Nov to Apr, Quarterly from May to Oct, and/or event based[1]	IB_SW_Pool12_01 IB_SW_Pool12_USN IB_SW_Pool12_USW_RSS [2] IB_SW_Pool12_USS
	Ions (Total Alkalinity, Cl, F, Sulphate, Bicarbonate/Carbonate, Ca, Mg, Na, K, Total Acidity SO_4, Hardness) total and dissolved metals (Al, As, Cd, Cr, Cu, Fe, Pb, Ni, Zn, Hg, B, Ba, Be, Co, Mn, Se, V) [7]	Quarterly monitoring	NS-0664

Reporting

Annual reporting will be undertaken in accordance with the OEPA's *Post Assessment Guideline for Preparing a Compliance Assessment Report (CAR), Post Assessment Guideline No. 3.* In the event that Trigger Criteria were exceeded during the reporting period, the CAR will include a description of the effectiveness of the Trigger Level Actions that have been implemented to manage the impact and any adaptive management measures applied as a result of the exceedance.

When an exceedance of Threshold Criteria has occurred, Fortescue will:

- Where the exceedance is attributable to surface run-off or groundwater seepage from the Project, report the exceedance to the CEO (of the OEPA) in accordance with condition 12-7 of MS 933.
- Implement the Threshold Contingency Actions specified in this table as soon as practicable and continue to implement those actions until the CEO has confirmed by notice in writing that it has been demonstrated that the Threshold Criteria are being met and the implementation of the Threshold Contingency Actions is no longer required.
- Investigate to determine the cause of the Threshold Criteria being exceeded.
- Investigate to provide information for the OEPA to determine potential environmental harm or alteration of the environment that occurred due to Threshold Criteria being exceeded.
- Provide a report to the OEPA within 21 days of the exceedance being reported. The report shall include:
  - Details of Threshold Contingency Actions implemented
  - The effectiveness of the Threshold Contingency Actions implemented, against the Threshold Criteria
  - The findings of the investigations
  - Measures to prevent the Threshold Criteria being exceeded in the future

EPA Factor/s and objectives: Inland Waters

Outcomes: There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope (MDE).

Key Environmental Values:

- Aquatic ecosystem

Key Impacts and Risks:

- Alteration of hydrological processes at Site 12 Pool that lead to degradation of the aquatic ecosystem;
- Changes in water quality at Site 12 Pool due to sedimentation and WRD leachate that lead to degradation of the aquatic ecosystem.

whether there is evidence of a natural hydrological cause that could have resulted in the exceedance.

b. Assess for evidence that groundwater connectivity is being maintained.

7. Investigate spatial trends upstream of Site 12 Pool and across the surface water pools at Iron Bridge. This may include:
   a. Assess water level data from loggers located at Site 12 North Upstream, Site 12 West and Site 12 Downstream.
   b. Check Site 12 Pool water quality relative to water quality from recent and baseline concentrations at Site 12 North Upstream, Site 12 West and Site 12 Downstream. This may include water quality from first flush sampling collected using rising stage samplers.
   c. Review water quality and levels across Iron Bridge pools for evidence of a spatial trend across the region.
8. If there is an exceedance of Early Response Trigger levels and the investigation determines no natural hydrological cause for the exceedance, then ecological monitoring is implemented.

Overall Contingency Actions and the Adaptive Management Process

1. Has an Early Response Trigger Level exceedance been recorded?
   a. NO - Resume standard monitoring frequency.
   b. YES - Proceed to Step 2.
2. Validate and investigate the cause for the exceedance as outlined in above contingency actions in response to Early Response Trigger Level Exceedance and proceed to Step 3.
3. Has a natural cause been identified by the Early Response Trigger Level Investigation as the cause of the Early Response Trigger Level exceedance?

	AMD suit (Ag, Bi, Ce, Cs, La, Mo, Rb, Sb, Sc, Sn, Sr, Th, Ti, Tl, U, W)[8]		
Visual inspection and laboratory analysis for ecological monitoring	Ecological Monitoring Indicator - Parameters Diatom community - DSIAR scores and diversity Aquatic macroinvertebrate community - EPT abundance index Fish community - Presence/absence Size structure Sediment quality - Total Alkalinity, Total Acidity SO_4, TSS, Nutrients (Total Nitrogen, Total Phosphorus, Nitrate+Nitrite (NOx as N), Total Kjeldahl Nitrogen: TKN), Ions (Cl, F, Ca, Mg, Na, K), total metals (As, Cd, Cr, Cu, Fe, Pb, Ni, Zn, Hg, B, Ba, Be, Co, Mn, Se, V), TOC Habitat assessment - Wider habitat health Macrophyte diversity - Presence/absence	Biannual[3]	Site 12 Pool ecological sampling site including - Diatom periphytometers – within 2 m of data logger - Fyke net – downstream 3 m from data logger - Sediment – northern edge of data logger cross section - Macrophytes – 50 m reach - Habitat Assessment – upper pools to downstream pools prior to downstream junction - Macroinvertebrates – southern and northern edge of channel at gorge entrance

[1] For the purpose of this Plan, 'event based' is defined as rainfall that has resulted in visual streamflow across a floodway or down a designated river/pool/creek/stream.

Monitoring following rainfall events will only be undertaken once it is considered safe to access monitoring sites.

[2] Water quality impacts are expected to be limited upstream of Site 12 Pool once the WRD access road is extended to block the stream flow from WRD.

[3] Biannual ecological surveys including water quality and sediment quality for laboratory analysis are conducted during the late-wet period (indicative February to April) and the dry periods (indicative September to November), only when water is present.

[4] Limit of Detection (LOD) on metals requested as meeting ANZG (2018) 99% EPL where applicable.

- Measures to prevent, control or abate the environmental harm which may have occurred
- Justification of the threshold remaining, or being adjusted based on better understanding, demonstrating that outcomes will continue to be met.

EPA Factor/s and objectives: Inland Waters

Outcomes: There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope (MDE).

Key Environmental Values:

- Aquatic ecosystem

Key Impacts and Risks:

- Alteration of hydrological processes at Site 12 Pool that lead to degradation of the aquatic ecosystem;
- Changes in water quality at Site 12 Pool due to sedimentation and WRD leachate that lead to degradation of the aquatic ecosystem.

	a. YES – Resume standard monitoring frequency. b. NO – Proceed to Step 4. 4. Has a Threshold Criteria exceedance been recorded? a. NO - Conduct a follow-up visual inspection and re-sampling within two weeks. Record for the purposes of reassessing the trigger levels as part of an active management review. b. YES - Report trigger exceedance as per Reporting Requirement and proceed to Step 5. 5. Develop a case specific Site 12 Pool Recovery Plan and implement the contingency management measures as determined by the plan. A period of time or event (such as substantial rainfall) will likely be required to occur before an assessment of the effectiveness of the Site 12 Pool Recovery Plan can be made. Therefore, proceeding the agreed and case specific time after implementation of the Site 12 Pool Recovery Plan, proceed to Step 6. 6. Reassess from Step 1 following the implementation of the Site 12 Pool Recovery Plan. Depending on the contingency actions implemented, the monitoring parameters or frequency may require review. Where reassessment of Early Response trigger parameters (and any other parameters, if warranted) finds they are below trigger levels, standard monitoring (or the revised monitoring plan) is resumed. Where the reassessment records an exceedance of Threshold Criteria, proceed to step 7. 7. If monitoring indicates that implemented management measures are not mitigating impacts to Site 12 Pool, consider the following a. Review management measures with an adaptive management response. For example: (i) Re-evaluate trigger levels and threshold criteria. (ii) Measure other indicators to assess if Site 12 Pool environmental values have been detrimentally impacted by the guideline value exceedance event.	[5] Site 12 Pool is the primary monitoring location as the reporting location in accordance with MS993 Condition 12, the remaining monitoring sites are non-reporting locations as the supplementary information to support multiple lines of evidence [6] Biannual data downloaded from data logger or when required. [7] For sites in the waterways (IB_SW_Pool12_USN, IB_SW_Pool12_USW_RSS, IB_SW_Pool12_USS) while all dissolved metal parameters are required, total metal parameters only Cu, Hg, Zn are to be measured. [8] AMD suits water quality analysis are applicable to the impacted waterways only (IB_SW_Pool12_USW_RSS, IB_SW_Pool12_USS) [9] TP, TN and NOx have a 28 day holding time, phosphate, nitrate and nitrite individually have a 2 day holding time. The remoteness of the site location prevents reliable laboratory delivery and analysis within less than 5 days (the laboratory recommendation is for samples to arrive at the lab with half the holding time remaining to allow for lab scheduling and processing). The locations of monitoring sites are provided in Figure 2.	

EPA Factor/s and objectives: Inland Waters
Outcomes: There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope (MDE).
Key Environmental Values:

- Aquatic ecosystem

Key Impacts and Risks:

- Alteration of hydrological processes at Site 12 Pool that lead to degradation of the aquatic ecosystem;
- Changes in water quality at Site 12 Pool due to sedimentation and WRD leachate that lead to degradation of the aquatic ecosystem.

	(iii) Workshop potential management measures with site (FMG) stakeholders (e.g., mining, environment, water departments) and potentially bring in expert/regulator advice. Implement appropriate measures. Carry on monthly monitoring frequency until water quality monitoring results do not exceed the Early Response Trigger Levels (see Table 5) for two consecutive sampling events, or as determined by the case specific Site 12 Pool Recovery Plan. Conduct sampling and analysis of biomarker lines of evidence to provide further evidence to establish cause and effect e.g., fish tissue analysis for heavy metal toxicity.		

3. ADAPTIVE MANAGEMENT AND REVIEW

This Plan is the outcome of the adaptive management approach for the preceding WQQMP. Condition 12-5 of MS 993 indicates that revisions to the WQQMP may be approved by the CEO.

Outcome based EMP:
Management of water quality and quantity at Site 12 Pool.

Outcome:
There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from the implementation of the Project within the catchment of Site 12 Pool located in the MDE. Using adaptive management, IBO identified the variability of ephemeral pools and adjusted the measures to meet the outcomes required of Condition 12. This was understood from the following:

- Evaluation of monitoring data and studies which identified that Site 12 Pool was highly variable and did not consider the seasonality of the pools and annual variations.
- Review of assumptions based on data collection undertaken since 2016.
- Re-evaluation of the monitoring triggers which previously assumed that it was a permanent water pool and not temporary, meaning that the ANZECC guidelines were no longer appropriate for use.
- Revision and submission of this Monitoring Plan.

Review of this Plan will be undertaken every three years.

3.1 Early Response Indicators, Criteria and Actions

3.1.1 Monitoring:

Water quality and water levels will be monitored at sites using pressure transducers, samplers and field samples at sites in, and upstream of Site 12 Pool. These sites will include:

- Site 12 Pool (within the pool) (Site name IB_SW_Pool12_01).
- Site 12 Pool_North Upstream (reference watercourse – unimpacted watercourse) (Site name IB_SW_Pool12_USN).
- Site 12 Pool_South Upstream (impacted watercourse) (Site name IB_SW_Pool12_USS).

- Site 12 Pool_West Upstream (impacted watercourse) (Site name IB_SW_Pool12_USW).
- Groundwater bore NS-0664.

The early response trigger and threshold criteria is only applicable for the monitoring of Site 12 Pool. The upstream impact and reference sites will be used to support the monitoring and studies of the Site 12 Pool water quality and quantity impact.

3.1.2 Indicators:

The selected indicators are conductivity, pH, turbidity, sulphate, total acidity, total alkalinity and dissolved iron for water quality. The Plan presents a three-step trigger assessment approach to align with the relevant guidelines.

Early Response Indicators:
Site 12 Pool water quality will assess the presence of stressors on Site 12 Pool as early detection for potential detrimental impacts to the ecosystem receptors.

Rationale for Choice of Early Response Indicators:
Site-specific indicators for water quality and ecological health are the key indicators in the monitoring program. Site-specific indicators of water quality were selected for Site 12 Pool for the relevant stressors and anticipated ecosystem receptors identified for the system in the conceptual model. Water quality indicators were selected from those recommended by *Managing Acid and Metalliferous Drainage Guidance* (DITR, 2017), as per MS 993 Condition 12 – 3 (iv) and from the PSER causal pathway as recommended by ANZG (2018) to be informative of water quality changes that potentially impact environmental values.

Refer to Section 1.4.4.2 for the rationale supporting the ecological indicators.

3.1.3 Trigger Criterium:

Trigger criteria for Early Response Trigger Levels for Site 12 Pool are provided in Table 4.

Table 4: Early Response Trigger Levels for Site 12 Pool

Parameter	Uni	Trigger Level (median seasonal baseline ± 2 SD)[5]	
		Wet season[1]	Dry season[1]
pH	-	<6.5[3] >9.0	<6.5[3] >9.0
Electrical conductivity (SPC)	µs/cm	>1854	>1517
Turbidity	NTU	>37	>1.6

Parameter	Uni	Trigger Level (median seasonal baseline ± 2 SD)[5]	
		Wet season[1]	Dry season[1]
Total alkalinity (as CaCO3)	mg/L	<82.2 >825.8	<364.1 >741.9
Total acidity (as CaCO3)	mg/L	>6.8	>5.5
Sulphate (SO4)	mg/L	>112.4	>65.0
Dissolved iron (Fe)	mg/L	>0.05[2]	>0.05[2]
Nitrite & **Nitrate (NO**x as N)[4]	mg/L	>0.6	>0.6

1. Seasons vary interannually and are determined by the site-specific hydrological cycle. For guidance only, the dry season is typically from May – October and the wet season is typically from November - April.

2 Dissolved Iron (Ferrous Iron mg/L) baseline concentrations consistently below LOD (0.05 mg/L), this LOD was applied as the trigger level as a reliable standard deviation could not be obtained.

3 ANZG 2018 default pH guidelines

4 TP, TN and NOx have a 28-day holding time, Phosphate, nitrate and nitrite individually have a 2-day holding time. The remoteness of the site location prevents reliable laboratory delivery and analysis within less than 5 days (the laboratory recommendation is for samples to arrive at the lab with half the holding time remaining to allow for lab scheduling and processing).

5 The trigger levels are expected to be reviewed and updated as required upon the completion of baseline collection.

Early response criteria:

An exceedance of Early Response Trigger Levels. The aquatic ecosystem is measured by a set of four ecological criteria that are assigned either low, moderate or high risk, indicating loss to the environmental value.

Threshold criteria:

When the designated number of moderate and/or high-risk criteria are met, the Threshold Criteria is determined to be exceeded. Detrimental impact or 'the loss of environmental value' is determined where the Threshold Criteria is exceeded (Table 5). The threshold is as follows:

- ≥2 High Risk Criteria; or
- ≥2 Moderate Risk and ≥1 High Risk Criteria; or
- ≥3 Moderate Risk Criteria.

Table 5: Threshold Criteria

Environmental parameters	LOW RISK[1]	MODERATE RISK[1]	HIGH RISK[1]
Macroinvertebrate communities[2]	Presence of EPT taxa > 0.5*B*	EPT index < 0.5*B* OR SIGNAL2 score < the lower of 2 or *B*-1	No EPT taxa present
Fish communities	*Melanotaenia australis* present including small size classes (<60 mm)	*Melanotaenia australis* present and no small size classes present	No fish species present
Diatom communities[3]	DSIAR score > 0.5*B*	0.5*B* > DSIAR score > 0.2*B*	DSIAR score less than 0.2*B*
Macrophyte communities	Emergent (reed like and tussock/rush like species) present in ≥ isolated abundance	Emergent macrophytes present, with evidence of deteriorating health > *B* maximum	Emergent and submerged macrophytes absent

[1] *B*=Baseline seasonally relevant mean (i.e., wet or dry season ecological baseline values).

[2] The EPT Richness Index estimates water quality by the relative abundance of three major orders of stream insects that have low tolerance to water pollution: *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Tricoptera* (caddisflies). SIGNAL (Stream Invertebrate Grade Number – Average Level) is a scoring system for macro-invertebrate samples from Australian rivers that indicates water quality based on tolerance or sensitivity of macroinvertebrate families present to water quality.

[3] DSIAR score (Diatom Species Index for Australian Rivers score) estimates water quality by the relative abundance of diatom species sensitive to water quality stressors.

3.1.4 Response Actions

3.1.4.1 Trigger Criteria Action

This section provides guidance for assessment steps undertaken in response to an Early Response Trigger Level exceedance and can be adapted on a case-by-case basis.

1. Re-examine water quality results by checking the QA/QC sample result is consistent and ensuring correct calibration of sampling equipment.
2. Resample and reassess to confirm the exceedance. This will also help to establish if the parameter in exceedance is increasing or decreasing in the timeframe since previous sampling.
3. Check project related operations that have the potential to impact the water quality. For example, this may include structural failures or the overflow of a sediment pond during storm events.

4. Acquire and use current North Star rain gauge data to ensure that the water quality parameter results are being assessed against the correct seasons Early Response Trigger Level (i.e., wet or drying season). Note that seasons vary interannually and the water quality parameters should be compared to the most representative seasons Early Response Tigger Levels, based on rainfall events, rather than sampling date. For example, if the wet season has not started prior to sampling in November, the November sample should be evaluated against the drying season Early Response Trigger Levels. For guidance only, the dry season is typically from May – October and the wet season is typically from November – April.

5. Assess the Visual Inspection results recorded during sampling for indications of causes to changes in water quality and preliminary evidence of ecological impacts. For example, check if the Visual Inspection notes nearly dry water levels, flood conditions, evidence of increased sedimentation or records of fish death.

6. Acquire and record logger data from the Site 12 Pool water level and water quality data logger and the Site 12 Pool Barometer. Correct the water level for barometric pressure using the barometric data. Assess the water quality relative to the hydrological cycle by plotting the depth, temperature and specific conductivity over time and:

    a. Inspect the conductivity, depth and temperature data against the North Star rain gauge data and the sampled water quality parameters. Evaluate whether there is evidence of a natural hydrological cause that could have resulted in the exceedance.

    b. Assess for evidence that groundwater connectivity is being maintained. Baseline data shows the conductivity decline during a rainfall event, and subsequent increase to near pre-rainfall conductivity levels over a 2 to 3-week period (assuming no further significant rainfall). The lack of this pattern may be a preliminary indication that reduced groundwater inputs to Site 12 Pool are the cause of the Water Quality trigger exceedance. This may be further assessed by reviewing groundwater quality for changes in conductivity (similar surface water and groundwater levels may reduce the ability to discern connectivity through conductivity patterns) and check for declining groundwater levels in bore NS-0664.

7. Investigate spatial trends upstream of Site 12 Pool and across the surface water pools at Iron Bridge. Refer to Figure 2 for monitoring locations. This may include:

    a. Assess water level data from loggers located at Site 12 North Upstream, Site 12 West and Site 12 Downstream.

    b. Check Site 12 Pool water quality relative to water quality from recent and baseline concentrations at Site 12 North Upstream, Site 12 West and Site 12 Downstream. This may include water quality from first flush sampling collected using rising stage samplers.

    c. Review water quality and levels across Iron Bridge pools for evidence of a spatial trend across the region.

8. If there is an exceedance of Early Response Trigger levels and the investigation determines no natural hydrological cause for the exceedance, then ecological monitoring is implemented.

3.1.4.2 Early Response Actions

Validate and investigate the cause of the Early Response Trigger level exceedance. Where impacts may result from sedimentation, acid and/or metalliferous drainage, consider the following:

- Review the water quality at the groundwater monitoring bore
- Review the seepage management and minimisation control measures
- Review the management and minimisation control measures relating to acid and/or metalliferous drainage to reduce the transport of material from WRD to Site 12 Pool
- Review of erosion control management on WRD.

It is noted that a large toe bund will be constructed as part of the WRD development to minimise the sediment discharge from the WRD catchment to Site 12 Pool.

3.1.4.3 Threshold Criteria Action

Implement the Site 12 Pool Recovery Plan contingency management measures. If monitoring indicates that the measures are not mitigating impacts to Site 12 Pool, consider:

- Review of management measures with an adaptive management response. For example:
  - Re-evaluate trigger levels and threshold criteria.
  - Measure other indicators to assess if Site 12 Pool environmental values have been detrimentally impacted by the guideline value exceedance event.
  - Troubleshooting potential management measures with site stakeholders and potentially bring in expert/regulator advice. Implement appropriate measures.
- Increase the frequency of biannual monitoring to monthly until Water Quality monitoring results do not exceed the Early Response Trigger Levels (see Table 5) for two consecutive sampling events, or as determined by the case specific Site 12 Pool Recovery Plan.
- Conduct sampling and analysis of biomarker lines of evidence to provide further evidence to establish cause and effect (e.g., fish tissue analysis for heavy metal toxicity).

3.2 Review

Revisions of this Plan will be submitted to the relevant State and Commonwealth Governments for approval, in accordance with the applicable approval conditions. In accordance with Condition 12 of MS 993, IBO will continue to implement the latest revision of this Plan.

4. STAKEHOLDER CONSULTATION

The stakeholder engagement undertaken to date is summarised in Table 6. This is a live register and will be updated as required.

Table 6: Stakeholder Consultation

Stakeholder	Correspondence	Comments
DWER	18 January 2016	• Commitment to obtain at least 12 months of baseline water quality data as soon as possible • Inclusion of hydrogeology information upstream of Site 12 Pool Clarification regarding contingency actions and monitoring frequency where trigger levels are exceeded.
DWER	4 April 2016	EPA recommends the monitoring programme is extended to include groundwater levels and water quality at bore NS-0064, as water in this bore is likely to represent the alluvial sources of Site 12 Pool water. It is not necessary to develop triggers for this bore.
EPA	12 August 2016	• EPA requires the Plan to include locations of surface water/storm water monitoring sites within the proposal boundary, in particular in culverts, drainage basins and around the base of the waste rock dump to monitor any leachate discharged to the environment. • EPA considers the site-specific Trigger Values should be developed using the 80th percentile value of collected data. • Frequency of monitoring activities detailed in the plan will not provide sufficient early warning for potential breaches. The EPA requires the frequency in the plan to be amended to include the following: o Monthly leachate monitoring from the waste rock dump o Significant rainfall event monitoring following each event • Specified trigger levels should include a measure for total alkalinity given the current chemical composition of the Site 12 Pool water and the likely that buffering of some metals may occur. Parameters should also reflect the analytes that would likely to occur in the leachate from the proposed Waste Rock Dump • The information provided in the Site 12 Pool Water Quality and Quantity Monitoring Plan indicates that water quality is close to pristine. This indicates that any perceived impact on pool water quality from feral animal grazing is negligible. The Environmental Protection Authority Report 1514 determined that the Site 12 Pool was regionally significant and recommended that condition 12 be applied to maintain existing water quality and quantity in Site 12 Pool The EPA requires the protection level to be amended to 99% species protection level to adequately ensure condition 12-2 is met and the existing quality and quantity of the Site 12 Pool is maintained. Any change to this protection level should only occur where comprehensive biological effects and monitoring data show that biodiversity would not be altered.

Stakeholder	Correspondence	Comments
		• Plan is required to be amended to clearly detail that the monitoring frequency will be adjusted to monthly when an investigation determines that trigger exceedances are Project attributable. EPA requires the Plan to be amended to include threshold criteria and include threshold contingency actions.
EPA	26 October 2016	Approval of the Site 12 Pool Water Quality and Quantity Monitoring Plan.
	January 2018	North Star Stage 1 Project placed in care and maintenance
	June 2019	Project restarted in preparation for Stage 2.
DWER	29 January 2020	Meeting with DWER to discuss updated Site 12 Pool Water Quality and Quantity Monitoring Plan
DMIRS	13 March 2020	Feedback on Mine Proposal Stage 2A: **Section 6.3.1 – Environmental Management Plans**: The following additional plans are required, or, where FMG consider they are addressed in other existing documents, detail the name and scope of the management: • Surface Water Management Plan, with a brief summary of key surface water management during operations. DMIRS expect that this document will present locations of all surface water management controls and monitoring sites, detail the design criteria based on the critical duration rainfall event, specify maintenance and monitoring program (water quality, quantity, erosion and sedimentation, riparian vegetation health). Specific areas which need to be addressed are: o Turner River; o Central Creek Pool; o Fig Pool; o Pit Flood Response Pipeline (PFRP) discharge location, discharge water quality criteria and rate of discharge o RWP emergency spillway discharge location.
DWER	31 August 2021	Meeting with DWER to discuss DWER RFI on the groundwater items 1, 2, 3 and 5 of the Site 12 Pool Water Quality and Quantity Monitoring Plan received on 18 August 2021. Recommendation from DWER: • Update the conceptual hydrogeology in the Site 12 Pool Water Quality and Quantity Monitoring Plan – include photos from the

Stakeholder	Correspondence	Comments
		catchment and figure with proposed WRD development area within the catchment and proposed monitoring sites (SW and GW sites) • Update the conceptual hydrogeology in the Hydrobiology report (2020a) • Resubmit the plan to the EPA with the amendments.

REFERENCES

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Environmental Protection Authority, 2007. EPA Guidelines Regulatory Monitoring and Testing: Water and Wastewater sampling.

FMG IB. (2021a). Site 12 Pool Hydrogeology. Report 662MI-5700-RP-HY-0003.

Hydrobiology. (2021). P19028 v1.1 Site 12 Pool Water Quality and Hydrological Regime Investigation. Prepared on behalf of Iron Bridge Operations.

Hydrobiology. (2021). P21012 v1.1 Surface Water Monitoring and Aquatic Ecology Survey Baseline Report. Prepared on behalf of Iron Bridge Operations.

Attachment 1: Site 12 Pool Hydrology Memorandum (FMG, 2021)

Memo

Iron Bridge – Site 12 Pool Hydrogeology

OUR REF	662MI-5700-RP-HY-0003_Rev1	**DATE**	27/10/2021
TO	Mudit Tandon; Ying Yu; Kristy Chandler	**CC**	Doug Brown; Callum Gilligan
FROM	Sylvie Ogier-Halim		

SUMMARY

This memorandum summarised the conceptual hydrogeology of the Site 12 Pool area.

The main geological units within the Site 12 Pool area are the Kangaroo Caves Formation, the Cardinal Formation, and the Corboy Formation made of metamorphosed sandstone, siltstone, and shale. Structurally the Formations are sub-vertical as they are located on the eastern limb of the regional Pilgangoora Syncline.

All creek lines within the Site 12 Pool upper catchment and Site 12 Pool lay directly on the fractured bedrock Formations.

Groundwater is only found within the weathered fractured bedrock (i.e. Corboy Formation and Kangaroo Caves Formation) and the groundwater levels mimic the local topography and flow from higher hill terrains (ridge area) to low-lying areas. Groundwater levels within the Site 12 Pool upper catchment ranged from 340 m AHD at the watershed divide/ridge to 285 m AHD at the NS-0664 monitoring bore, and 279 m AHD further downstream at Site 12 Pool.

Under the arid climate experienced in the Pilbara region, the main recharge processes to groundwater are infiltration of rainfall associated with cyclonic events. Analysis of local monitoring bore hydrograph with daily rainfall records indicate that a minimum of 20 mm/day of rain is required before enough infiltration is generated to recharge the local fractured aquifers within the Site 12 Pool area.

During the dry season, local groundwater levels tend to decrease progressively due to groundwater discharge mechanisms such as seepage into creek beds/pools and evapotranspiration.

Analysis of both Site 12 Pool and NS-0664 bore hydrographs indicate that Site 12 Pool is sustained by the local fractured groundwater aquifers during the dry season until the local groundwater levels drop below ~ 279.25 m AHD at Site 12 Pool. When this elevation is reached, the pool is no longer sustained by local groundwater seepage, and pool water levels decrease with time due to evaporation until the pool becomes dry, or until a rainfall event replenishes the pool and/or recharges the local groundwater aquifers.

1. BACKGROUND

Site 12 Pool is part of a series of shallow pools that lie to the east of the Iron Bridge (IB) Project on a small tributary to the upper Six Mile Creek. The pool is located within the Strelley River catchment and downstream of the proposed Waste Rock Dump (WRD; Figure 1).

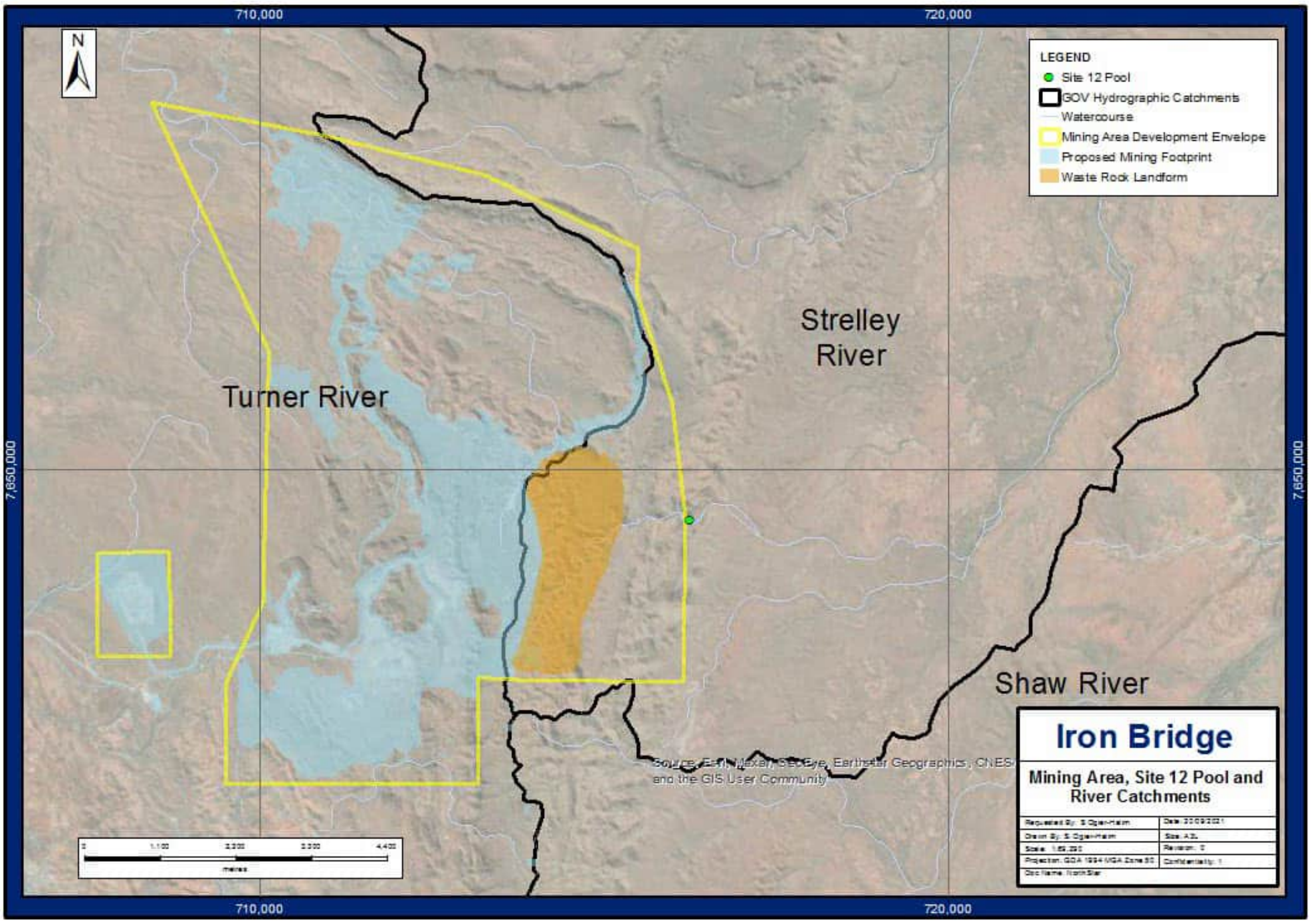

Figure 1 : Location of Mining Area, Site 12 pool and River Catchments

The proposed WRD is located within the Site 12 Pool upper catchment area within the Strelley River Catchment. The WRD will be contained between the Turner River / Strelley River watershed divide, and a north-south ridge line that sub-divides the Site 12 Pool upper catchment in several sub-catchments (Figure 2). This location has been chosen to physically contain the WRD and any potential WRD runoffs behind the north-south ridge line. The proposed WRD footprint will entail mainly 1 sub catchment (sub-catchment B) and will encroach on a small part of the sub-catchment C, leaving the others sub-catchments (sub-catchment A and sub-catchment D) in their natural states, i.e. free of WRD and potential WRD runoffs.

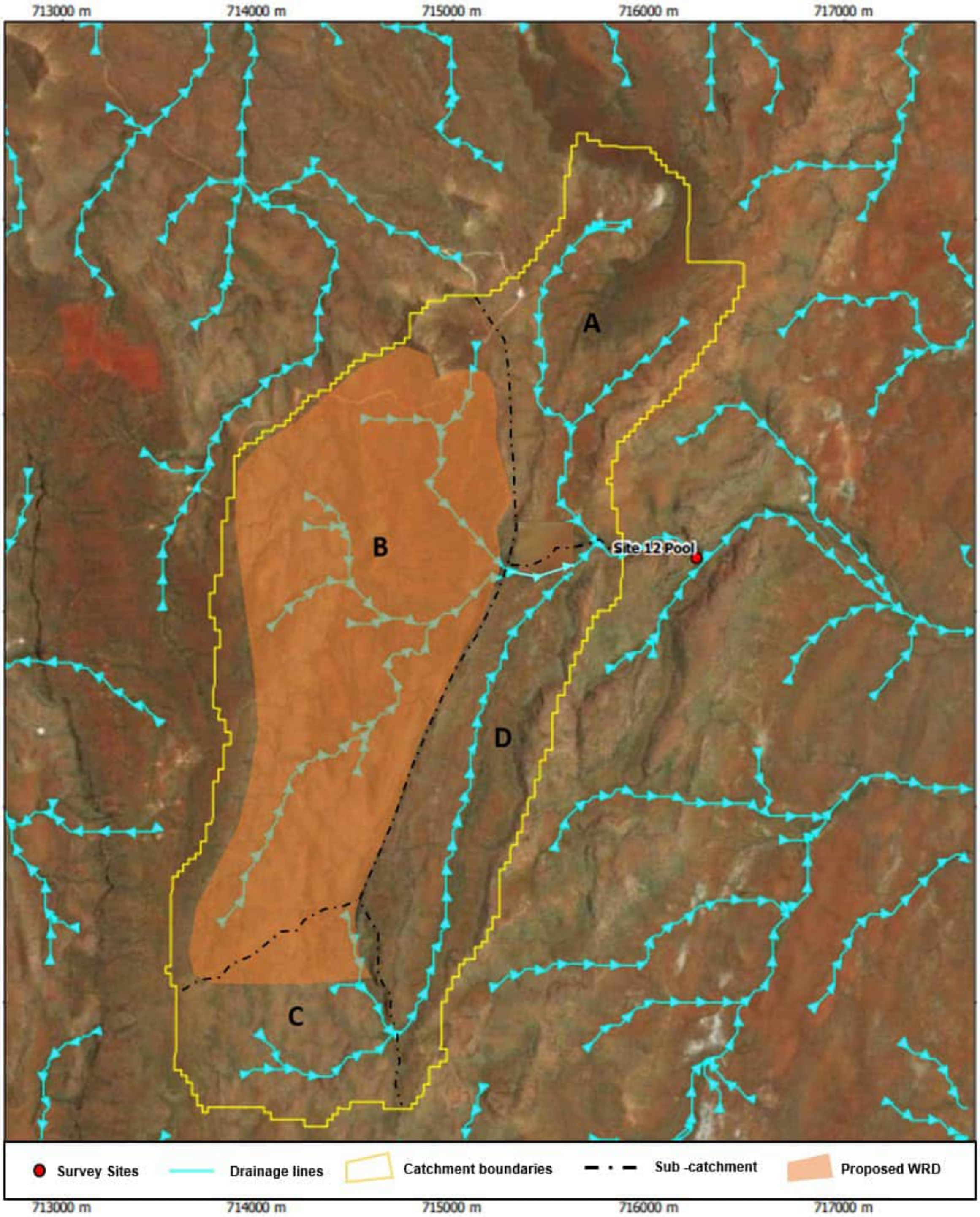

Figure 2: Site 12 Pool Sub-catchments and proposed WRD location (modified from Hydrobiology, 2021)

2. GEOLOGY

2.1 Mine Geology

The IB magnetite iron ore deposit is hosted within the Palaeoarchaean Pincunah Banded-iron Member of the Sulphur Springs Group in the granite-greenstone terrane of the Archaean core of the Pilbara craton (Table 1 and Figure 3).

Table 1: Stratigraphy of the IB Deposit

Geology				
SOANESVILLE GROUP	CARDINAL/ CORBOY FORMATION			EASTERN SHALE AND QUARTZITE (interbedded shale and sandstone, gradational contact marked by a silicified zone)
SULPHUR SPRINGS GROUP (2,500 – 3,000 m)	KANGAROO CAVES FORMATION	Pincunah Member		GRADATIONAL BIF FROM SEDIMENTARY SEQUENCE Micro-mesobanded stilpnomelane + siderite w meso-macrobanded quartz-rich cherts. Magnetite (5-10%) laminations overprint bands
				SILTSTONE & SANDSTONE (Fine Grained siliceous sediments) Micro-mesobanded stilpnomelane + siderite w meso-macrobanded quartz-rich cherts. Magnetite (10-15%) laminations overprint bands
			Main ore zone	GREY AND RED BIF (Main Magnetite bearing lithology) Red bands of Jasper Cherts, micro-mesobands of Magnetite (15-20%) w stilpnomelane + siderite
				WESTERN SHALE (micro-mesobanded fine grained shales and dark cherts with stilpnomelane, siderite + pyrite (2-10%)) Macrobanded BIF (up to 15 m) near top of the formation. Identified as a source of potentially acid generating materials.

The Sulphur Springs Group comprise from base to top:

- the Leilira Formation composed of metamorphose quartz sandstone and minor layered quartz carbonate rock and siltstone, overlain by
- the Kunagunarrina Formation composed of greenschist facies, dominantly of komatiitic, high-Mg and tholeiitic metabasalt, and
- the Kangaroo Caves Formation, representing a differentiated volcanic-volcaniclastic pile of mainly tholeiitic magmatic affinity, varying from basalt to rhyolite, with comagmatic granite. It includes chert, local polymictic mega breccia and iron-formation, and calc-alkaline rhyodacite. The Pincunah Banded-iron Member occurs at the top of this unit and comprises metamorphosed jaspilitic banded-iron formation (BIF) with minor layered chert and shale.

Structurally, the ore body is located on the western limb of the regional Pilgangoora Syncline within the Pincunah BIF. The Pincunah BIF varies in stratigraphic thickness from 350 to 450 m, forming a north-south oriented flat-top strike-ridge with an elevation of 80 to 120 m above the surrounding countryside. The host BIF dips between 70°E and 80°W and is continuous to at least 500 m below the surface. Small scale folding is evident, although no macrofolds have been identified. The western footwall sequence of the host BIF comprises highly recessive and poorly exposed shales up to 500 m thick (Kangaroo Formation). The contact between the shales and the host BIF, which is likely a sheared/faulted zone, forms on the surface a prominent cliff. The eastern hanging wall sequence of the host BIF is over 400 m thick and is made up of inter-bedded shales, mudstones, cherts, BIF and quartzite typically between 1 and 20 m thick (Corboy Formation). The sequence is cut by a number of faults which are in general sub-parallel to strike.

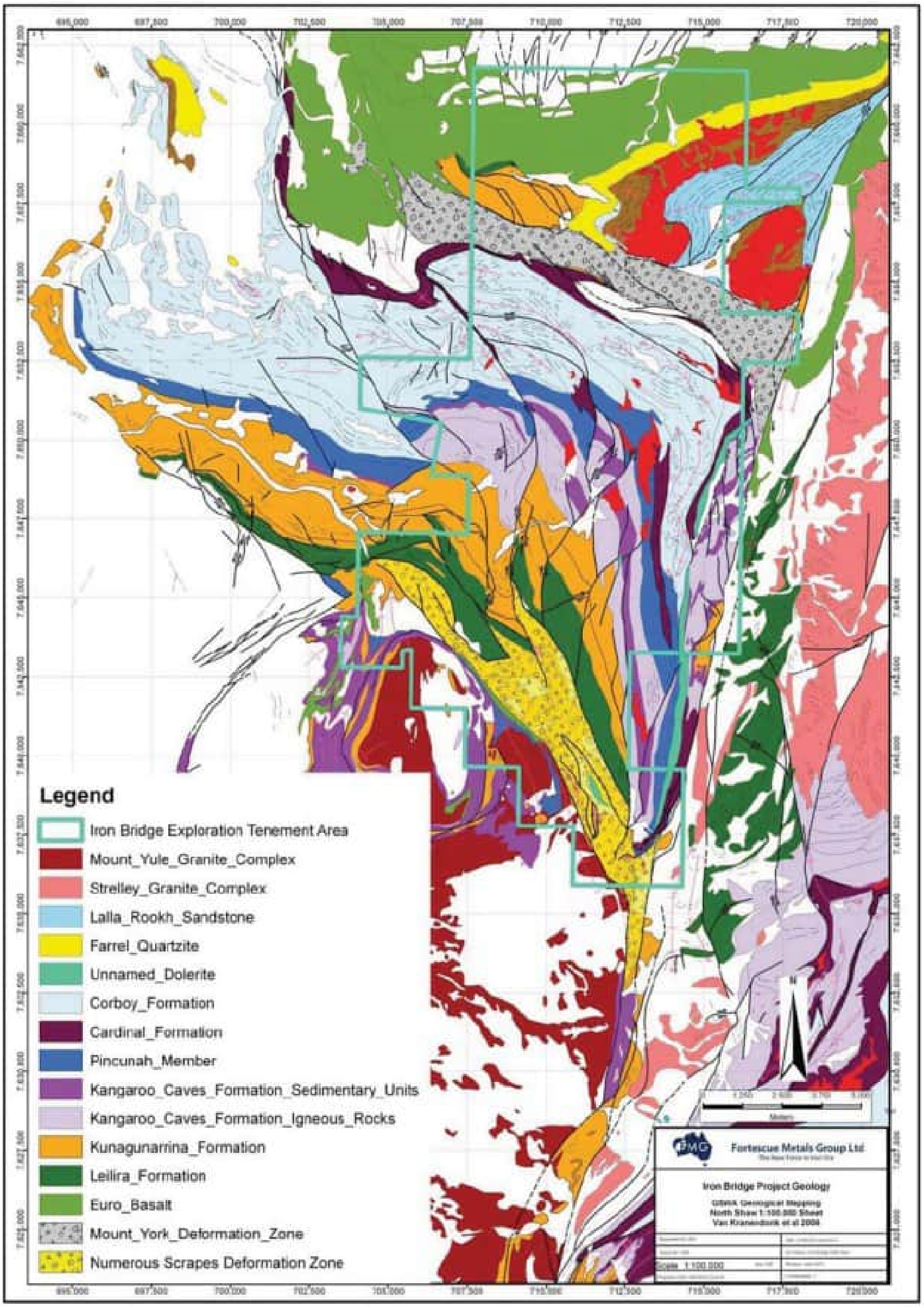

Figure 3: IB Deposit Geology

2.2 Site 12 Pool Geology

The main geological units within the Site 12 Pool area are the Kangaroo Caves Formation made of metamorphosed shale and andesite, the Cardinal Formation made of metamorphosed sandstone, siltstone and shale, and the Corboy Formation made of metamorphosed sandstone, siltstone and shale and forming the Eastern Shale Sequence of the IB magnetite mineralisation (Figure 4).

Structurally, the Formations are sub-vertical (dipping between 70°E and 80°W) as they are located on the eastern limb of the regional Pilgangoora Syncline.

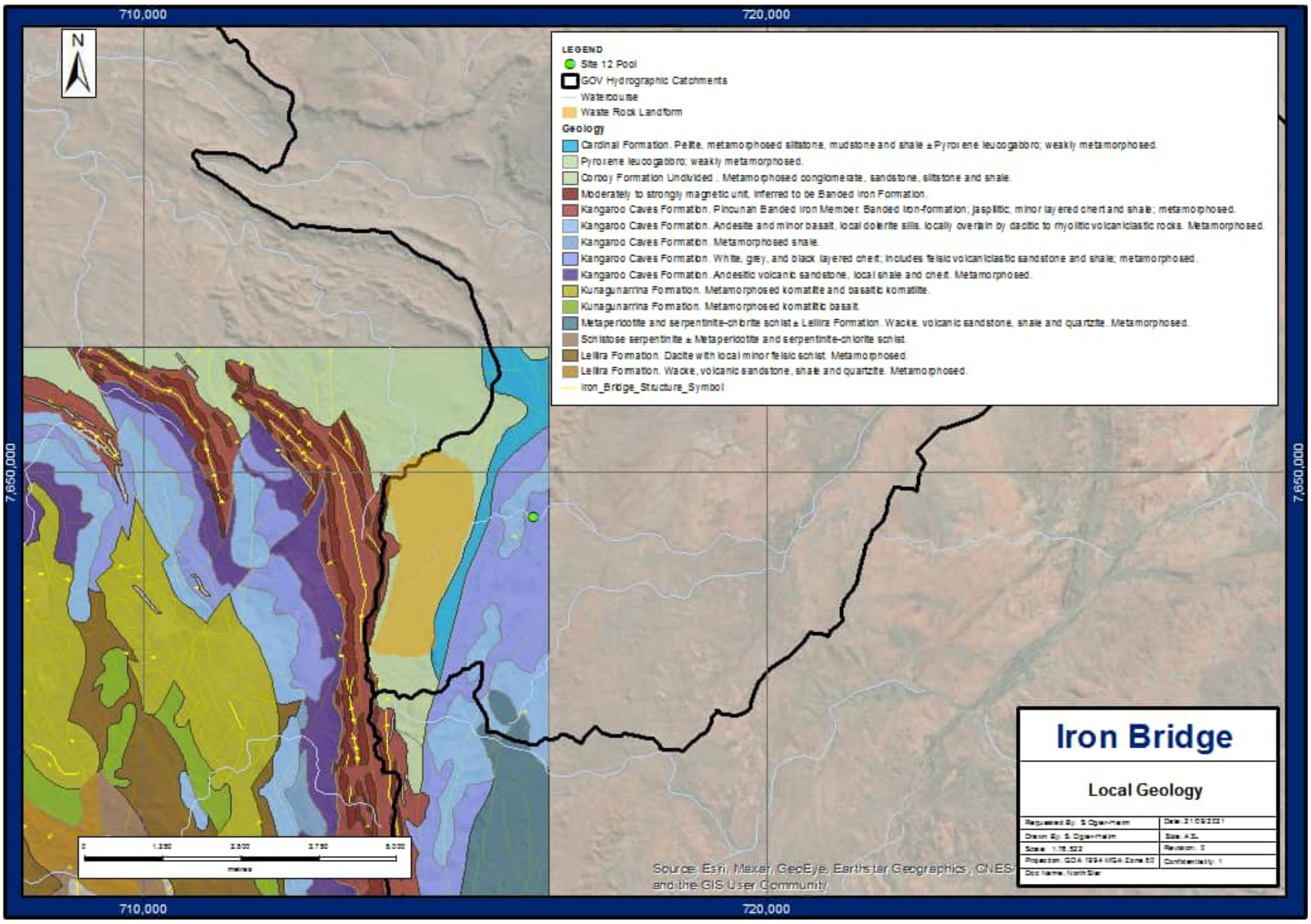

Figure 4: Local Geology

Photos from the Site 12 Pool upper catchment (Plate 1) indicate that the creek lines that convey intermittent rainfall events have incised the local bedrock Formations, and all creek beds and the Site 12 Pool itself lay directly on the fractured bedrock.

Additional photos of the upstream catchment of the Site 12 Pool can be found in Appendix 1.

Plate 1: Photos of the upstream catchment of the Site 12 Pool

3. HYDROGEOLOGY

3.1 IB Mine Hydrogeology

The Project is located within the Granite Greenstone Terrane hydrological province of the Pilbara. Groundwater resources of this province are limited to alluvial aquifers and fracture zones in greenstones.

At the Project, the hydrogeological investigation undertaken between 2012 and 2020 have identified four key hydrostratigraphic units:

- Alluvial sand and gravel deposits adjacent to substantial creeks. They are a few metres thick, mostly restricted to the immediate stream channel area, and intermittently saturated following major rainfall events. Transmissivity values of the alluvial aquifer are relatively high ($0.32 < T < 2.3$ m^2/day and $8.8E\text{-}8 < K < 6.3E\text{-}7$ m/s) and the storage capacity is considered reasonably high, however, this is not an extensive unit across the site.

- The weathered and oxide/fresh transition zone is up to 60-70 m deep. Fractured rock aquifers within the weathered profile present transmissivity values that can be locally high, but generally low. It is considered a poor aquifer in terms of storage and transmissivity and is highly reliant on rainfall recharge. The transmissivity values of the weathered rock mass are generally ($11.1 < T < 590$ m^2/day or $1E\text{-}5 < K < 1E\text{-}3$ m/s) one to two orders of magnitude higher than in the oxide/fresh transition zone ($0.5 < T < 1$ m^2/day or $1E\text{-}7 < K < 1E\text{-}6$ m/s)

- The deep fractured bedrock that consists of various greenstone rocks of mainly igneous basalt, ultramafic and andesitic tuff, and sedimentary rocks of sandstone, siltstone, shale, chert and banded iron-formation (i.e. Corboy Formation, Pincunah Hill Formation and Kangaroo Caves Formation). This unit has no appreciable transmissivity and water storage, except along very localised geological structures. Permeability values are lower than 0.5 m^2/day (or $K \leq 1E\text{-}8$ m/s).

- The deep shale units, that structurally sandwich the host BIF in a syncline (i.e. western shale of the Kangaroo Formation and Eastern inter-bedded shales of the Corboy Formation), form a poorly developed aquifer(s). The shale units are over 400 m thick on both side of the ore body, and generally present very low permeability values (0.05 m^2/day < T or $K < 1E\text{-}9$ m/s), except when major fractures are encountered the permeability values can increase by up to 2 orders of magnitude ($7.8 < T < 12$ m^2/day or $1E\text{-}7 < K < 1E\text{-}6$ m/s). Water yield from storage in this unit is expected to be very low, especially at depth.

The main aquifers encountered within the Project are the weathered and fractured rocks of the Proterozoic basement (i.e. Corboy Formation, Pincunah Hill Formation and Kangaroo Caves Formation). The weathered profile within the Disturbance Envelope is up to 70 m deep and the groundwater is generally found at the interface of the weathered oxide and fresh bedrocks.

Groundwater levels mimic the local topography and flow from higher hill terrains to low-lying areas. Groundwater levels ranged from 360 m AHD along the ridge to 195 m AHD in the low-lying area of the surrounding countryside (Figure 5).

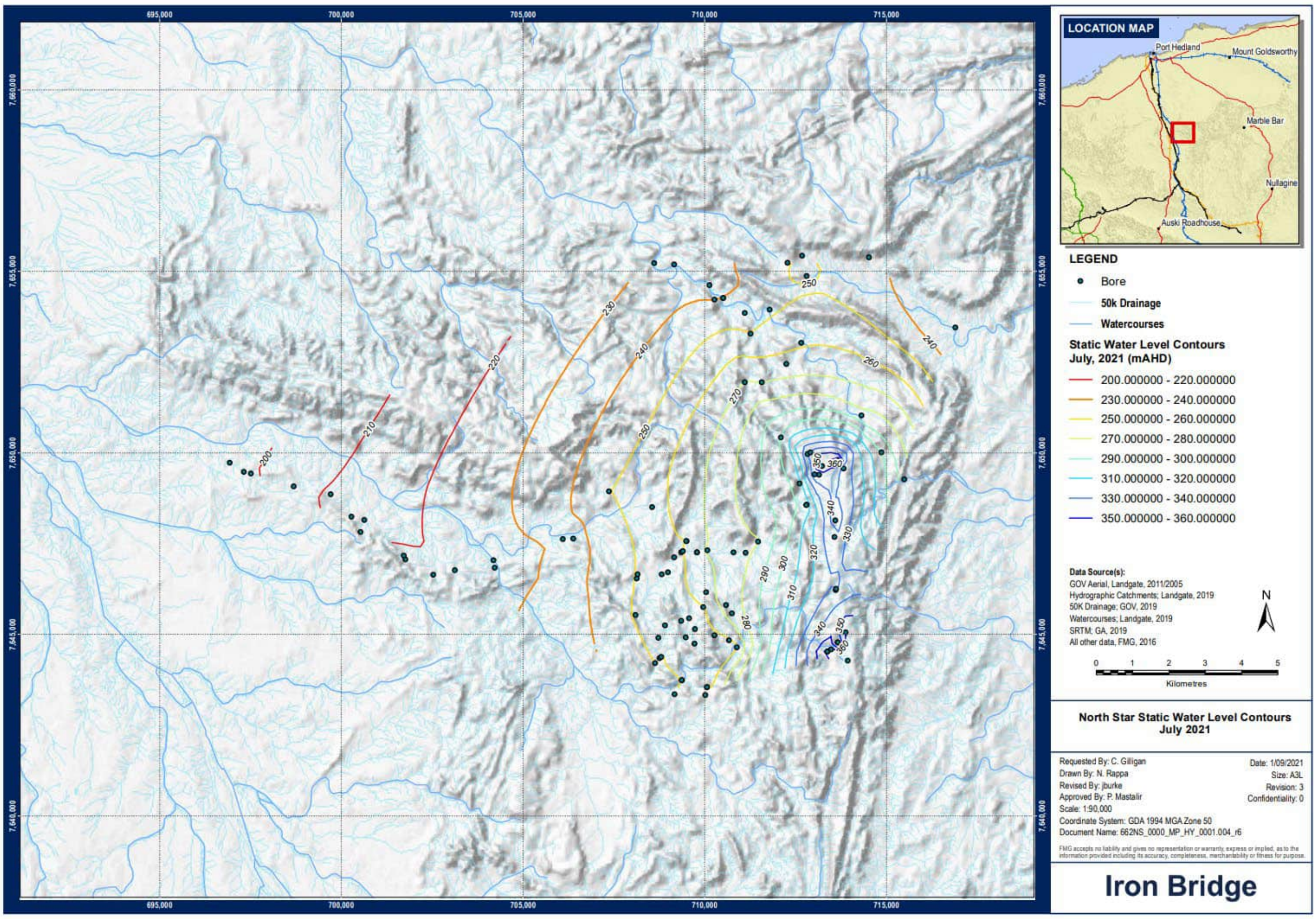

Figure 5: North Star Groundwater Level Contours – July 2021

Under the arid climate experienced in the Pilbara region, the main recharge processes to groundwater are infiltration of rainfall associated with cyclonic events and the interaction with intermittent stream flows occurring during the wet season. Analysis of the groundwater monitoring data indicate that a minimum of 20 mm/day of rain is required before enough infiltration is generated to recharge the local fractured aquifers. The average estimated groundwater recharge rate at the Project is estimated at 5% of the annual rainfall.

The main groundwater discharge mechanisms are seepage into creek beds and evapotranspiration.

3.2 Site 12 Pool Hydrogeology

At the Site 12 Pool upper catchment area, groundwater is found only within the weathered fractured bedrock (i.e. Corboy Formation and Kangaroo Caves Formation). No alluvial aquifers are present along the intermittent small creeks of the Site 12 Pool upper catchment (Plate 1; Appendix A).

Groundwater levels mimic the local topography and flow from higher hill terrains (ridge area) to low-lying areas. Groundwater levels ranged from 340 m AHD along the watershed divide (IB_ELC_M03) to 285 m AHD at the NS-0664 monitoring bore, and 279 m AHD further downstream at Site 12 Pool (Figure 6).

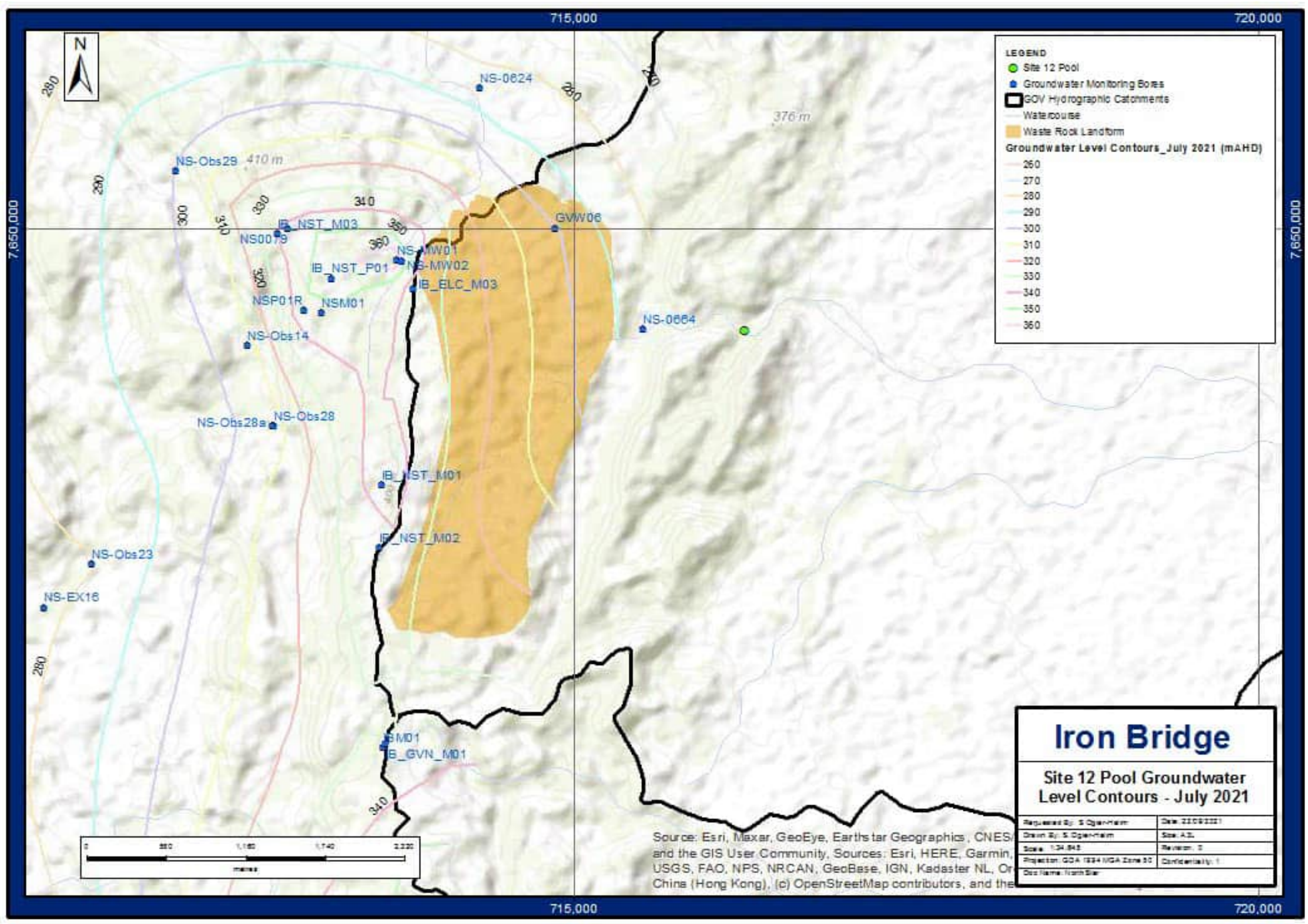

Figure 6: Site 12 Pool Groundwater Level Contours – July 2021

As for the Project, groundwater recharge is primarily driven by infiltration of rainfall associated with cyclonic events occurring during the wet season, while the main discharge mechanisms are seepage into creek beds, discharge as springs along cliff or steep slopes, and evapotranspiration.

Current groundwater monitoring at the Project and within the Site 12 Pool area (i.e. NS-0664) indicates that the local groundwater levels increased sharply from January to February/March following large rainfall events, and then progressively decreased during the dry season (Figure 7).

Analysis of the NS-0664 monitoring bore hydrograph with the local daily rainfall record (Weather station NS_Nate_WE_WS_01) indicate that a minimum of 20 mm/day of rain is required before enough infiltration is generated to recharge the local fractured aquifers within the Site 12 Pool area (Figure 5).

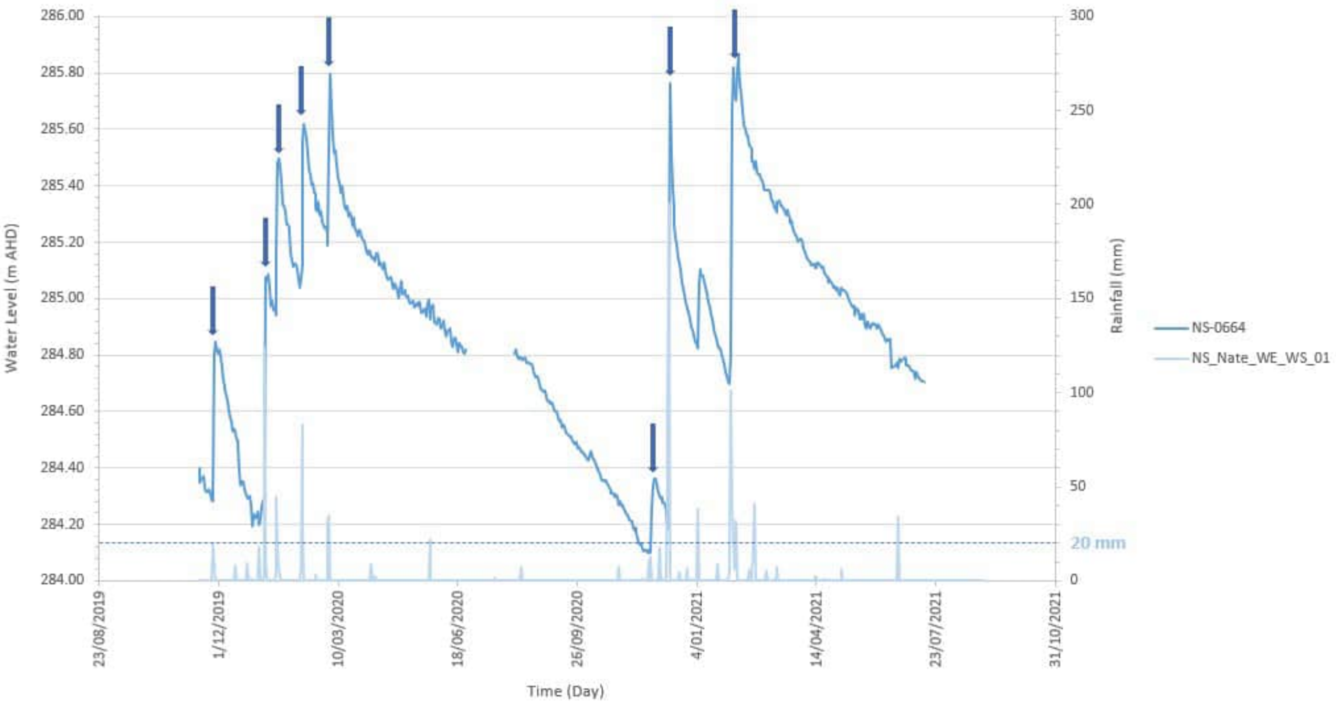

Figure 7: NS-0664 Monitoring Bore Hydrograph and Rainfall Events

Analysis of both Site 12 Pool and NS-0664 bore hydrographs indicate that Site 12 Pool is partially sustained by the local fractured groundwater aquifer during the dry season until the local fractured aquifer groundwater water levels drop below ~ 279.25 m AHD at Site 12 Pool (Figure 8).

When this elevation is reached, the pool is no longer sustained by local groundwater seepage, and pool water levels decrease with time due to evaporation until the pool becomes dry, as experienced in November 2020, or until a rainfall event replenishes the pool and/or recharges the local groundwater aquifers.

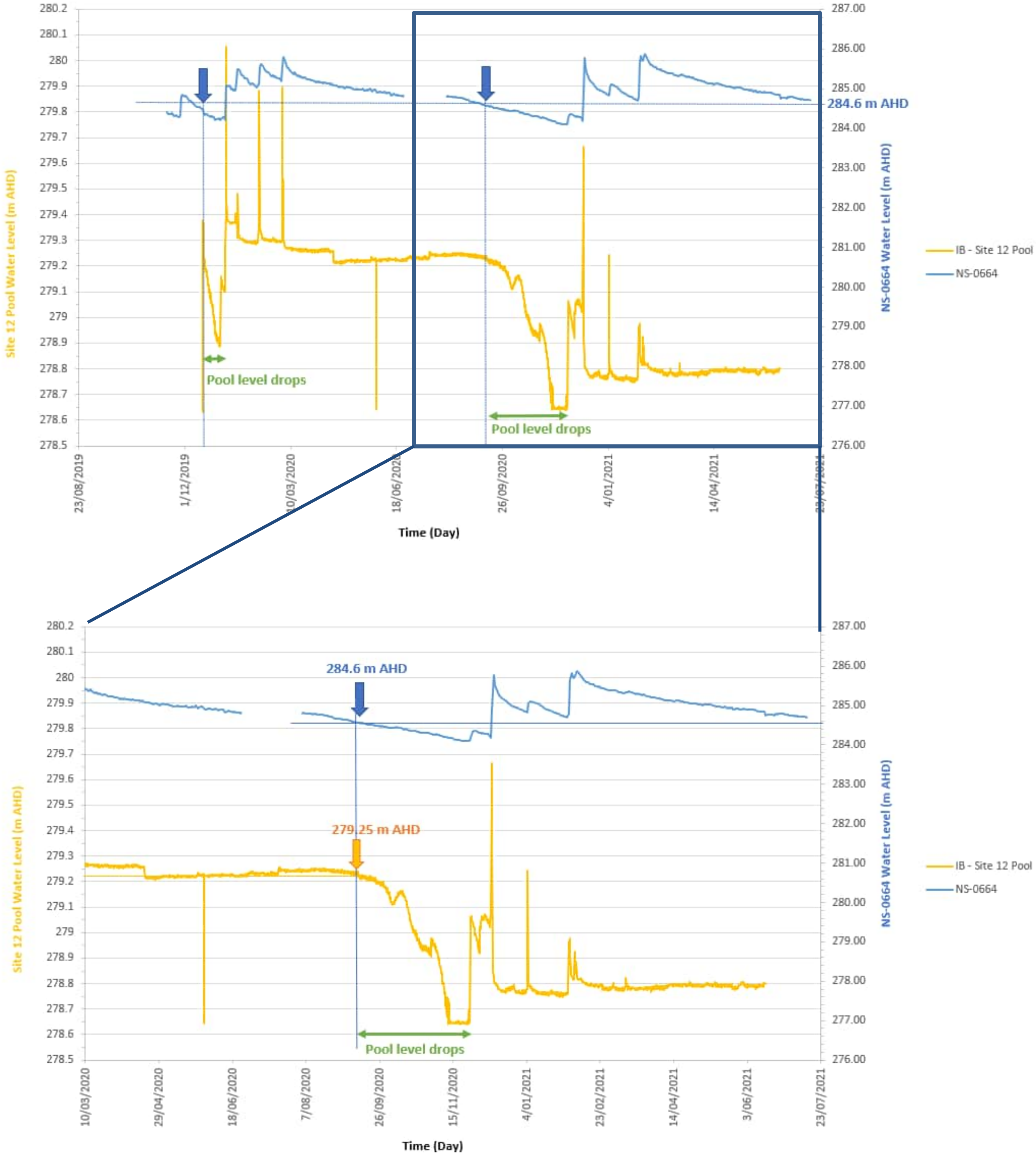

Figure 8: NS-0664 Monitoring Bore and Site 12 Pool Hydrographs with Daily Rainfall Events

Analysis of the stable isotope (δ 18O and δ 2H) of both Site 12 Pool water and NS-0664 groundwater (Figure 9) at the end of one dry season (i.e. 17 December 2019) and at the end of two wet seasons (i.e. 29 May 2020 and 15 June 2021) indicate also that:

- The fractured rock aquifer at bore NS-0664 is primarily recharged by modern meteoritic precipitation as indicated by the δ 18O and δ 2H values of the groundwater samples taken at the end of the 2020 and 2021 wet seasons that lie on the Local Meteoric Water Line.
- Variability of δ 18O and δ 2H values observed in the groundwater samples taken at the end of the wet seasons (May 2020 and June 2021) are likely related to change in the isotopic signature of the meteoric precipitation events (i.e. tropical low-pressure centres and cyclones developing off the north-west). Indeed, change in precipitation isotopic composition is principally due to variations in atmospheric conditions (temperature differences, changes in moisture sources and storm tracks).
- Only the groundwater sample taken in December 2019 has δ 18O and δ 2H values that lie onto the local evaporative enrichment line. This signature is indicative of a sample that has gone through isotopic fractionation / evaporation prior recharge infiltration. This groundwater sample was taken at the end of the dry season, when the soil moisture was at its lowest content, the static groundwater level was at its lower level (~284.34 m AHD or 4.45 m bgl) and a month after a rainfall event of 43.8 mm (25-27 November 2019) recharged the local groundwater aquifer. This offset observed in the groundwater sample likely reveals that the isotope signal of the precipitation at the end of the dry season becomes filtered due to evaporation of rain during infiltration and exchange of infiltrating water with atmospheric vapor.
- δ 18O and δ 2H values observed in the Site 12 Pool water samples are all located between the Local Meteoric Water Line and the Local Evaporative Line and are all more enriched in the heavy isotopes 18O and 2H relative to the NS-0064 groundwater samples. This isotopic pattern suggests that Site 12 Pool is sustained by groundwater and the pool water undertake high evaporation rate as expected in the arid environment of the Pilbara.

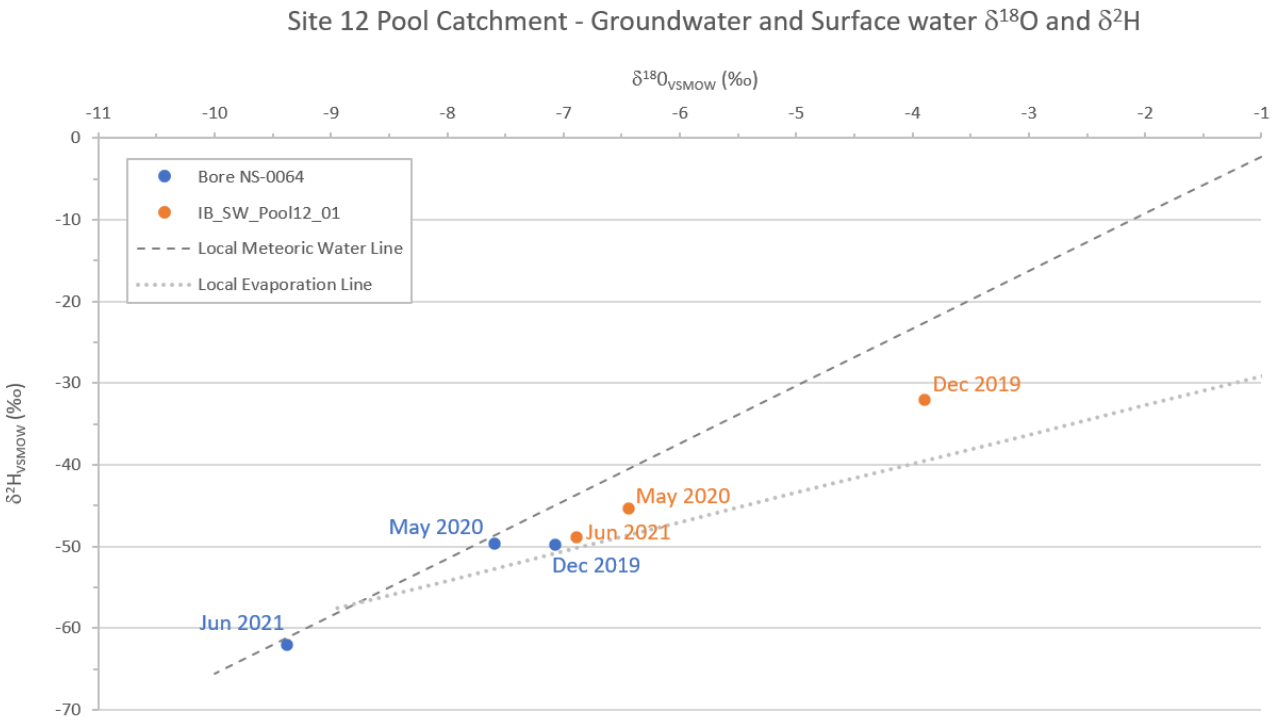

Figure 9: Stable isotope composition of groundwater from NS-0664 Monitoring Bore and surface water from Site 12 Pool at end of one dry season (December 2019) and at end of two wet seasons (May 2020 and June 2021). Local Meteoritic Water Line (dash line) and Local Evaporation Line (dot line) /Domain (shade area) were calculated by Dogramaci et al. (2012).

A summary of groundwater quality data at the Project and at the monitoring bore NS-0664 is presented in Table 2.

Table 2 : North Star 2013-2021 Groundwater analyses – Dissolved Element Concentrations (mg/L)

Range	Minimum	25th %o	Mean	75th %o	80th %o	90th %o	Maximum	Total Analyses	ANZECC 95% of Species Limit of Protection	NS-0664
pH	6.7	7.7	7.8	8.0	7.7	8.2	8.8	150	6.0-8.5	7.78
EC (µS/cm)	230	959	1448	1715	1986	2380	5420	150	-	828
TDS	218	603	897	1050	1240	1428	3252	142	-	538
HCO_3 as $CaCO_3$	89	404	419	499	516	537	626	142	-	311
CO_3 as $CaCO_3$	1	1	1.3	1	1	1	30	142	-	< 1
OH-	1	1	1	1	1	1	1	142	-	< 1
Alk as $CaCO_3$	89	404	420	499	516	537	626	142	-	311
Hardness as $CaCO_3$	26	429	539	684	727	829	1221	142	-	311
Ag	0.001	0.001	0.001	0.001	0.001	0.001	0.001	79	0.00005	-
Al	0.01	0.01	0.01	0.01	0.01	0.02	0.1	141	0.055	< 0.005
As (V)	0.001	0.001	0.011	0.006	0.009	0.021	0.227	97	0.013	0.0016
B	0.050	0.220	0.469	0.453	0.510	0.765	6.970	148	0.37	1.8
Ba	0.002	0.008	0.032	0.039	0.046	0.076	0.194	97	-	-
Be*	0.001	0.001	0.001	0.001	0.001	0.001	0.001	97	0.00013	< 0.0001
Ca	7.00	29.00	44.42	54.75	58.80	69.00	126.00	142	-	29
Cd*	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0009	97	0.0002	< 0.00005
Cl	28.00	89.13	221.49	265.25	357.40	441.10	1160.00	142	-	83
Co	0.001	0.001	0.003	0.002	0.003	0.007	0.062	97	0.0014	< 0.0001
Cr (VI)	0.001	0.001	0.001	0.001	0.001	0.001	0.006	97	0.001	< 0.0002
Cu	0.001	0.001	0.006	0.006	0.009	0.014	0.044	97	0.0014	0.001
F	0.10	0.18	0.42	0.55	0.60	0.75	0.90	6	-	0.195
Fe	0.05	0.05	0.11	0.05	0.05	0.05	3.64	141	0.3	< 0.002
Hg*	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0015	97	0.00060	< 0.00004
K	1.00	1.00	4.90	6.75	7.00	11.90	54.00	142	-	1.5
Mg	2.00	76.00	103.99	129.00	144.60	175.40	253.00	142	-	43.8
Mn	0.00	0.00	0.13	0.11	0.14	0.55	1.19	148	1.9	0.0261
Mo*	0.001	0.001	0.001	0.001	0.001	0.003	0.006	6	0.034	0.0011
Na	28.00	58.25	135.73	188.00	224.80	263.70	724.00	142	-	86.8
Ni	0.001	0.002	0.011	0.010	0.015	0.026	0.082	97	0.011	0.0023
NO_3 as N	0.01	0.02	0.41	0.58	0.72	0.86	7.44	142	0.70	-
NO_2+NO_3 as N	0.01	0.02	0.41	0.58	0.72	0.86	7.68	142	-	0.21
TN as N	0.01	0.02	0.41	0.58	0.72	0.86	7.68	142	-	-
Pb*	0.001	0.001	0.001	0.001	0.001	0.001	0.003	97	0.0034	< 0.0001
Se (Tot)*	0.01	0.01	0.01	0.01	0.01	0.01	0.02	97	0.011	< 0.0002
Si	6.85	15.93	24.24	32.98	34.62	37.32	43.00	142	-	49.7
SO_4	9.00	45.25	118.70	144.00	189.60	240.90	738.00	142	-	43
Sr	0.06	0.17	0.29	0.34	0.39	0.48	1.06	135	-	0.239
U*	0.001	0.001	0.001	0.002	0.002	0.002	0.002	6	0.0005	0.00035
V	0.01	0.01	0.04	0.06	0.07	0.08	0.24	97	0.006	0.0359
Zn	0.005	0.012	0.106	0.080	0.108	0.389	0.912	97	0.008	< 0.001

U*: value below detection limit

0.008: value exceeding ANZECC 95% of Species Limit of Protection

Groundwater within the Project is fresh to slightly brackish with recorded values of total dissolved solids (TDS) generally between 220 and 3,300 mg/L (Table 2). Lower salinity is generally recorded near recharge areas of higher permeability (high up/rocky hills), while higher salinity is recorded downgradient or with increasing depth due to low permeability aquifers where groundwater is held in storage for a longer time.

Groundwater is generally of a magnesium bicarbonate type water except in monitoring bores located in low-lying areas where groundwater is more of a magnesium/calcium bicarbonate/chloride type. This difference reflects the increase in salinity/mineral dissolution along the recharge pathway and/or lower permeability aquifers where groundwater is held longer in storage.

Groundwater in monitoring bore NS-0664 is fresh (TDS ~ 538 mg/L) and of a magnesium bicarbonate type, reflecting its position within the ridge line and its proximity to the recharge area during wet season.

Common elements present in groundwater at the Project and at NS-0664 include iron, manganese, arsenic, boron, copper, nickel, vanadium, and zinc reflecting the local ore mineralisation.

4. CONCLUSIONS

Site 12 Pool is connected to both surface water and groundwater over the hydrologic cycle, typically sustained by the local fractured aquifer until the local groundwater level drops below ~ 279.25 m AHD at Site 12 Pool. When this elevation is reached, the pool is no longer sustained by local groundwater seepage, and pool water levels decrease with time due to evaporation until the pool become dry, or until a rainfall event replenishes the pool and/or recharges the local groundwater aquifers.

Baseline monitoring indicates that under natural conditions and without disturbance within the Site 12 Pool upper catchment, Site 12 Pool is known to dry out following small wet seasons / small infiltration of rainfall to the local fractured aquifers.

5. REFERENCES

Dogramaci, S., Skrzypek, G., Dodson, W., Grierson, P.F., 2012. Stable isotope and hydrochemical evolution of groundwater in the semi-arid Hamersley Basin of subtropical northwest Australia. J. Hydrol. 475, 281–293.

Attachment 1 – Site 12 Pool Upper Catchment Photos

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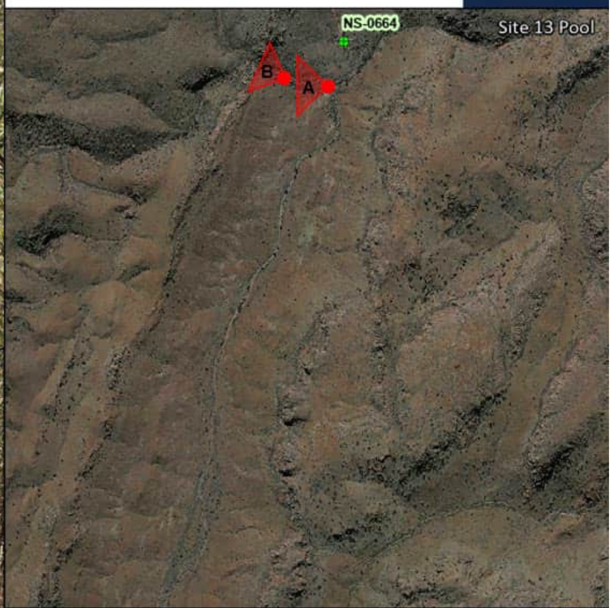

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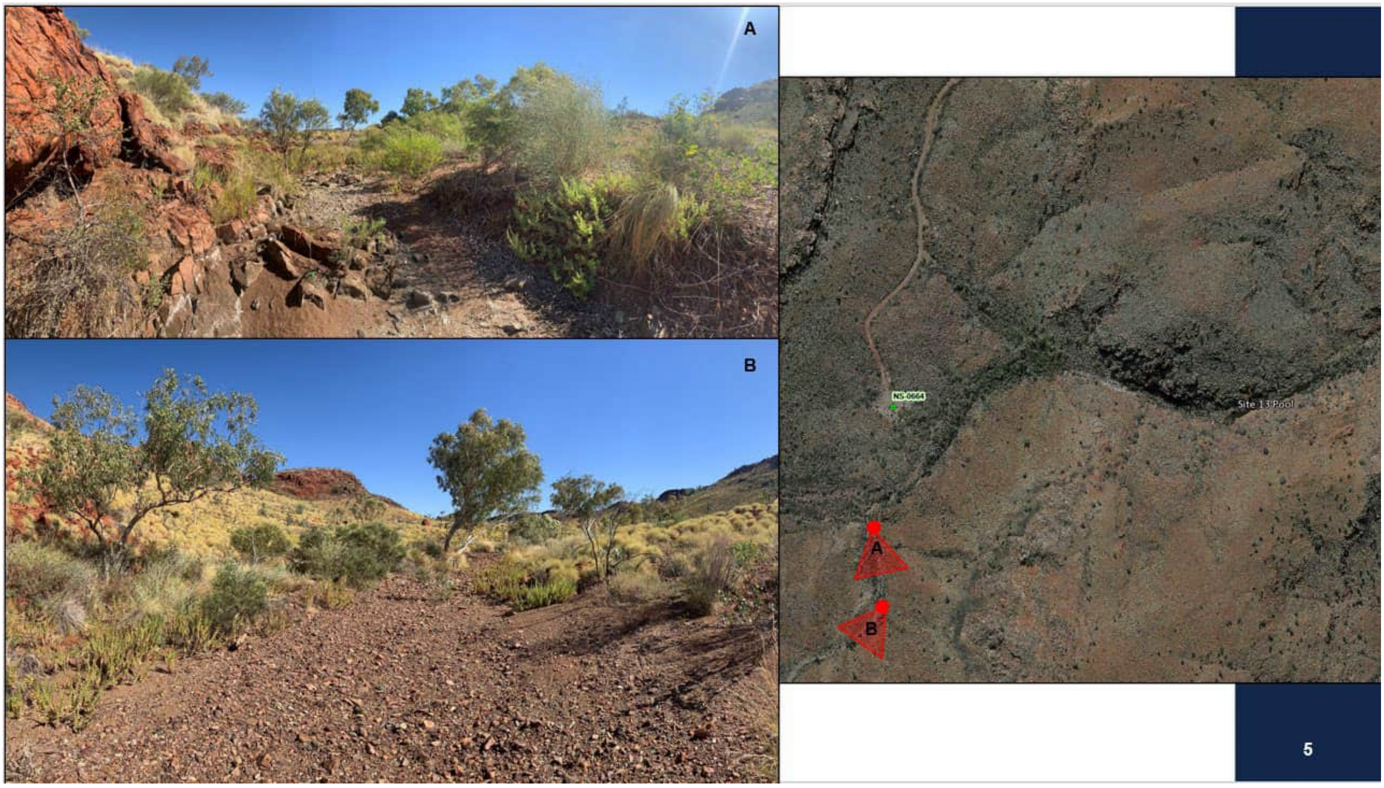

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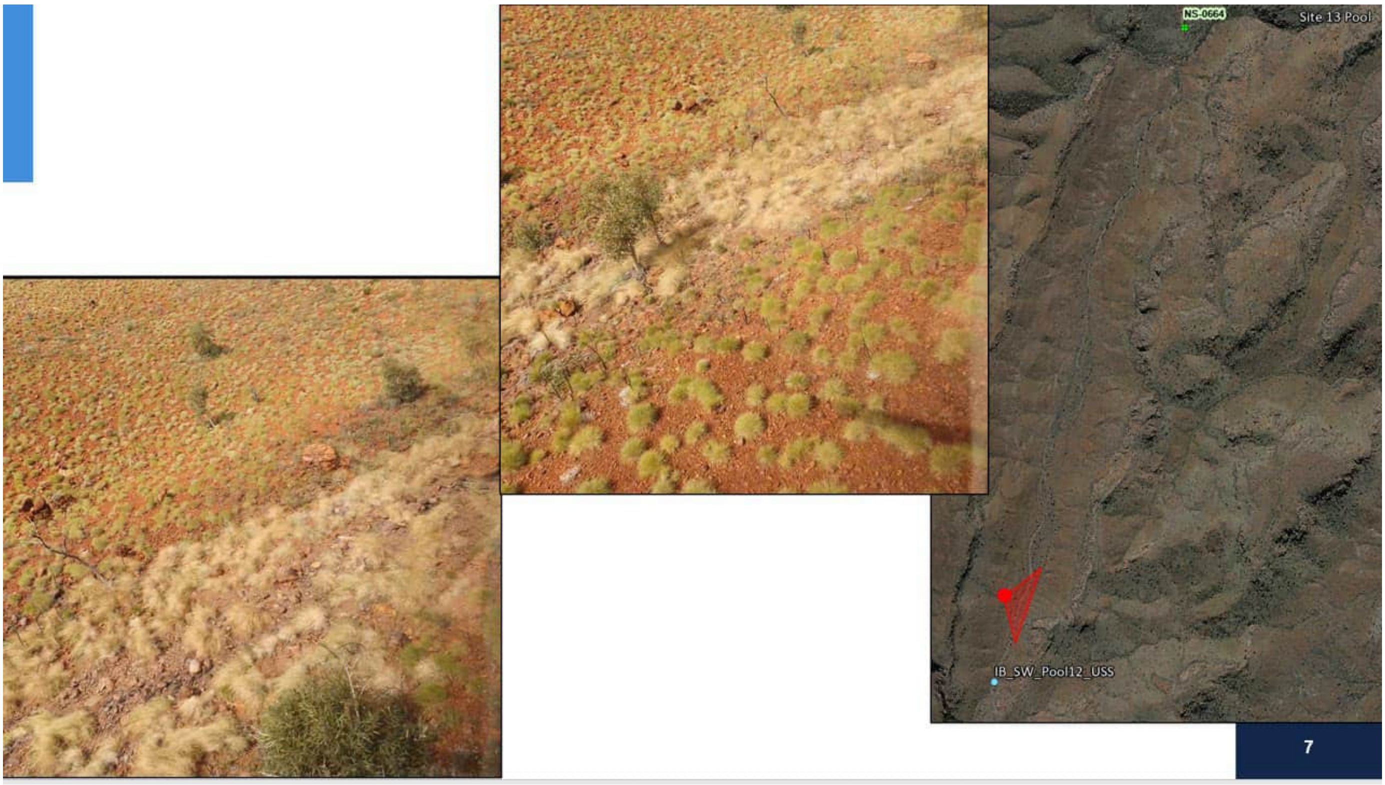
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Site 13 Pool
IB_SW_Pool12_USS
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Attachment 2: Site 12 Pool Water Quantity Assessment and Management

Iron Bridge

Site 12 Pool – Water Quantity Assessment and Management

Report

24/01/2020
662NS-5700-RP-WM-002

	Site 12 Pool – Water Quantity Assessment and Management Report		**662NS-5700-RP-WM-002**
Revision Number	**0**		**24/01/2020**
Status	**IFI - ISSUED FOR INFO**		
Author	Hui Min Lee	Signature	24/01/2020
Checked	Ying Yu	Signature	24/01/2020
Approved	Richard Connell	Signature	24/01/2020
Confidentiality	Choose an item.	**Publish on Extranet**	☐ Yes ☐ No
Review Date	Click here to enter a date.		

Revision History *(to be completed for each version retained by Document Control)*					
Author	**Checker**	**Approver**	**Rev No.**	**Status**	**Issued Date**
Hui Min Lee	**Ying Yu**	**Richard Connell**	A	**IFR**	20/01/2020
Initial/Surname	Initial/Surname	Initial/Surname		Choose an item.	Click here to enter a date.

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1. INTRODUCTION

The Project is located approximately 110 km south-southeast of Port Hedland in the Pilbara region of Western Australia. Stage 1 (North Star Hematite Project) involved the mining of approximately 10 million tonne per annum (mtpa) of an oxide layer of the North Star deposit. Stage 2 of the Project is a 30 mtpa magnetite iron ore mine, with ore processing on site to produce approximately 20 mtpa of magnetite concentrate for export. The Project has an estimated life of mine of 30-40 years. Magnetite concentrate will be delivered to Port Hedland via a slurry pipeline and exported through the Port Hedland Inner Harbour. The Project has received approval (Ministerial Statement 993) under Part IV of the EP Act (Ministerial Statement 993) and under the EPBC Act.

Condition 12-2 of the Ministerial Statement 993 states that “The proponent shall ensure that the implementation of the proposal within the catchment of Site 12 Pool … does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool”. This study assesses the hydrological regime of Site 12 Pool to determine the likelihood of a detrimental impact.

1.1 Site 12 Pool

Site 12 Pool is a gorge with a series of small surface water pools over a linear distance of approximately 650 m. Most pools are shallow, with the deepest pool being approximately 2.5 m deep.

Monitoring of pool levels began in 2013 and the monitoring locations are depicted in Figure 1. The pools are typically filled by runoff from the upstream catchment and baseflow from alluvial during the wet season (January – June). Towards the end of the dry season (July – December), the baseflow ceases and the shallow pools dry up. A review of the recorded data indicated that there are large gaps over both wet and dry season where no data is recorded. This is most likely a combination of the pools being dry, and the equipment is not functioning properly.

The size and locations of the pools are approximated based on 1 m LiDAR and they are shown in Figure 1.

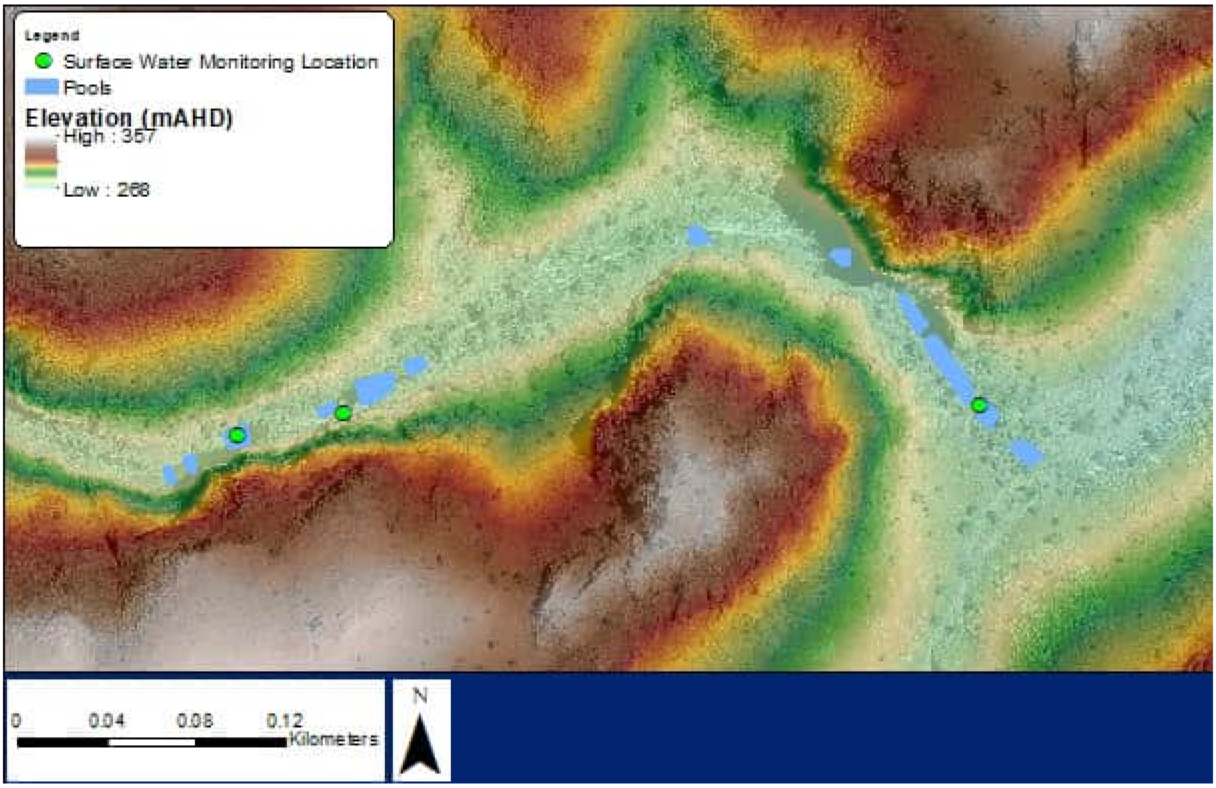

Figure 1: Surface water monitoring locations and approximate footprint of pools

1.2 Proposed Development

A waste rock dump (WRD) has been proposed to be constructed within the Site 12 Pools catchment. The ultimate footprint of the WRD is approximately 3 km² and is presented in Figure 2. That constitute to approximately 40% of the pools' catchment area.

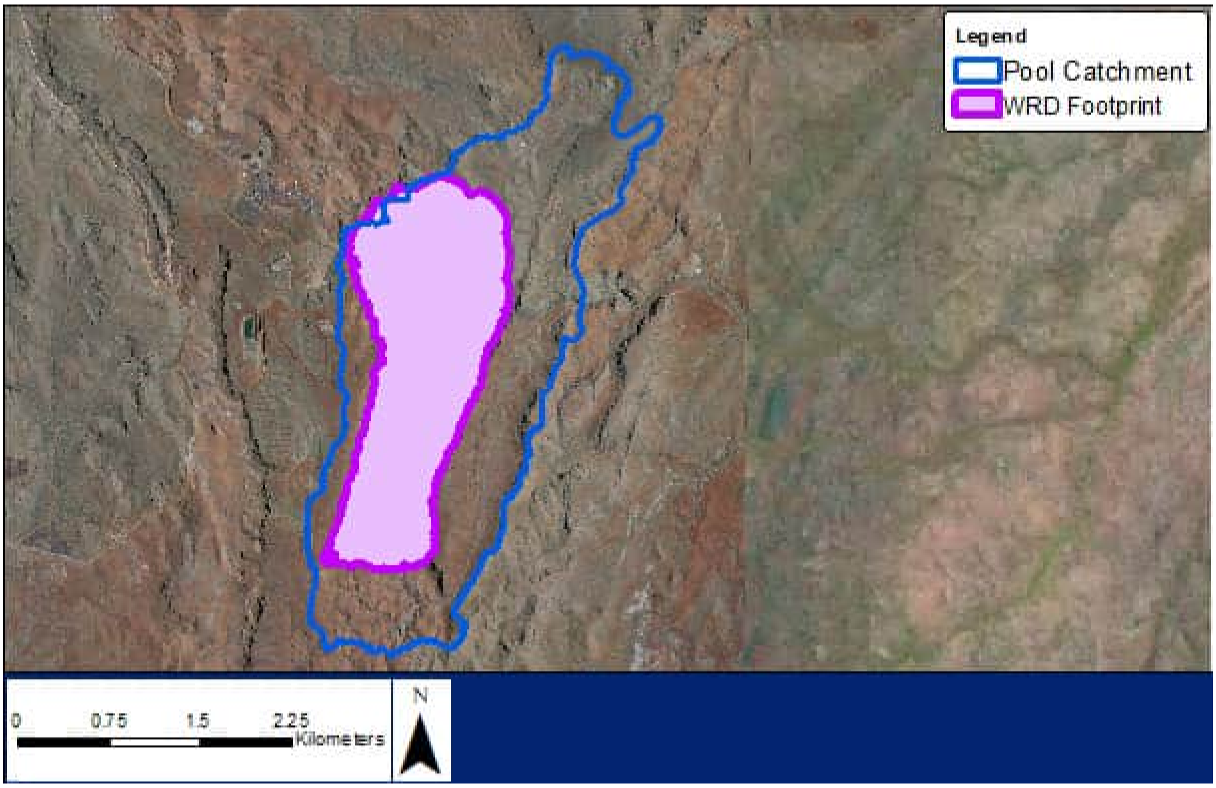

Figure 2: Pools catchment area and proposed WRD footprint

1.3 Objectives

The aims of this study are as follow:

- To investigate the impact of the proposed WRD on the quantity of inflow into the pool systems;
- To determine if the impact of the proposed WRD will have a detrimental impact on the hydrologic and geomorphic characteristics of the pool system.

2. HYDROLOGY

A RORB model had been developed by BG&E for the catchment of interest. RORB is a non-linear rainfall runoff and streamflow routing model for estimation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reaches and storage areas. Observed or design storm rainfall is input to the centroid of each subarea. Specific initial and continuing/proportional losses are then deducted, and the excess runoff is routed through the reach network.

The adopted methodology is based on current guidelines described in ARR (2019). Monte Carlo (MC) is a probabilistic approach whereby a large number of potential parameter combinations are randomly modelled to determine a range of design flow estimates, from which an appropriate design flow value is derived. In this instance 5,000 model runs were simulated for each storm duration, with varying initial losses and temporal patterns, to produce a probabilistic distribution of design flows. This allowed design peak flows for the range of design events to be derived from a flood frequency analysis of the simulated series of storm events.

In the absence of calibration data, MC provides a robust understanding of uncertainty compared to a traditional deterministic approach, due to the analysis of a range of variables (in this case losses and temporal rainfall pattern).

Hydrographs generated from RORB are used as inflow to the hydraulic model which is described in Section 3.

2.1 RORB Setup

The model developed by BG&E was updated to suit the purpose of this study. Existing and post-development scenarios were set up to calculate the runoff generated by the catchment under existing and post-development conditions. The model attributes are tabulated in Table 1

Table 1: RORB model setup

Scenario	Existing	Post-Development
Catchment area (km²)	8.9	5.3
Number of subareas	15	10
Average subarea size (km²)	0.59	0.53
Average flow distance (km)	3.18	2.72

Scenario	Existing	Post-Development
Kc	1.88	1.61

ARR (2019) recommends the use of non-uniform spatial pattern for catchment greater than 20 km². Since the catchment of interest in this study is less than the threshold, a uniform spatial pattern is used. Point temporal pattern were used because the catchment is less than 75 km² (Ball, et al., 2019).

The design rainfall depth for the catchment were obtained from the Bureau of Meteorology's (BOM) online IFD tool. The rainfall IFD parameters were generated for a point approximately at the centre of the catchment and are shown in Table 2.

Table 2: Design rainfall depth in mm

Duration	Depth (mm)													
	12EY	6EY	4EY	3EY	2EY	1EY	0.69EY/ 50%AEP	0.5EY	0.22EY/ 20%AEP	0.2EY	0.11EY/ 10%AEP	0.05EY /5%AEP	0.02EY/ 2%AEP	0.01EY/ 1%AEP
10 min	2.85	3.86	5.63	6.92	8.78	12.1	14	15.5	20.1	20.5	24.4	28.8	34.7	39.2
15 min	3.67	4.97	7.26	8.93	11.3	15.6	18	20	25.9	26.4	31.4	37	44.5	50.3
20 min	4.27	5.78	8.46	10.4	13.2	18.2	21	23.3	30.2	30.8	36.6	43	51.7	58.3
25 min	4.73	6.41	9.39	11.5	14.7	20.2	23.4	26	33.5	34.2	40.6	47.7	57.2	64.6
30 min	5.09	6.91	10.1	12.5	15.9	21.9	25.3	28.1	36.2	37	43.9	51.5	61.7	69.7
45 min	5.86	7.96	11.7	14.4	18.4	25.6	29.6	32.8	42.3	43.2	51.2	60	72	81.4
1 hour	6.35	8.64	12.7	15.8	20.2	28.2	32.6	36.2	46.8	47.7	56.6	66.4	79.7	90.4
1.5 hour	6.97	9.52	14.1	17.5	22.6	31.8	36.9	41	53.4	54.4	64.8	76.3	92	105
2 hour	7.36	10.1	15.1	18.8	24.2	34.5	40.2	44.6	58.5	59.7	71.4	84.4	102	117
3 hour	7.88	10.9	16.4	20.5	26.7	38.5	45.1	50.1	66.8	68.2	82.3	98	120	138
4.5 hour	8.38	11.7	17.8	22.4	29.5	43	50.8	56.4	76.8	78.3	95.6	115	142	165
6 hour	8.75	12.3	18.8	23.9	31.6	46.6	55.4	61.5	85	86.7	107	130	162	188
9 hour	9.31	13.2	20.5	26.2	35	52.3	62.8	69.7	98.6	101	125	154	194	227
12 hour	9.75	14	21.9	28.1	37.7	56.8	68.7	76.2	109	112	140	174	220	257

2.2 Flow Verification

Design losses used in the RORB model has a significant impact on the predicted runoff produced by the catchment. ARR (2019) recommends initial loss (IL) of 59 mm and continuing loss (CL) of 8.2 mm/hr for this catchment. However, recent studies conducted around the Pilbara suggest that the region's runoff generation mechanism is dominated by infiltration excess. This typically occurs during high intensity, short duration storms (Lee & Connell, 2019; Heyting, 2019). For low intensity rainfall events, no runoff is generated due to the high losses within the catchment.

However, due to a lack of recorded flow and rainfall data within the catchment of interest, the losses were not able to be calibrated using historical events. Thus, design losses were adjusted and compared regional peak flow methods. The methods used to estimate the flow generated by the catchment up to the 1% AEP in this study are:

- Regional Flood Frequency Procedure (RFFP); and
- Regional Flood Frequency Estimate (RFFE)

Flows are extracted downstream of the pools from the RORB models and compared to RFFP and RFFE estimates. The comparisons are illustrated in Figure 1 and Figure 2.

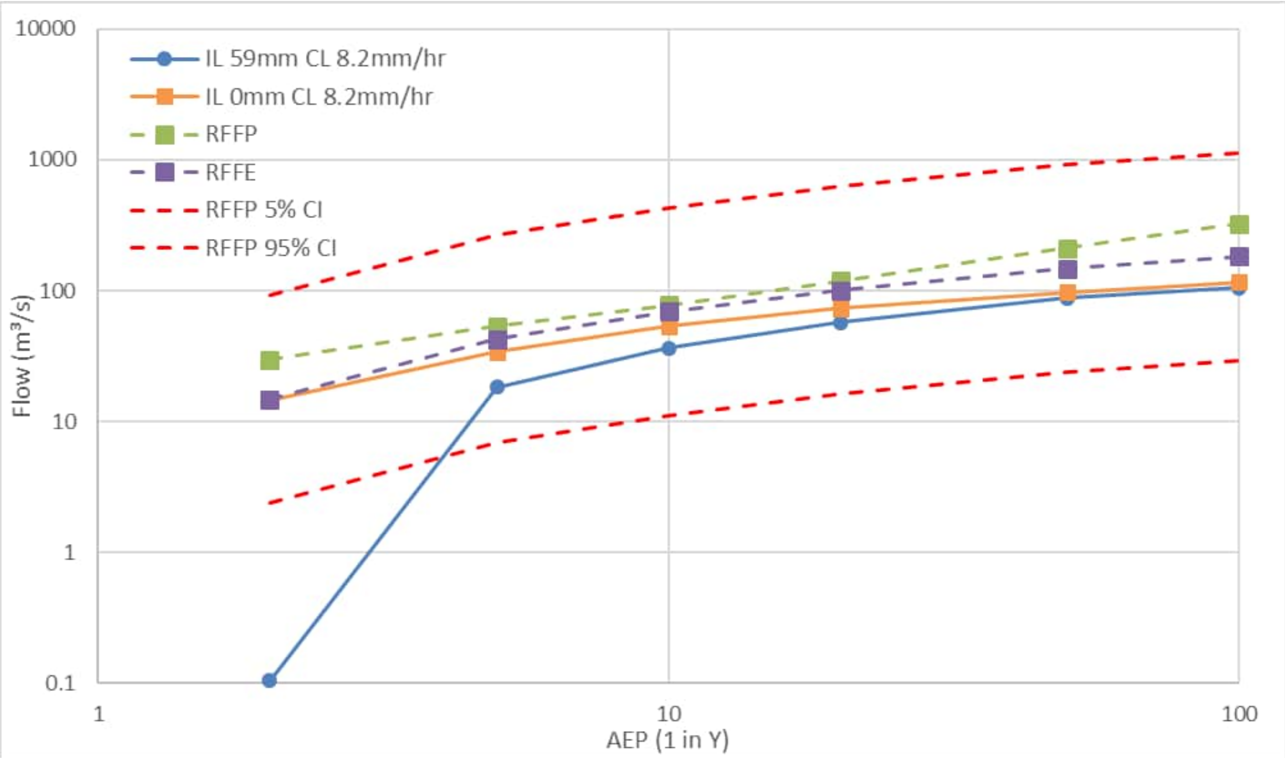

Figure 3: Flow comparisons downstream of Site 12 Pool for existing conditions

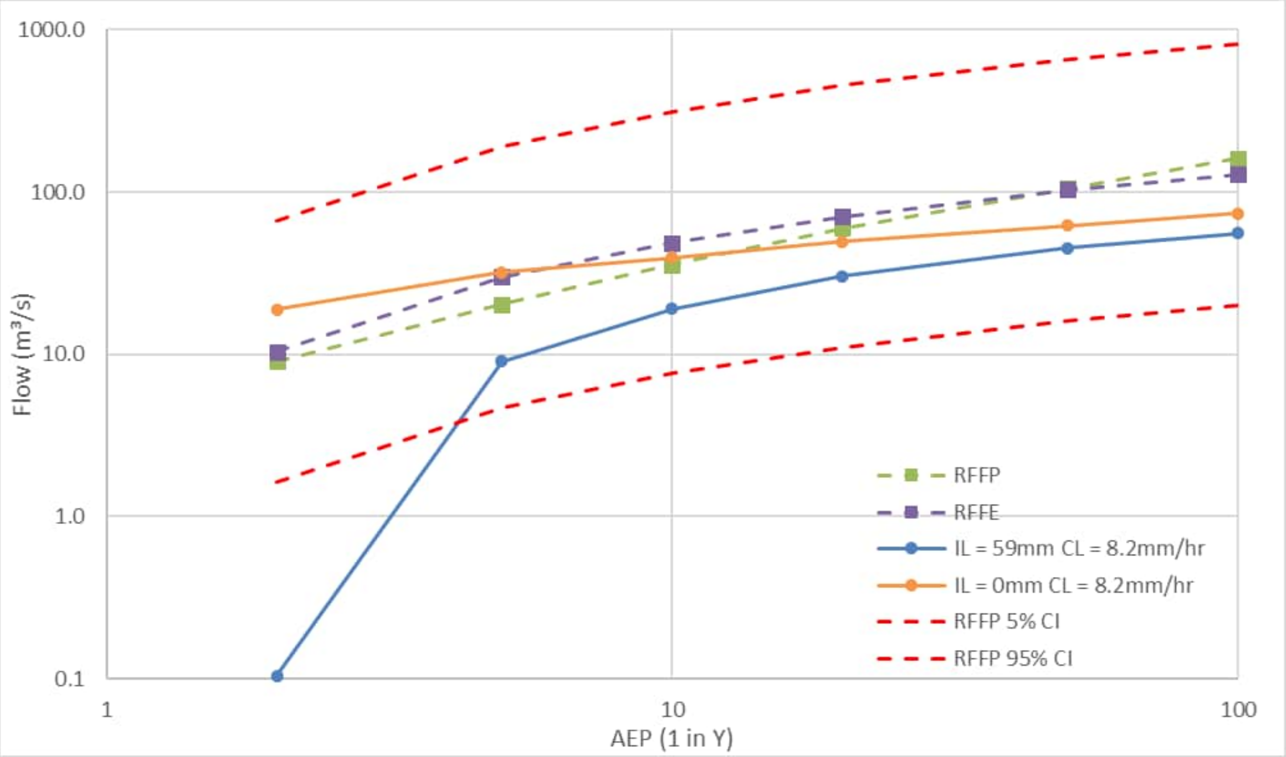

Figure 4: Flow comparisons downstream of Site 12 Pool for post-development conditions

For existing conditions, the estimated runoff from RORB for rarer events (>10% AEP) are less than the regional estimates but remains within the 95% confidence limits of RFFE. For the more frequent events (<10% AEP), the scenario with 0 mm IL shows better correlation with regional estimates whereas the scenario with 59 mm IL peak runoff is significantly lesser than regional estimates.

In the post-development scenario, the 0 mm IL scenario generates more runoff in frequent events than the regional estimates and less than the regional estimates for rarer events. The 59 mm IL scenario consistently produces less runoff than both RFFE and RFFP and the 50% AEP event fall outside of the RFFE 95% confidence limit.

Therefore, IL of 0 mm and CL of 8.2 mm/hr has been adopted for this study.

Table 3: Peak flow comparison between existing and post-development scenario

EY	Peak Flow (m^3/s)		Difference (%)
	Existing	Post-Development	
6	1.14	0.91	-20
4	6.54	3.95	-40
3	10.08	5.95	-41
2	15.58	8.99	-42
1	27.44	15.04	-45
0.69	34.83	18.93	-46

EY	Peak Flow (m^3/s)		Difference (%)
	Existing	Post-Development	
0.5	40.94	22.32	-45
0.22	60.73	33.02	-46

2.3 RORB Design Flows

Hydrographs for very frequent events were extracted at multiple locations from RORB to be used as inflow for the hydraulic model. The inflow locations are shown in Figure 3. The critical durations and peak flows for each event are summarised in Table 4.

Table 4: Critical duration and peak runoff at TUFLOW boundary

Scenario	Event (EY)	Critical Duration	Flow (m^3/s)		
			North	South	West
Existing	4	30 min	3.42	1.68	3.65
	3	30 min	4.86	2.47	5.41
	2	45 min	7.71	3.68	8.41
	1	1 hr	10.58	6.11	13.70
	0.69	1 hr	14.57	8.69	18.21
	0.5	1 hr	17.13	10.37	21.59
	0.22	1 hr	24.37	15.38	31.43
Post-development	4	25 min	3.78	1.66	0
	3	30 min	5.12	2.38	0
	2	30 min	7.39	3.21	0
	1	1 hr	12.93	6.10	0
	0.69	1hr	12.91	6.74	0
	0.5	45 min	15.89	7.48	0
	0.22	45 min	20.76	11.49	0

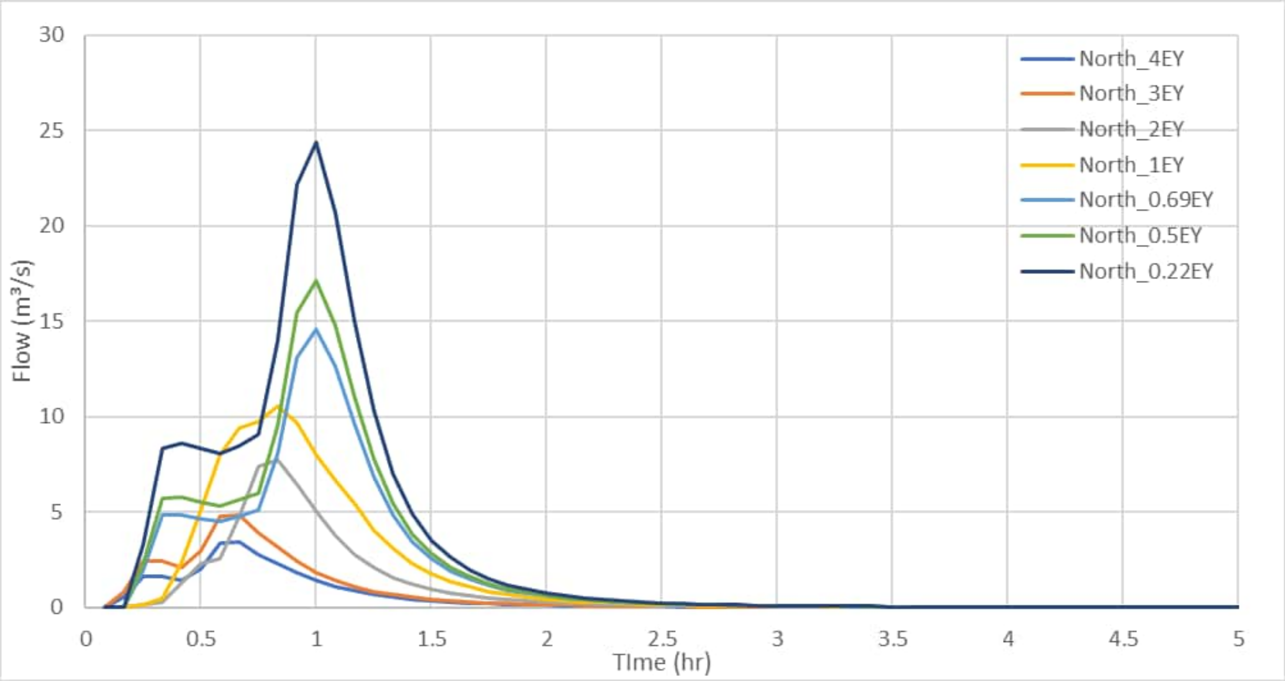

Figure 5: Inflow hydrographs for boundary North for existing conditions

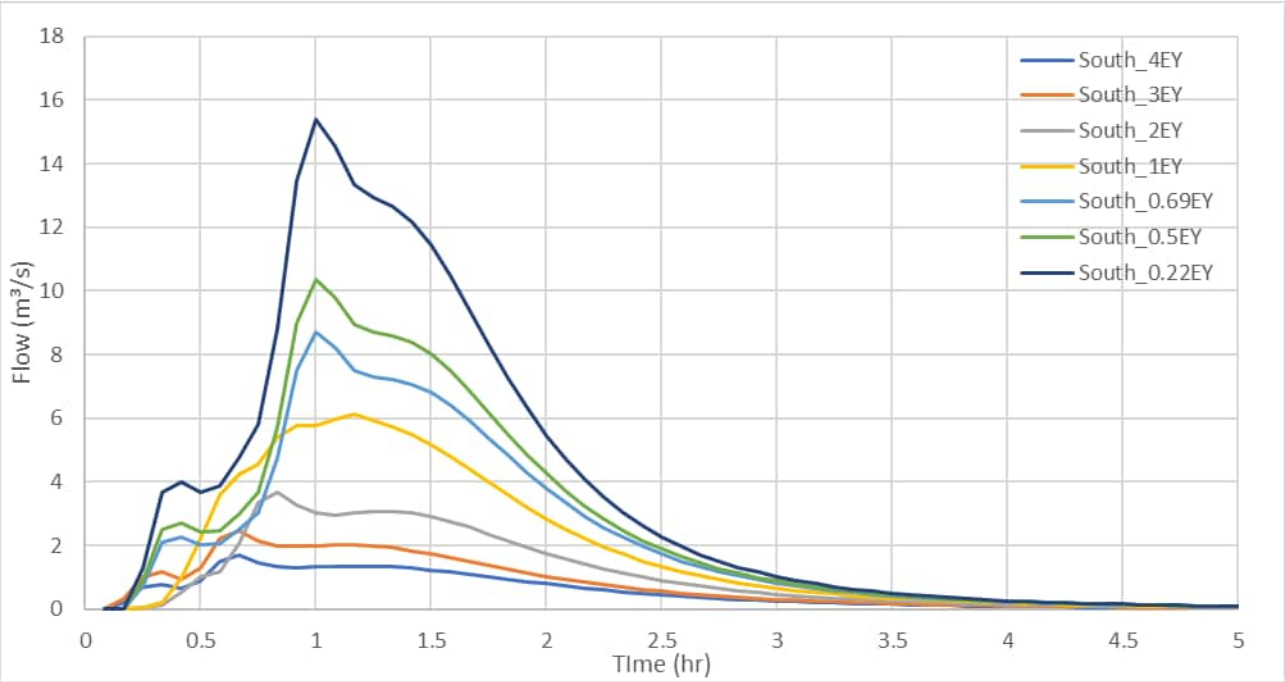

Figure 6: Inflow hydrographs for boundary South for existing conditions

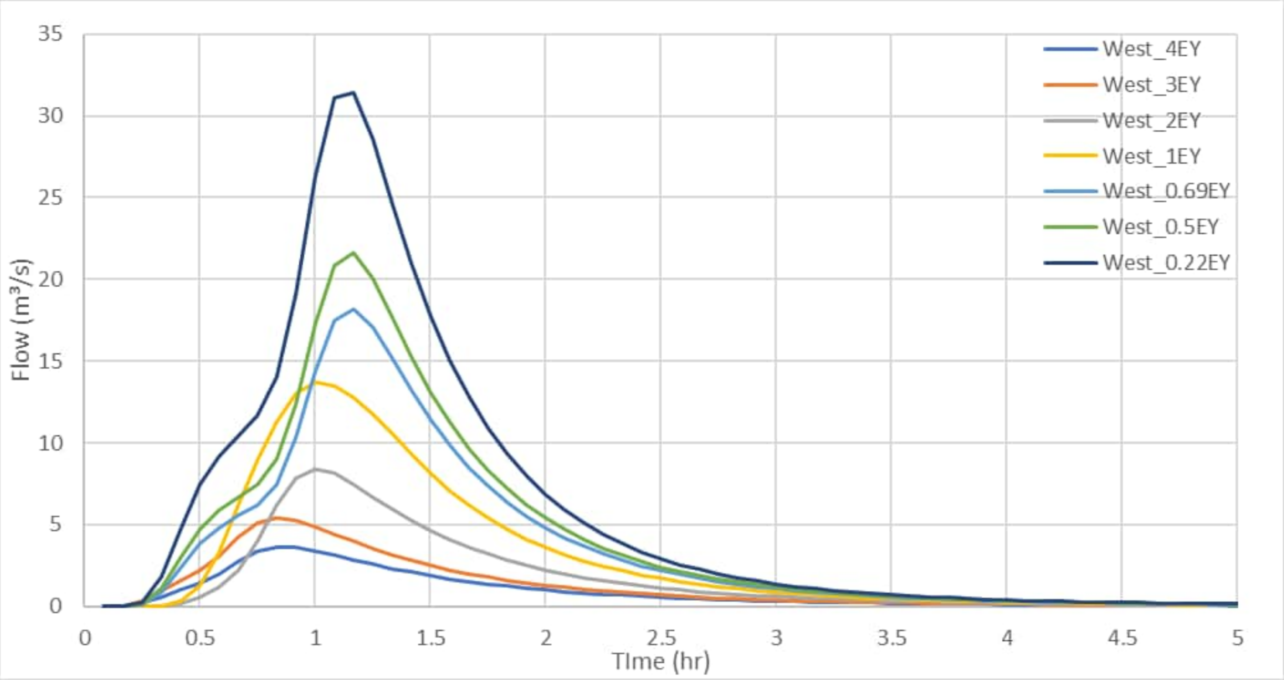

Figure 7: **Inflow hydrographs for boundary West for existing conditions**

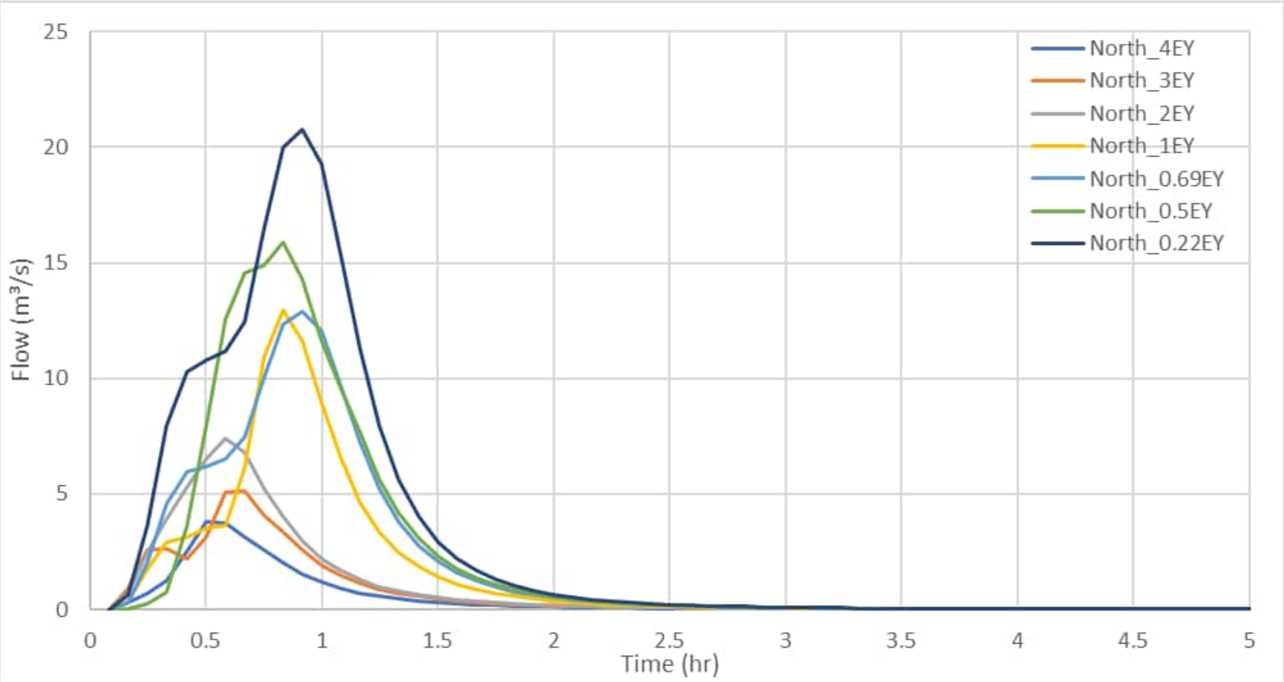

Figure 8: **Inflow hydrographs for boundary North for post-development conditions**

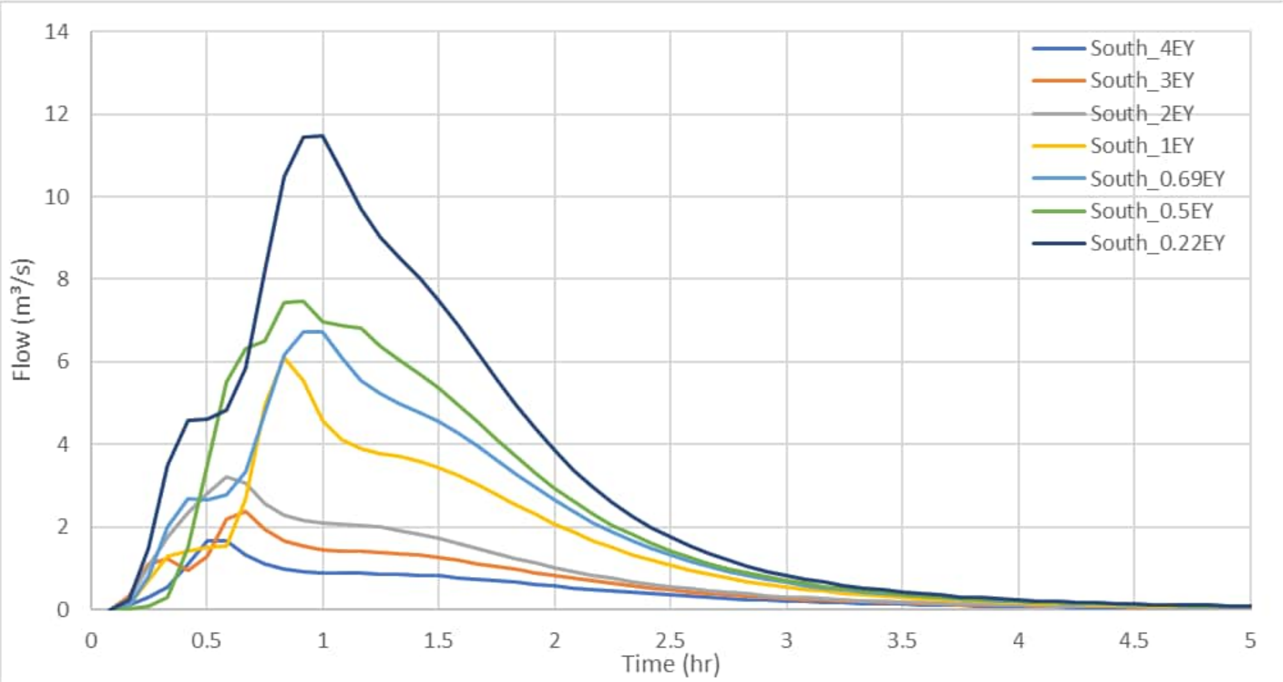

Figure 9: **Inflow hydrographs for boundary South for post-development conditions**

3. HYDRAULIC MODELLING

TUFLOW is a hydraulic model software package that solves 1D and 2D of the free-surface flow equations over a regular grid of square elements. TUFLOW is used to simulate a range of very frequent design events at the pool to calculate the flow, velocity and water level at the pool systems.

3.1 Model Development

The TUFLOW model domain includes the upstream reaches of the pool systems as illustrated in Figure 8. The model has three inflows from the upstream catchment and one outflow boundary with a nominal slope of 1.5%. A 1 m DEM was developed using 1 m LiDAR captured in June 2019.

A constant manning's 'n' roughness coefficient of 0.05 was selected based on experience from the region. Model uncertainty due to potential variation in the parameter is considered to be significantly lower than rainfall and loss uncertainty, consequently the constant roughness is considered to be reasonable.

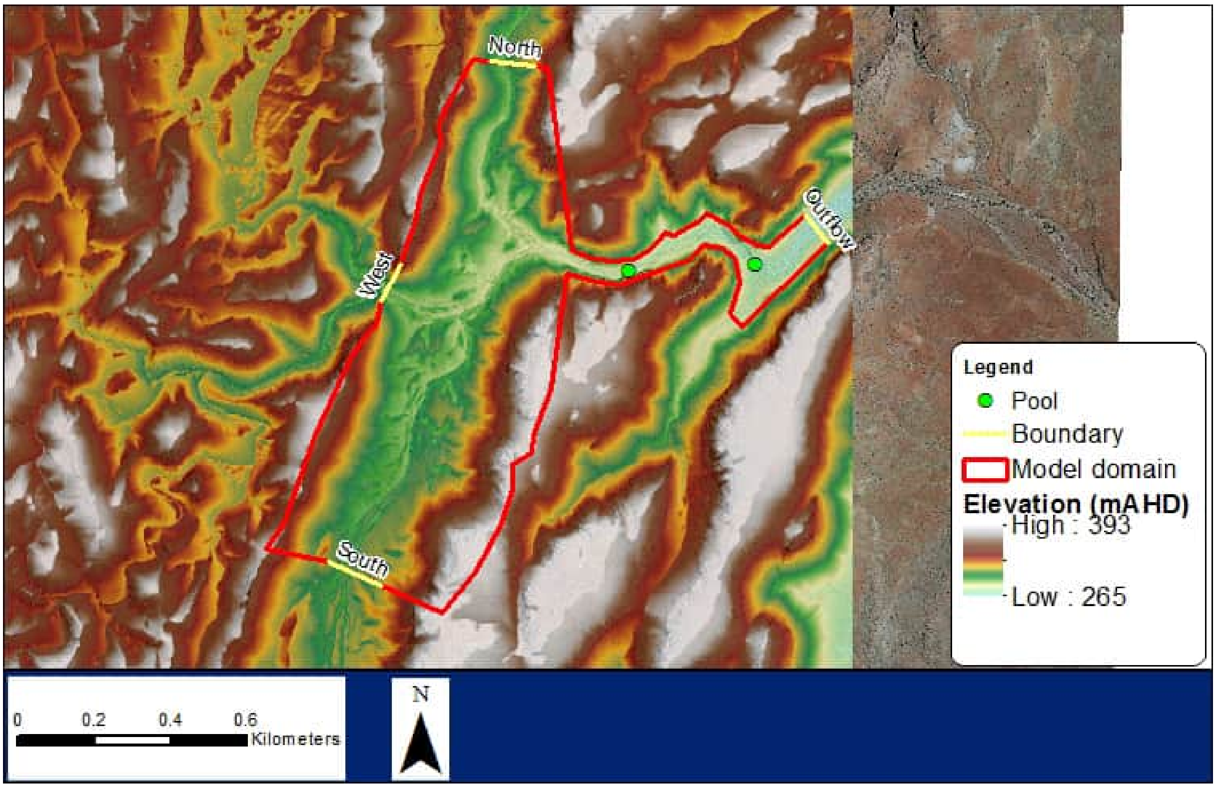

Figure 10: TUFLOW model configuration

3.2 Results

The peak flow depth and velocity maps of existing and post-development scenarios are presented in Appendix 1 to 4.

The results from TUFLOW indicates that the velocities of the inflow tributaries are less than the main tributary flowing into the pools. Even though the velocities within the pools have reduced in the post-development scenario, they are still larger than the velocities from the inflow tributaries.

4. IMPACT ASSESSMENT

The impact of the proposed WRD on the catchment flow regime is studied by comparing the change in flow, volume and velocity between existing and post-development scenario.

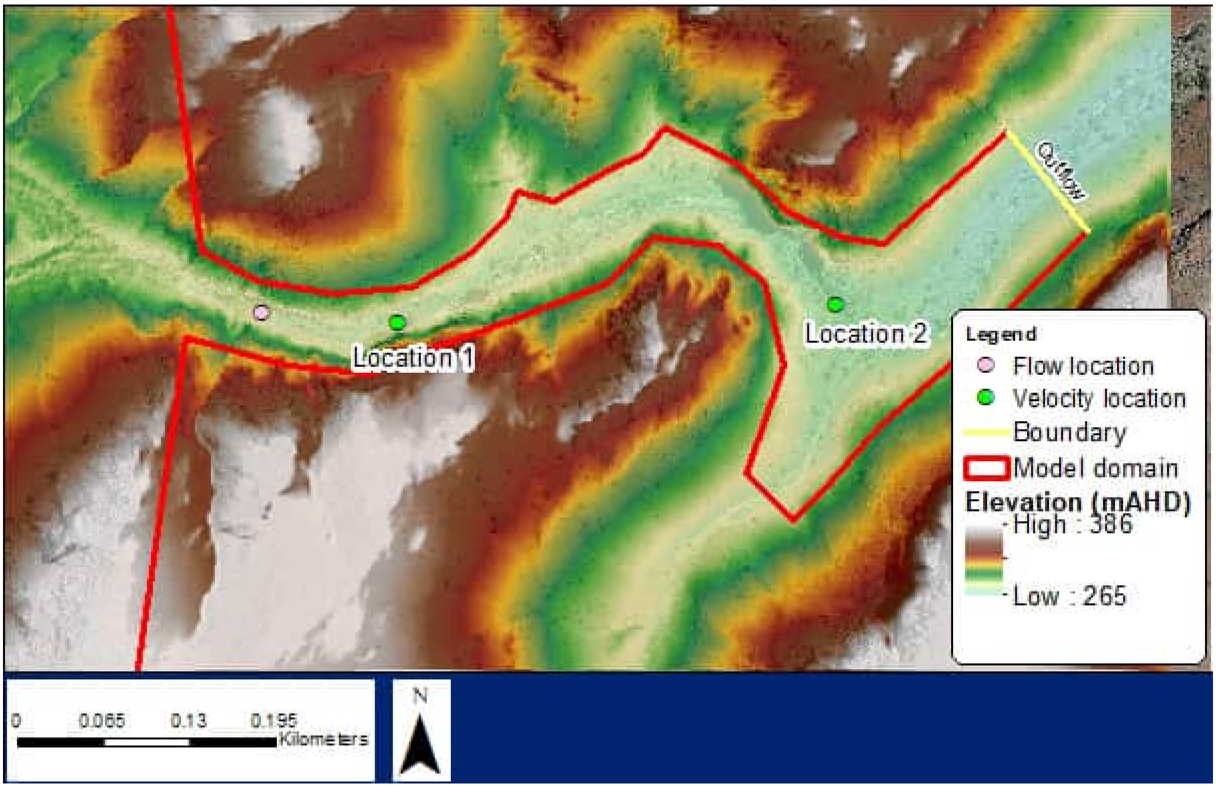

Figure 11: Flow and velocity output locations from TUFLOW

4.1 Flow

The location where flows were extracted for comparison is upstream of the pools as shown in Figure 11. On average, the inflow to the pools has reduced by 50% due to the proposed WRD. The proposed WRD has cut off 40% of the pools contributing catchment, most of them from the west inflow boundary and some areas on the south inflow boundary.

Table 5: Flow comparisons upstream of pools

Event	4EY	3EY	2EY	0.69EY	0.5EY	0.22EY
Existing Flow (m^3/s)	7.73	11.28	17.60	37.69	45.88	66.46
Post-Development Flow (m^3/s)	3.84	6.01	9.35	18.23	21.84	29.97

Event	4EY	3EY	2EY	0.69EY	0.5EY	0.22EY
Difference (%)	-50%	-47%	-47%	-52%	-52%	-55%

4.2 Volume

Based on the approximate footprints of the pools (Figure 1), the total area of the pools is estimated to be approximately 1266 m². Using a conservative assumption that the average pool depth is 2 m, the total volume of the pools is estimated to be 2532 m³. The ratio of pool volume against catchment inflow volume in the post-development scenario based on event magnitude is presented in Table 6. Based on this high level, conservative analysis, the pools' volume is relatively small compared to the inflow volume from the reduced catchment in the post-development scenario. Even in the smallest and most frequent event, it is predicted that the pools would be filled and overflow, maintaining catchment connectivity.

Table 6: Ratio of pool volume against inflow volume in the post-development scenario

Event	Inflow Volume (m^3)	Pool Volume / Inflow Volume (%)
4EY	16,501	15%
3EY	24,299	10%
2EY	33,050	8%
1EY	54,198	5%
0.69EY	70,076	4%
0.5EY	80,870	3%
0.22EY	112,215	2%

4.3 Velocity

It is understood that there is a concern that a reduction in flow rate and flow energy associated with the proposed development will subsequently reduce the stream's competence to scour/transport sediment through the reach where the pools exist.

Predicting the flow rate and hydraulic conditions at which sediments will commence to move is both a problematic and complex task. The prediction of sediment entrainment is usually based on the identification of a critical state, above which particles begin to move (Gordon, et.al., 1992). There are several existing methods which take this approach. The extent of analysis which can be undertaken as part of the current project scope is limited by the absence of sediment samples and detailed hydraulic analysis, including channel geometry within the pools.

Hjulstrom (1939), developed a method of relating average velocity to particle size for erosion, transportation and deposition (Figure 12). There are several limitations associated with this approach and it is not considered best practice in predicting sediment entrainment. However, the Hjulstrom Curve can be useful to provide general estimates of sediment entrainment. The work of Hjulstrom indicates that silts and sands and are quite easily eroded, whereas clays are not eroded unless velocities are higher.

Sediment samples have not been collected or analysed as part of the current project scope. In order to make use of the Hjulstrom Curve, it has been assumed that in-channel sediments at the through the relevant reach are sands with a diameter ranging between 0.5 mm to 2.0 mm. The Hjulstrom Curve incates for sediment of this size, incipient motion will begin to occur between approximately 0.15 and 0.6m/s (Figure 12).

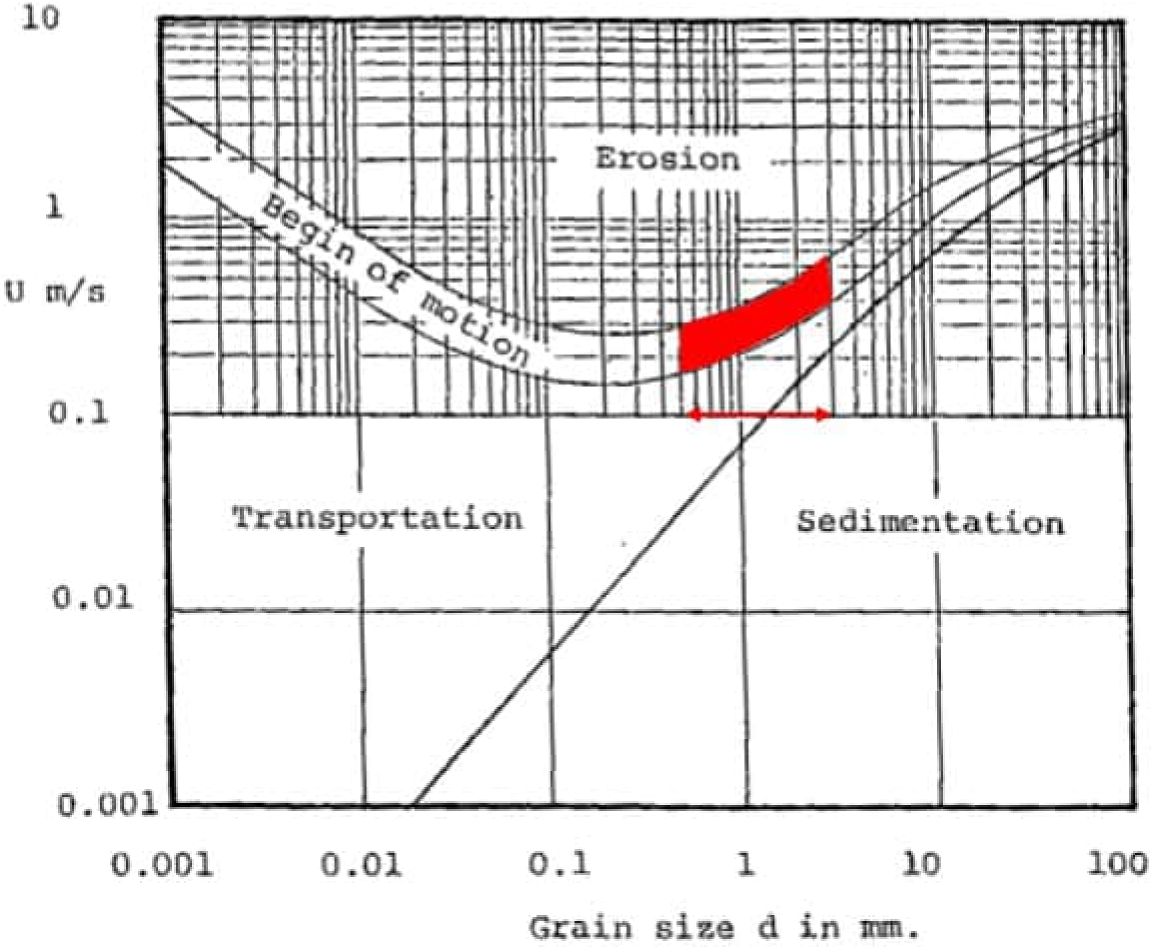

Figure 12: Hjulstrom Curve (Raudkivi, 1998)

Comparison of velocities at the pools indicates that on average the flow velocity has reduced 25% and 30% at Location 1 and Location 2 respectively. Even with the reduced velocity, the post-development flow through the pools is above the threshold of 0.5 m/s for all design events analysed as illustrated in Table 7 and Table 8. It is important to note that the application of Hjulstorm Curve in this study has several limitations including:

- The absence of sediment samples and detailed hydraulic analysis, including channel geometry within the pools.
- The Hjulstorm Curve does not take into account the influence of vegetation on erosion or water depth.

Table 7: Velocity comparisons at Location 1

Event	4EY	3EY	2EY	0.69EY	0.5EY	0.22EY
Existing Flow (m/s)	0.94	1.16	1.49	2.25	2.46	3.04
Post-Development Flow (m/s)	0.66	0.84	1.04	1.52	1.66	1.99
Difference (%)	-30%	-27%	-30%	-33%	-33%	-34%

Table 8: Velocity comparisons at Location 2

Event	4EY	3EY	2EY	0.69EY	0.5EY	0.22EY
Existing Flow (m/s)	1.31	1.50	1.75	2.33	2.50	2.99
Post-Development Flow (m/s)	0.91	1.18	1.40	1.76	1.88	2.12
Difference (%)	-30%	-21%	-20%	-25%	-25%	-29%

5. CONCLUSION

The proposed WRD would reduce the existing Site 12 Pool catchment by 40%. Such reduction has resulted in the reduced of peak flow into the pool system by approximately 50%. Even though the reduction in peak inflow has been significant, the impact on the scouring ability and total inflow volume to the pools remain largely unchanged.

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Heyting, M., 2019. *Hydrological Analysis of the Queens Catchment,* s.l.: s.n.

Lee, H. M. & Connell, R., 2019. *Raven Project Baseline Hydrological Assessment,* s.l.: s.n.

Raudkivi, A. J., 1998. *Loose Boundary Hydraulics.* s.l.:s.n.

Appendix 1: Existing Scenario Maximum Flood Depth

Iron Bridge

Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.5EY Existing Scenario Maximum Depth

Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.22EY Existing Scenario Maximum Depth

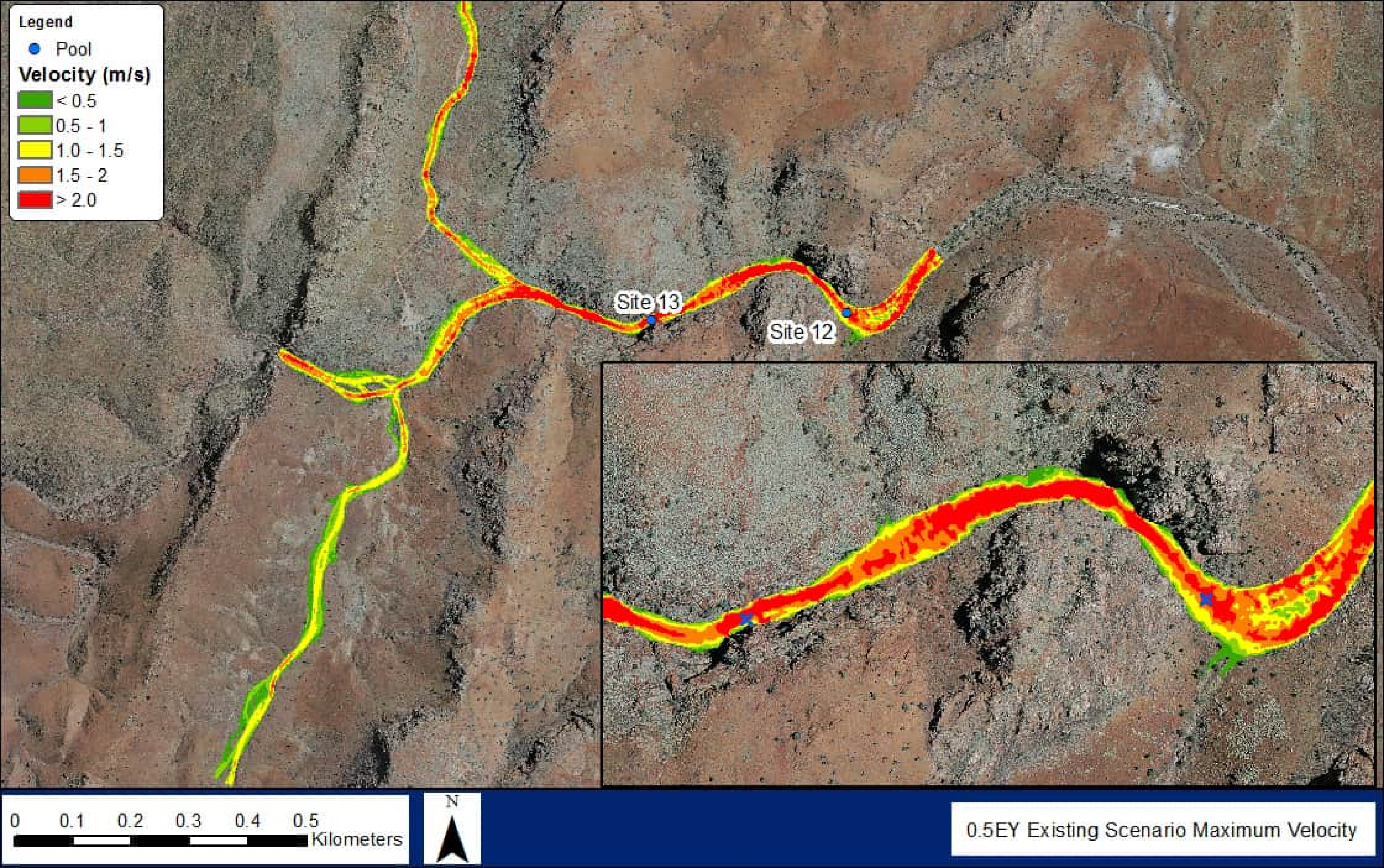

Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.69EY Existing Scenario Maximum Depth


Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
2EY Existing Scenario Maximum Depth

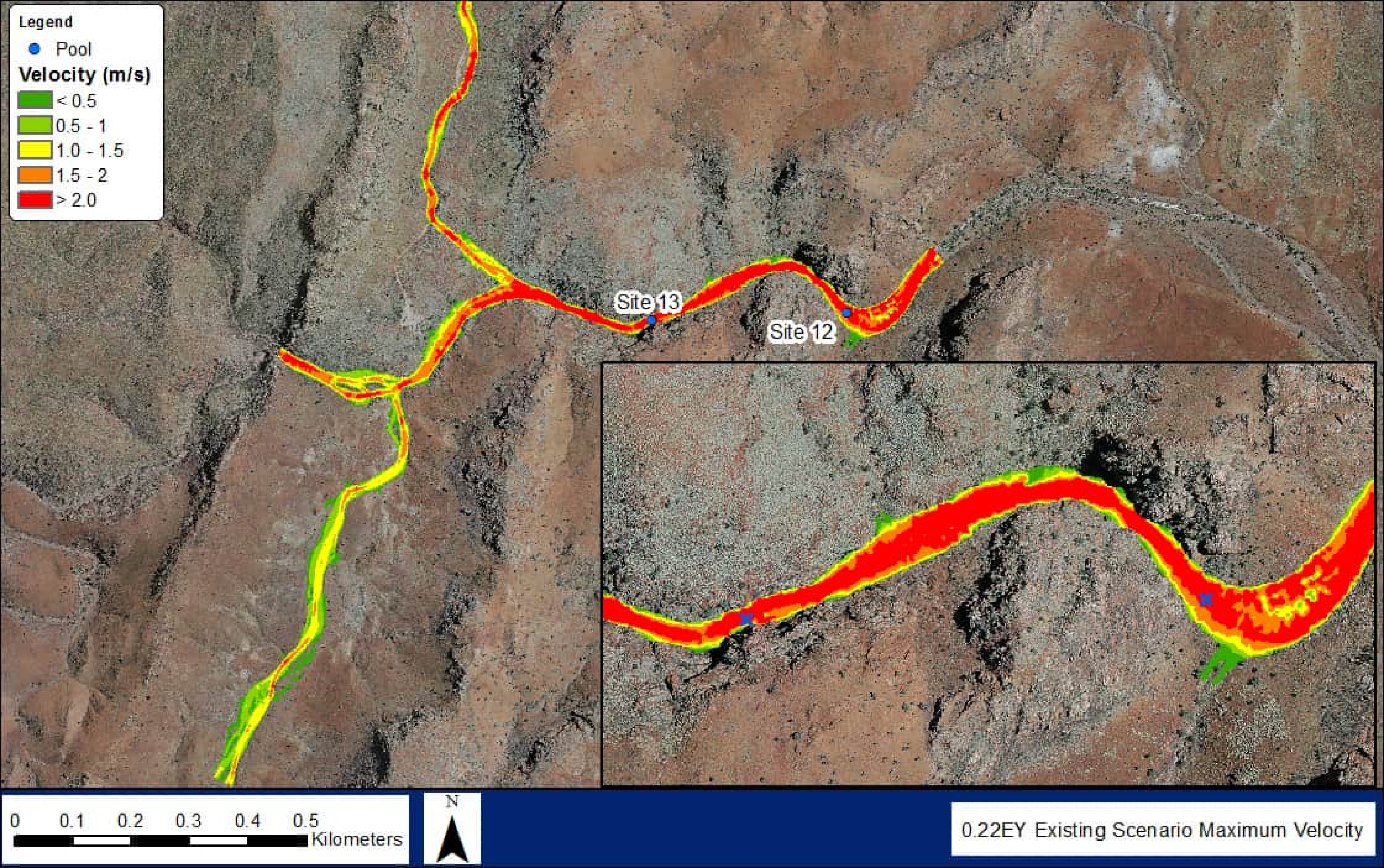
Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
3EY Existing Scenario Maximum Depth

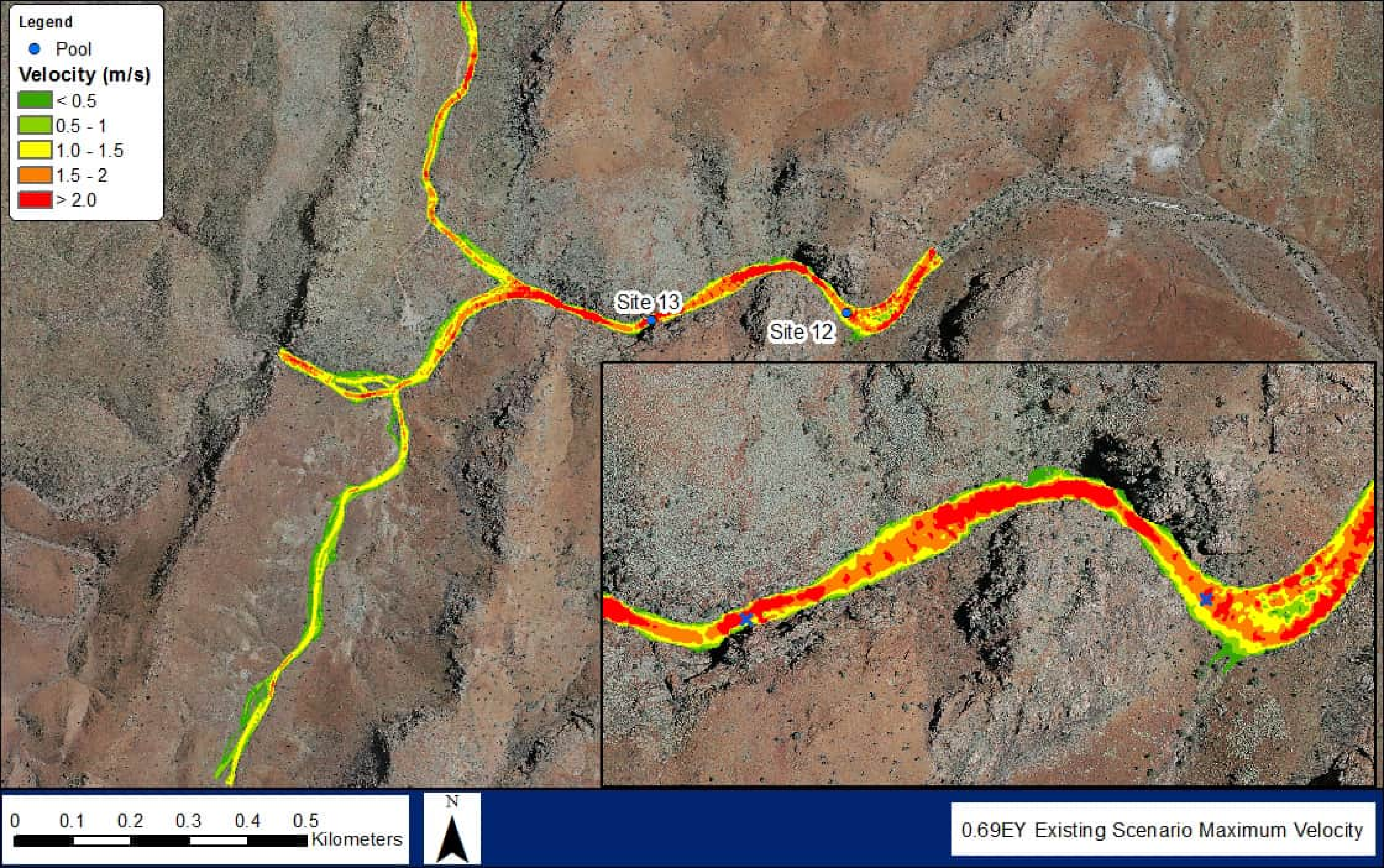

Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
4EY Existing Scenario Maximum Depth

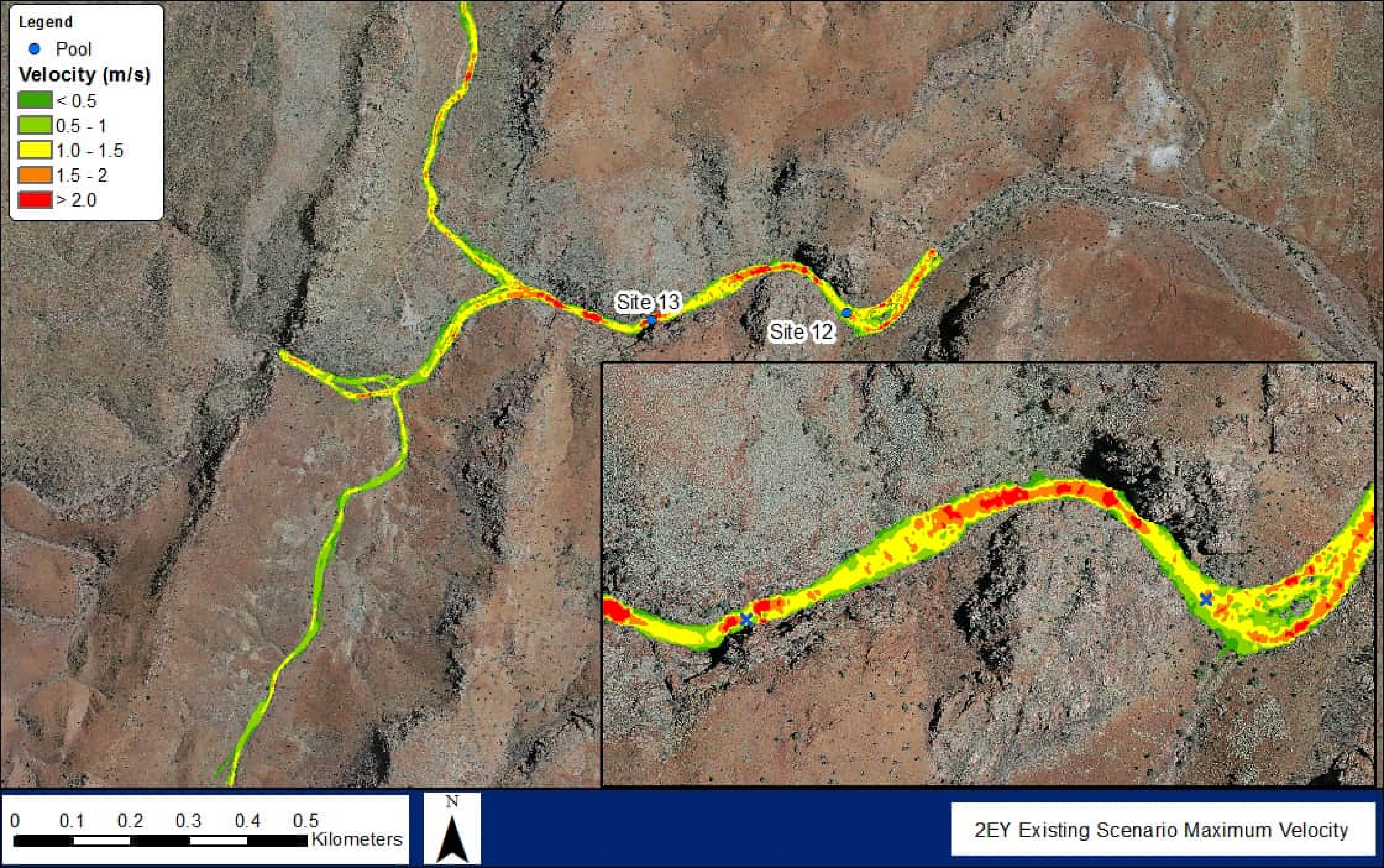
Appendix 2: Existing Scenario Maximum Flood Velocity

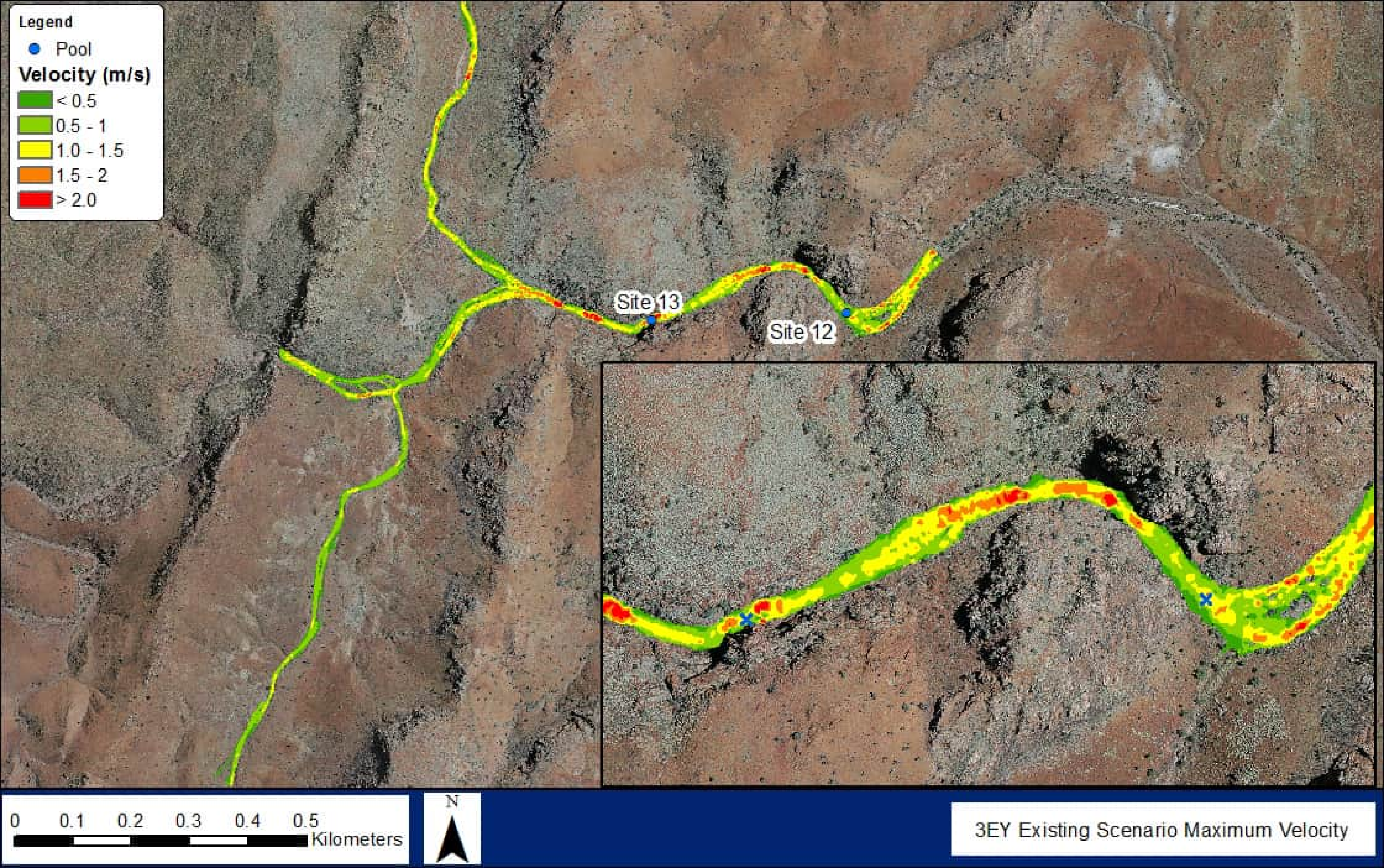


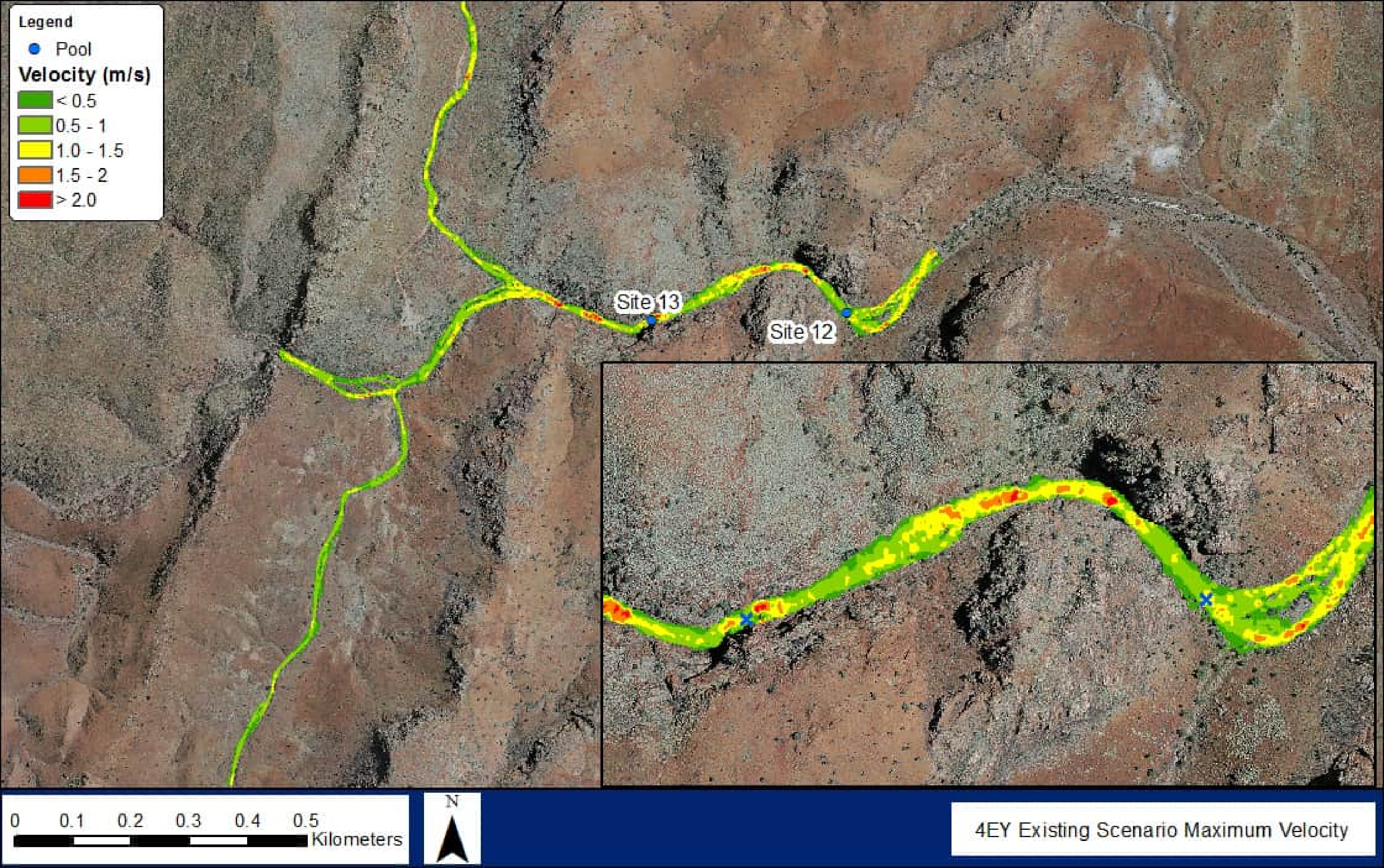
Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0
0.1
0.2
0.3
0.4
0.5
Kilometers
N
0.5EY Existing Scenario Maximum Velocity


Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.22EY Existing Scenario Maximum Velocity

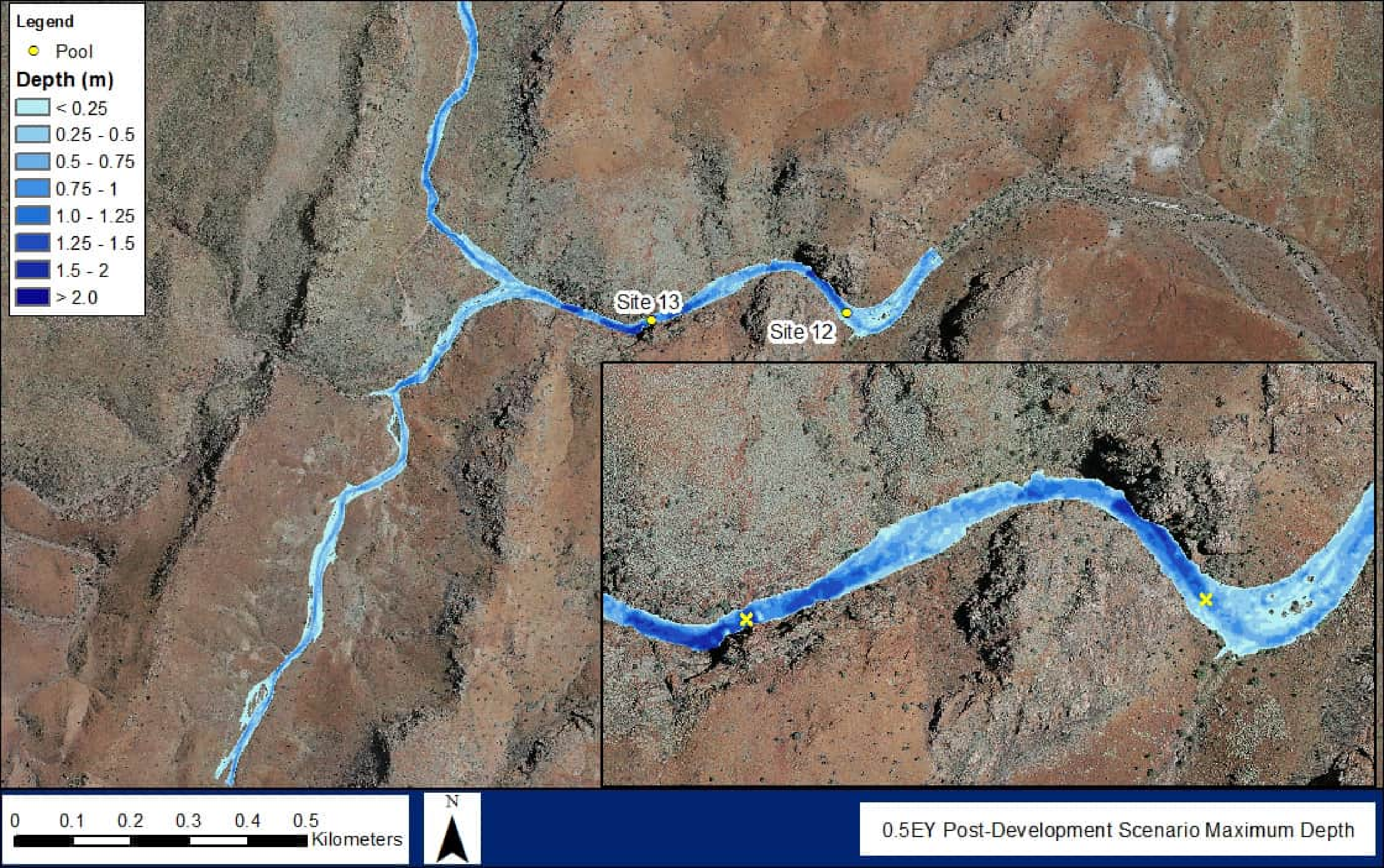

Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.69EY Existing Scenario Maximum Velocity


Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
2EY Existing Scenario Maximum Velocity


Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
3EY Existing Scenario Maximum Velocity


Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0
0.1
0.2
0.3
0.4
0.5
Kilometers
N
4EY Existing Scenario Maximum Velocity

Appendix 3: Post-Development Scenario Maximum Flood Depth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0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.5EY Post-Development Scenario Maximum Depth

Legend
Pool
Depth (m)
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0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.22EY Post-Development Scenario Maximum Depth


Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
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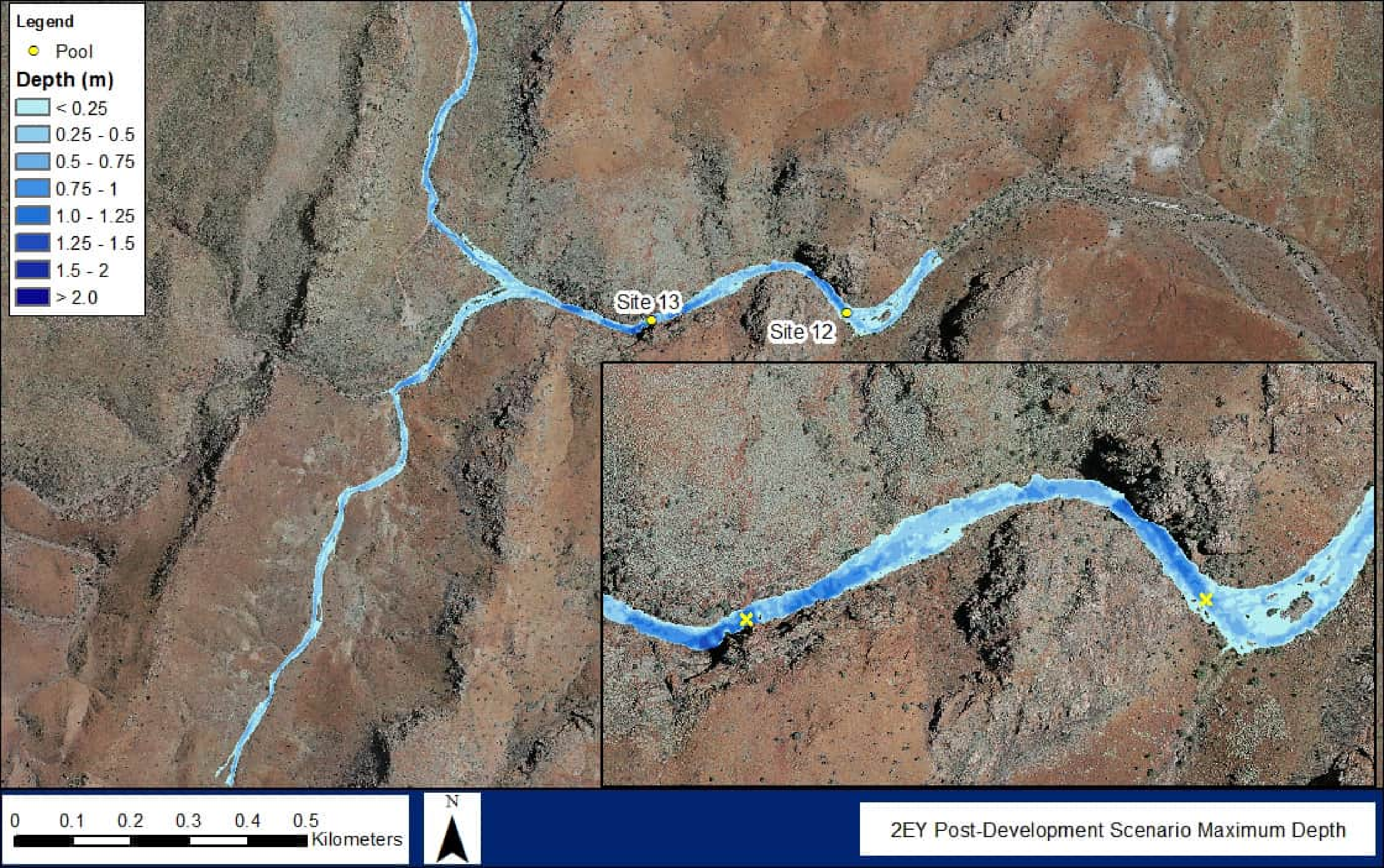
Kilometers
N
0.69EY Post-Development Scenario Maximum Depth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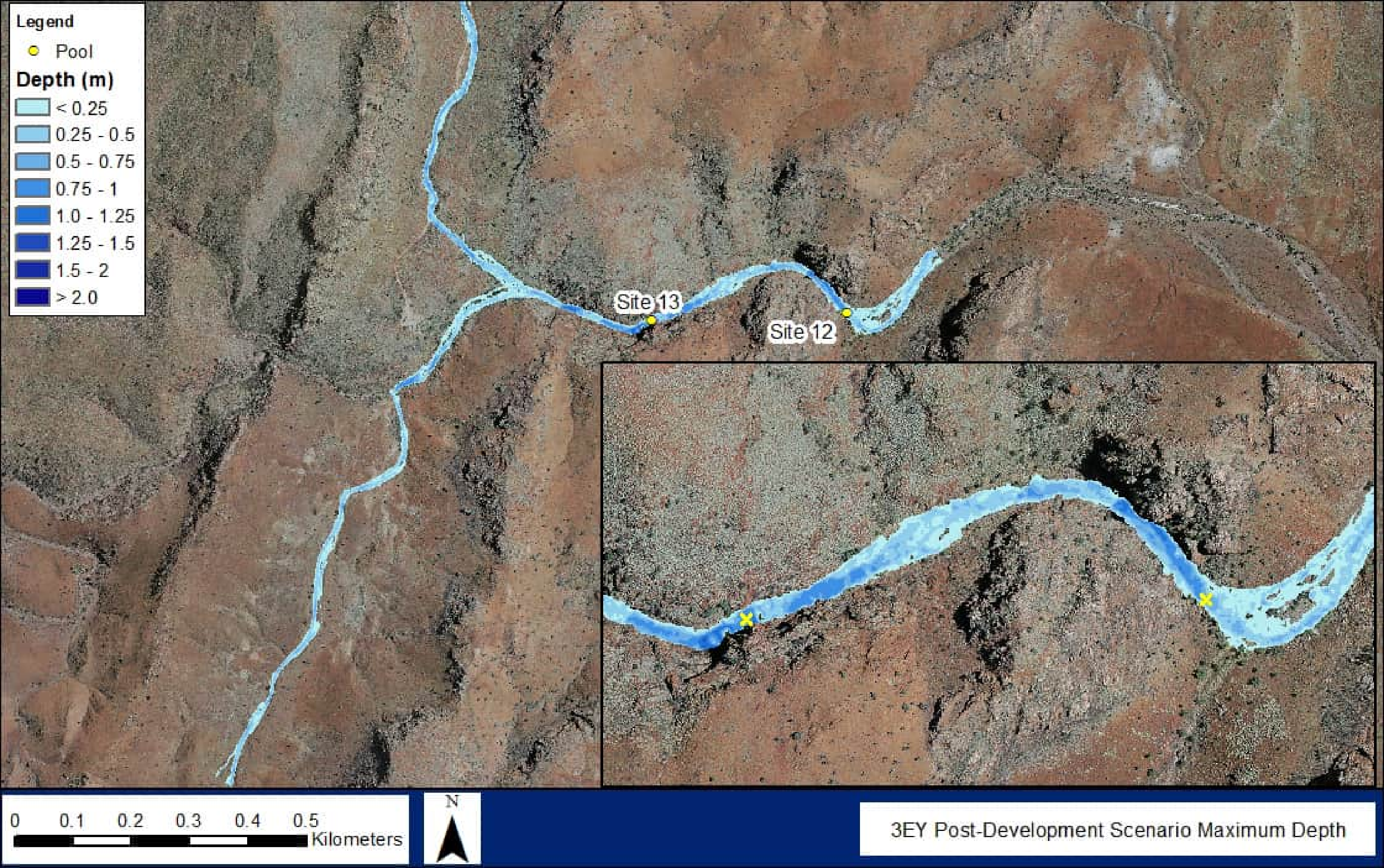
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
2EY Post-Development Scenario Maximum Depth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Pool
Depth (m)
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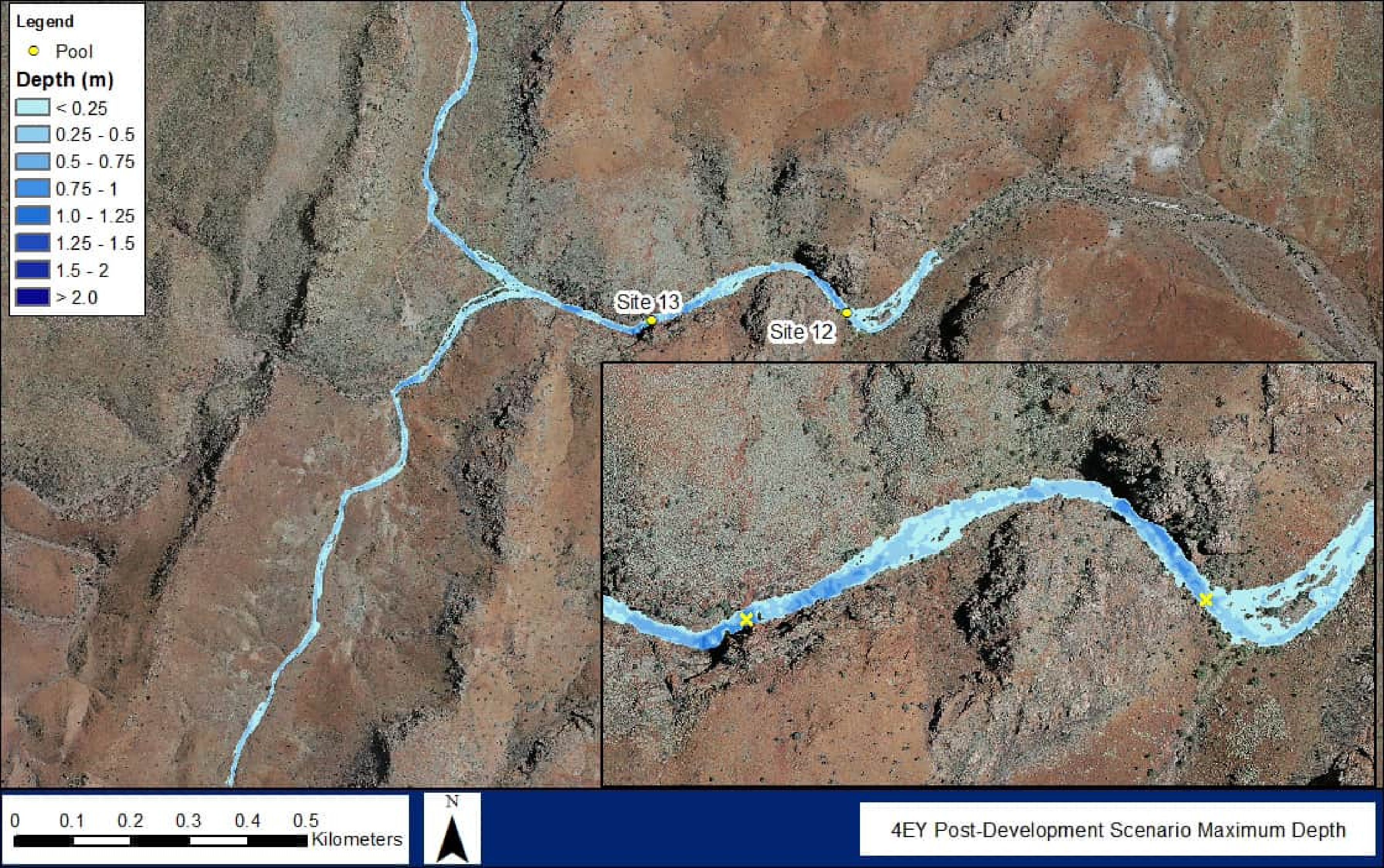
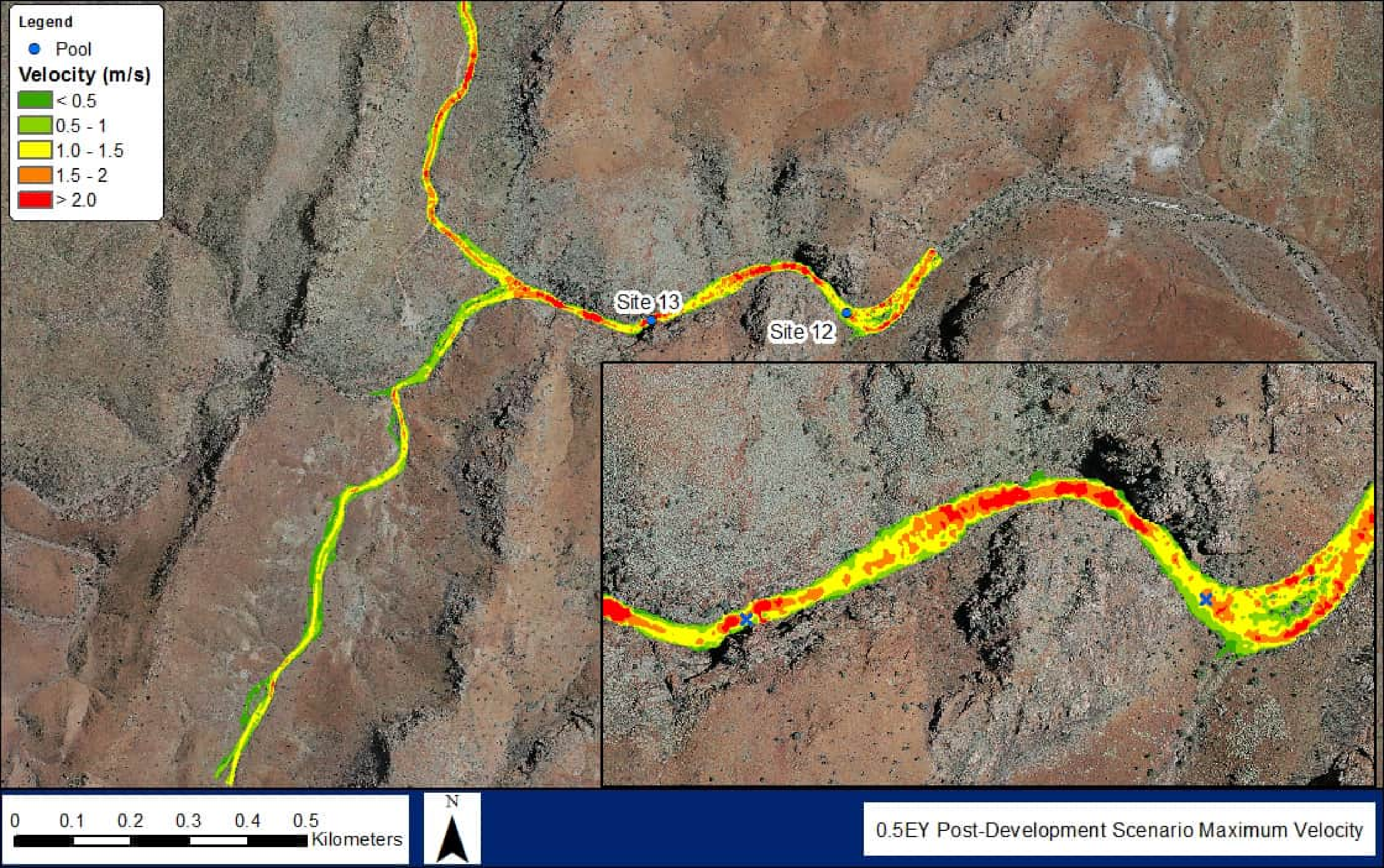
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
3EY Post-Development Scenario Maximum Depth



Legend
Pool
Depth (m)
< 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1.0 - 1.25
1.25 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
4EY Post-Development Scenario Maximum Depth

Appendix 4: Post-Development Maximum Flood Velocity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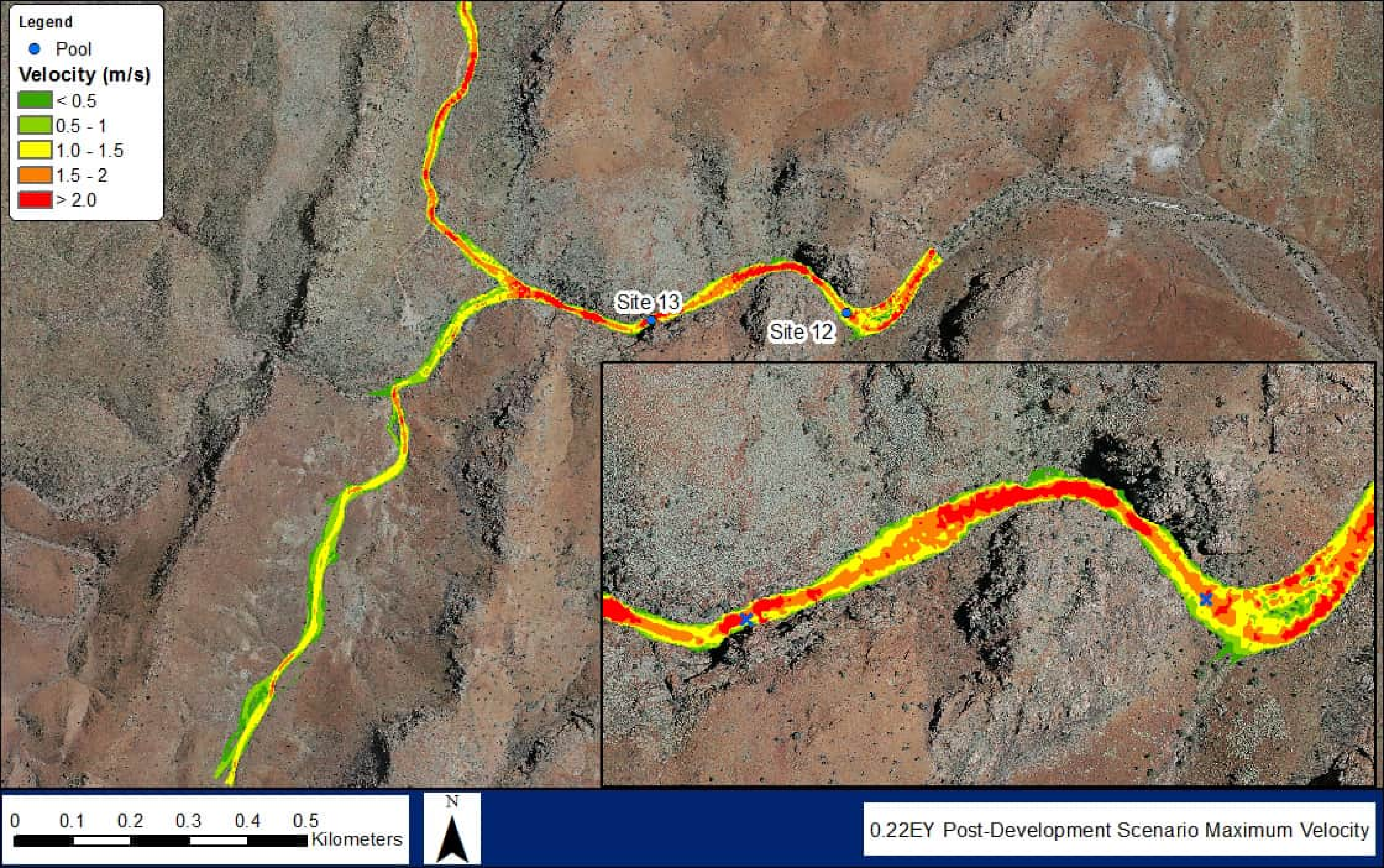
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.5EY Post-Development Scenario Maximum Velocity


Legend
Pool
Velocity (m/s)
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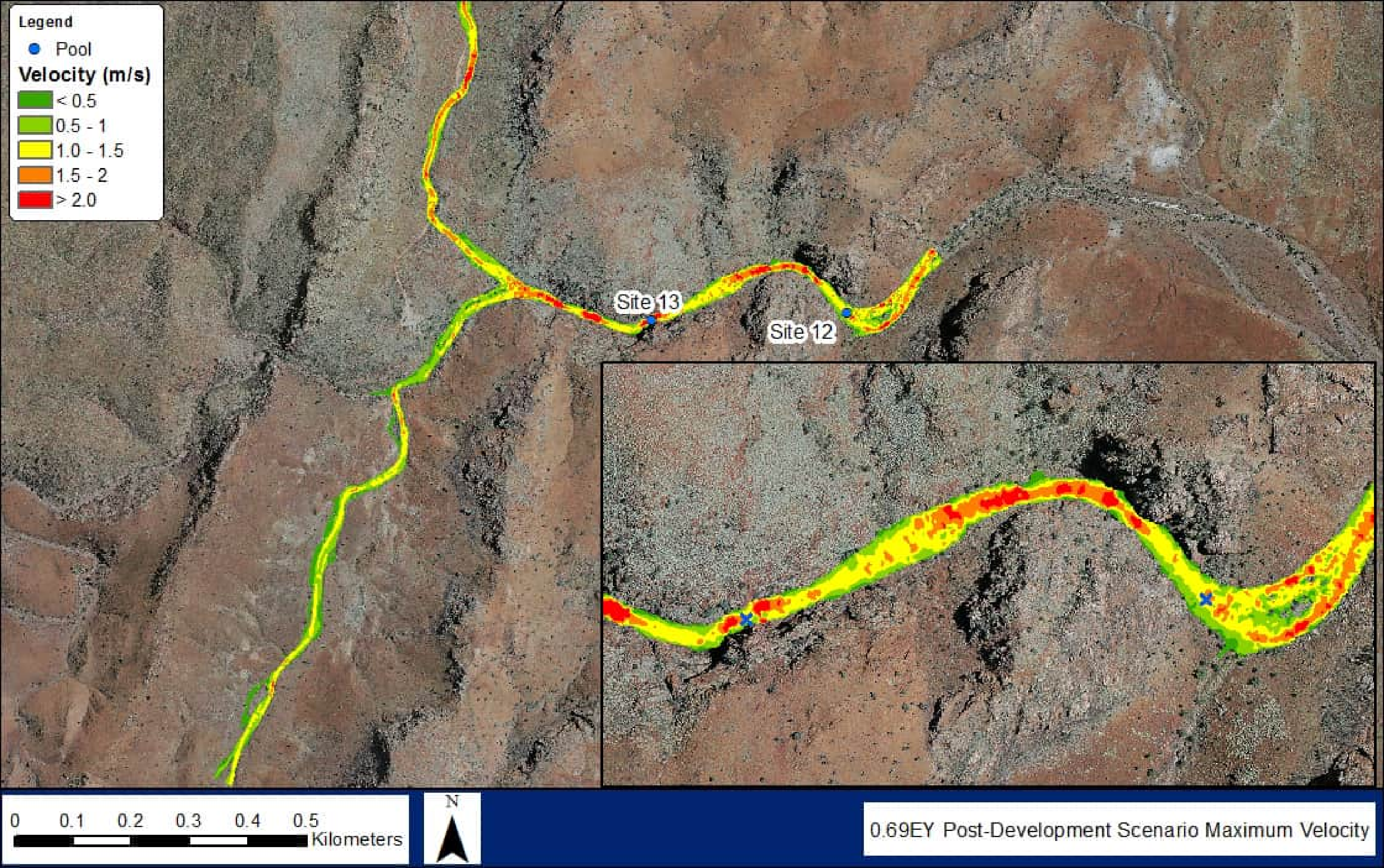
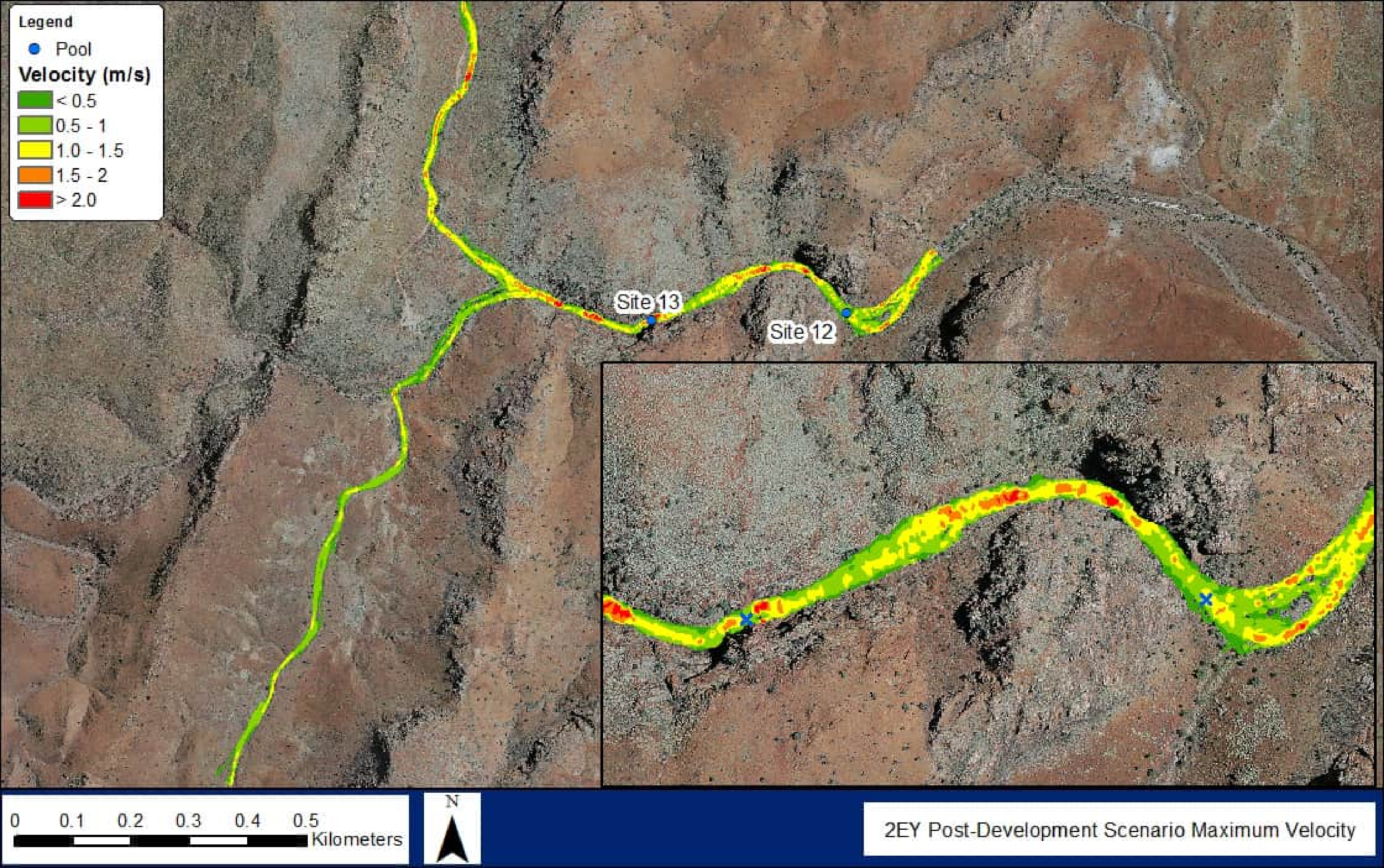
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0
0.1
0.2
0.3
0.4
0.5
Kilometers
N
0.22EY Post-Development Scenario Maximum Velocity



Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
0.69EY Post-Development Scenario Maximum Velocity



Legend
Pool
Velocity (m/s)
< 0.5
0.5 - 1
1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
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Kilometers
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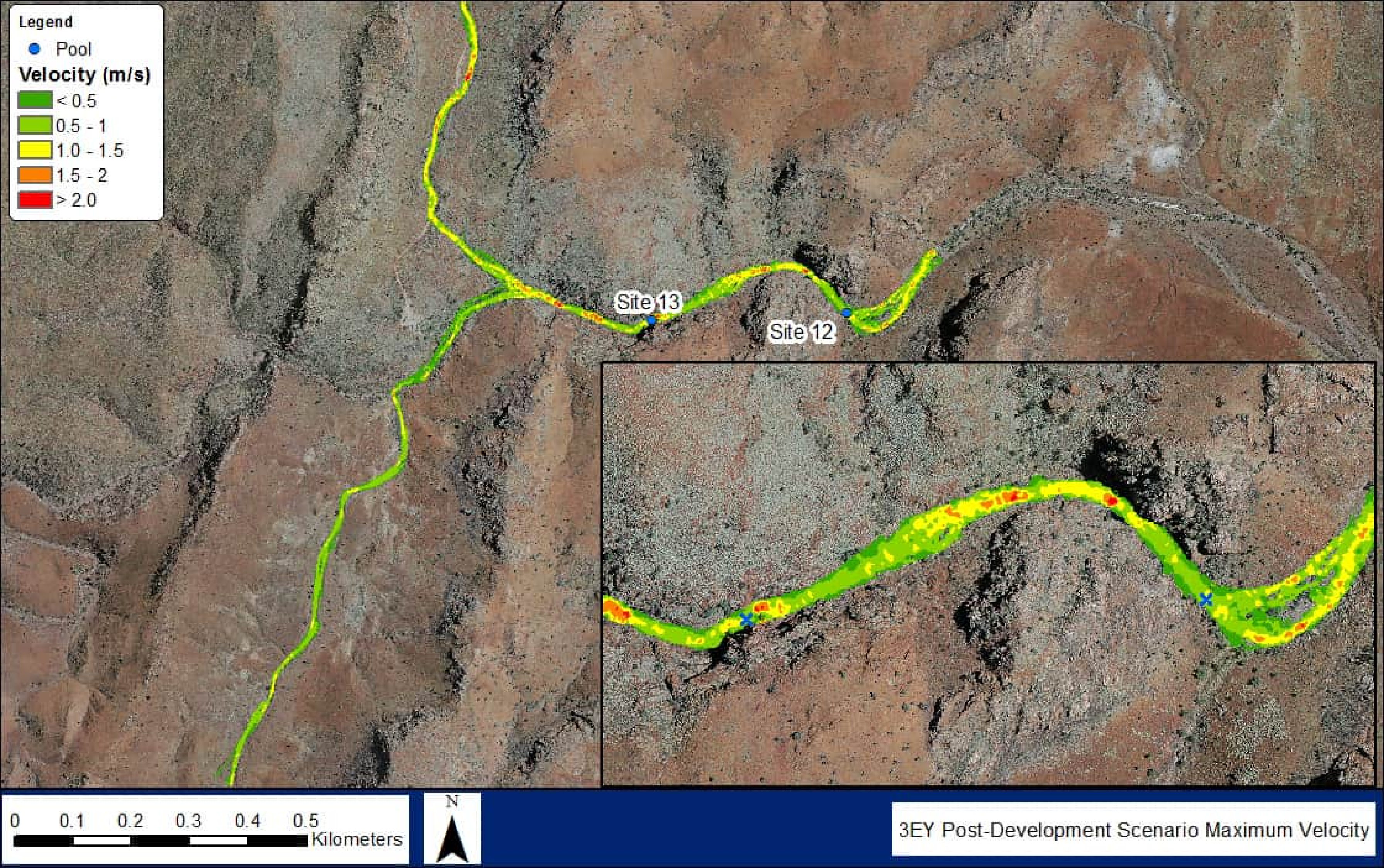
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Pool
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1.0 - 1.5
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0 0.1 0.2 0.3 0.4 0.5
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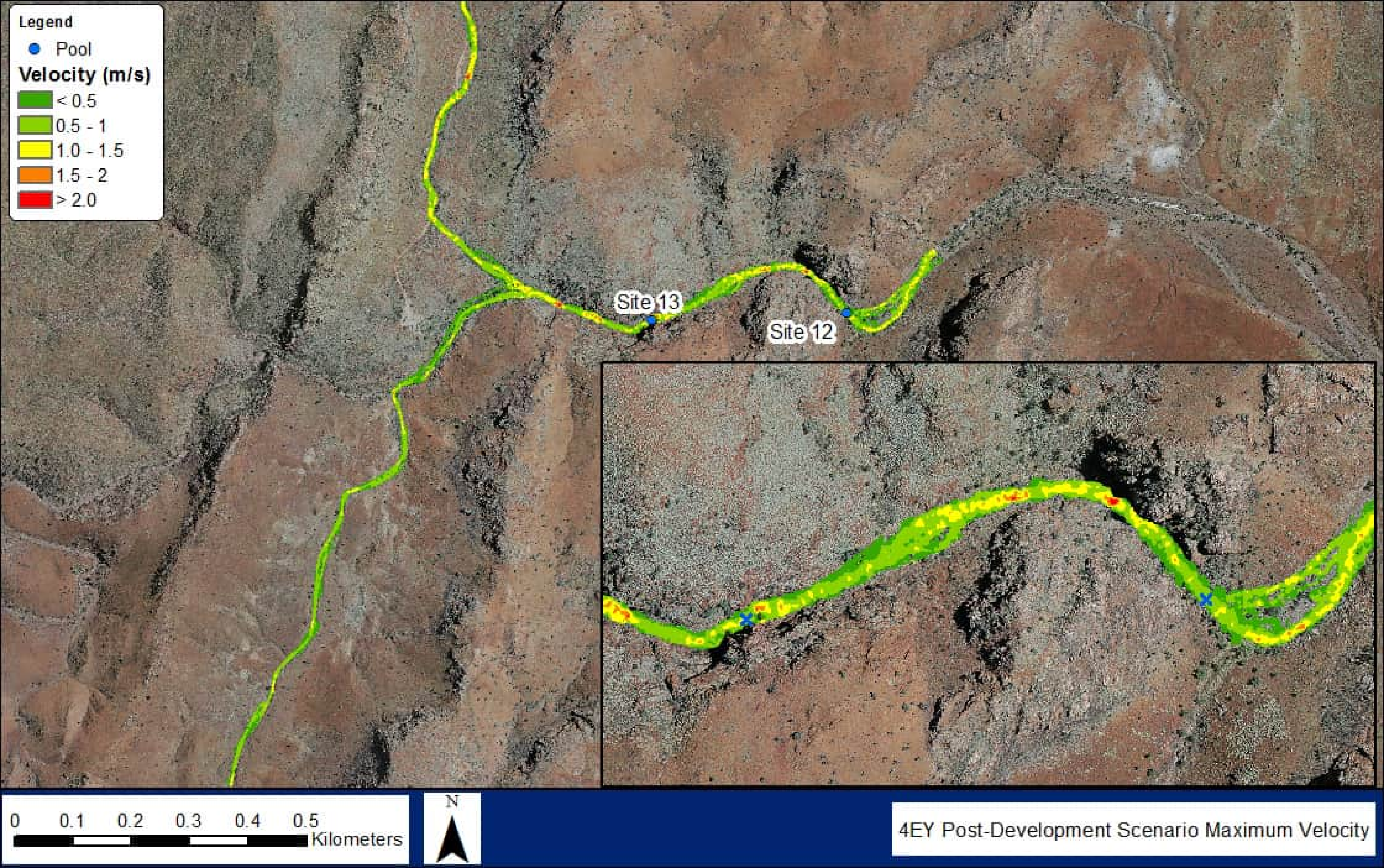
3EY Post-Development Scenario Maximum Velocity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Velocity (m/s)
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1.0 - 1.5
1.5 - 2
> 2.0
Site 13
Site 12
0 0.1 0.2 0.3 0.4 0.5
Kilometers
N
4EY Post-Development Scenario Maximum Velocity

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Attachment 3: Visual Inspection Field Datasheet

Site 12 Pool Visual Inspection Field Data Sheet

Date: / /
Name:

Undertake the following visual inspection during routine water quality monitoring at Site 12 Pool Water Quality Monitoring Site. This will form part of the site investigation assessment in the event of Primary Trigger Levels being exceeded. See below for visual guide for conducting inspection, and example of site photo. Coordinates for all monitoring locations are provided on the site photo using the coordinate system is GDA 1995 MGA Zone 50. The access to the specified location for the individual monitoring sites are subject to the safe access particularly during the wet season.

Record YES or NO below as an indication of observed status of the ecological health.

Habitat health parameter	YES	NO
Fish presence	☐	☐
Macrophyte presence	☐	☐
Recent sedimentation presence *(Provide additional details below)* *(Include photos with GPS coordinates for future reference)*	☐	☐

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Observations of change *(i.e. recent fire, nearly dry, flooding, cattle impact or dead animals)* *(Provide additional details below)*	☐	☐

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Site photo taken *(Details of type of camera type (i.e. digital vs 35mm etc)*	☐	☐

…………………………………………………………………………………………………

Any additional comments

…………………………………………………………………………………………………

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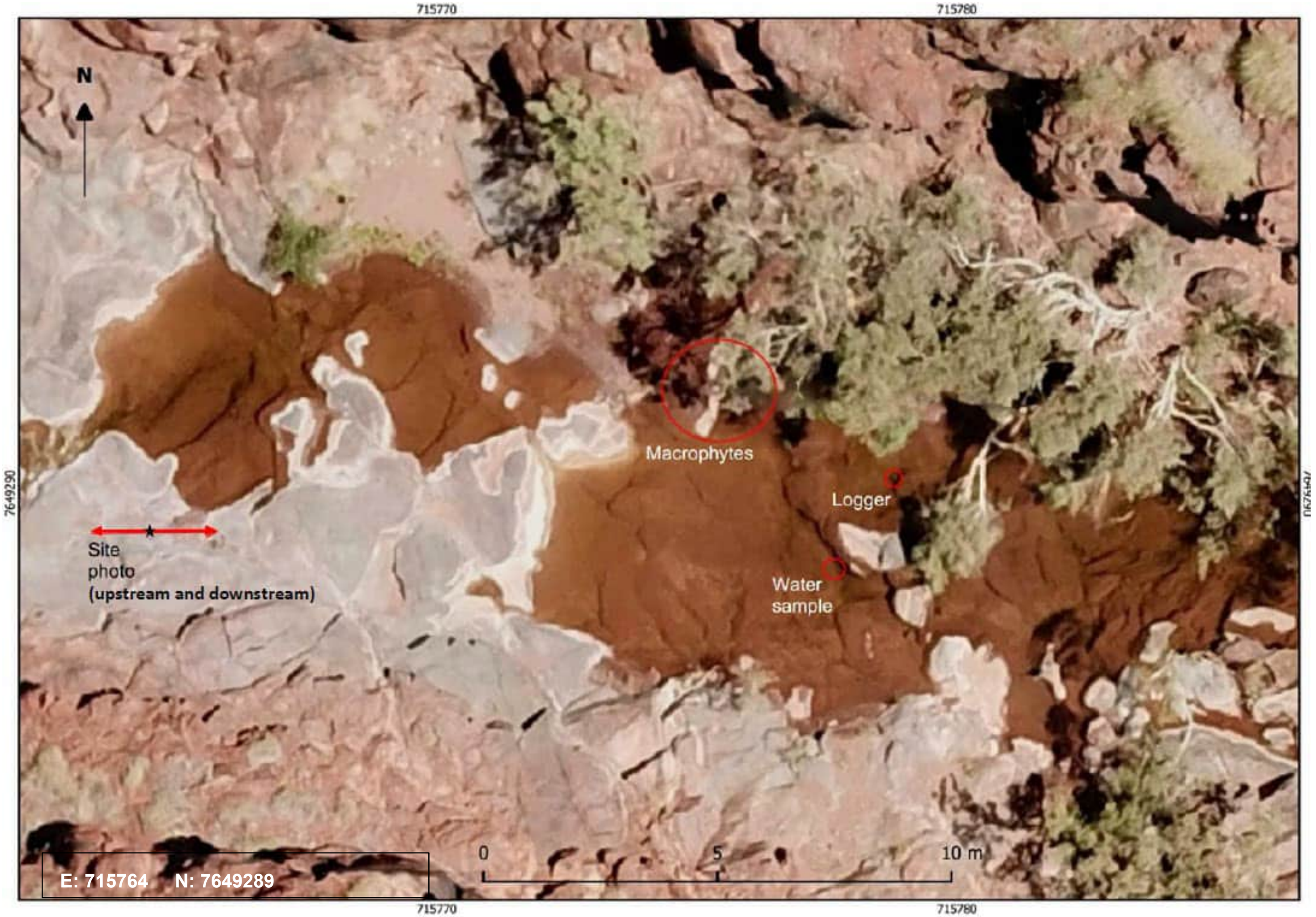

Guide for conducting visual inspection at Site 12 Pool

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Attachment 4: Surface Water Monitoring Procedures

SURFACE WATER MONITORING PROCEDURES

Surface water sampling should be conducted in accordance with:

- AS/NZS 5667.1:1998 Water Quality- Sampling - Guidance on the design of sampling programs, sampling techniques and preservation and handling of samples
- Department of Water (2009) Field Sampling Guidelines: A guideline for field sampling for surface water quality monitoring programs
- The methods outlined below.

Water Quality

Equipment Preparation

This section outlines standard procedures (appropriate equipment, sample bottles, safety gear and a sampling procedure) to ensure that field staff are suitably prepared and able to collect high-quality monitoring data.

Any equipment that comes into contact with water samples (e.g. pH probes, scoops) must be appropriately cleaned and decontaminated prior to each use and between samples to minimise possible cross contamination. Sampling equipment (aside from bottles supplied by the laboratory) should be washed using detergent and tap water, and then rinsed thoroughly with deionised (DI) water before setting out. Sampling equipment should be rinsed with DI water again in between collection of each sample.

Field meters (e.g. pH and conductivity meters) must be calibrated according to the manufacturer's instructions at the start of each day of monitoring. Calibration should be performed using standards of a known concentration appropriate to the anticipated range of values in the water to be sampled. Calibration standards should be stored appropriately (e.g. keep refrigerated and do not exceed 'use by' dates) to ensure their accuracy. The required volume of standard should always be decanted into a suitable receptacle for calibration purposes and then discarded.

After all equipment is cleaned and calibrated, a field kit with the following items should be prepared to take out on the sampling round.

- Field data sheets
- Completed sample labels
- Chain of custody forms
- Container for field measurements

- Sample bottles for dispatch to a NATA accredited laboratory
- If necessary, equipment for collection of samples from a safe distance (e.g. sample pole)
- Filtration equipment and syringe (for metals analysis)
- Field parameter meters or test kits (pH and turbidity meter)
- Container with sufficient DI water
- Powder-less nitrile gloves
- Esky and ice packs for preserving samples
- Personal Protective Equipment (PPE), first aid, and communication equipment
- Other equipment may be needed and should be added to the field kit as required.

Sample Bottle Preparation

When collecting water quality samples using the grab sample method the following instructions should be followed:

- The most important factor when sampling is personnel safety. If the monitoring program cannot be carried out in a reasonably safe manner, then alternative options should be considered. Always sample in pairs and have adequate safety equipment available
- Use non-powdered latex gloves when handling the sample bottles and try not to contaminate the sample by touching it with dirty hands or smoking during the sampling event
- Use an extendable water sampler with a plastic scoop on the end to collect the sample. Rinse the plastic scoop three times and collect the sample following the third rinse. Before adding the water sample to the bottle, check if the bottle has preservative (acid) within it, if it does, do not rinse this bottle
- Before filling, rinse the sample bottle out three times with the water being collected, unless the bottle contains a preservative. Fill the sample container to the top so no oxygen can enter the bottle
- Ensure sample blanks and replicates are collected
- All samples should be refrigerated or placed on ice in an esky immediately after being collected
- Water quality Suite A samples should be submitted for analyses at an NATA accredited laboratory within 4 days of collection (to take the holding time for surfactants into account); water quality Suite B and C stages should be submitted within 7 days

- Complete the necessary freight form and ensure it is attached to the esky
- Sample details should be recorded on a Chain of Custody (CoC) form and sample bottles should have corresponding labels. The laboratory copy of the CoC should be provided with the samples when they are couriered to the laboratory
- Attach both the CoC and the freight form to the esky and then take it to the courier who will transport it to the laboratory
- Results and confirmation from the laboratory receiving the samples will be e-mailed to the addresses that are put on the CoC
- Ensure the sample analysis invoice is submitted for processing.

Field Measurements

Parameters to be monitored as 'field measurements' should be sampled and recorded on the Field Sampling Sheet. Sensors should be kept in gentle motion through the water column (or be immersed in gently flowing water) while a reading is being taken. Allow up to several minutes for the meter to stabilise.

Where possible, measurements are to be made directly from the water body. Where a risk assessment deems that it is unsafe to take samples directly from the water source a sampling device (i.e. a sampling pole) must be used, and the field measurements taken from a container. Care must be taken to ensure that any containers coming into contact with the sample have been properly decontaminated and rinsed with sample water prior to taking any readings.

Electrical Conductivity (EC) data are logged automatically at 6-hourly intervals at each location, and do not require to be manually measured. The EC data will be downloaded from the data logger during one of the sampling events (approximately quarterly) for analysis.

Sample Collection

Where possible, water samples are to be collected directly from the water body. Where a risk assessment deems that it is unsafe to take samples directly from the water source, a sampling device (i.e. a sampling pole) must be used, and the sample bottles filled from the sampling container. Care must be taken to ensure that any containers coming into contact with the sample have been properly decontaminated and rinsed with sample water prior to collection of samples. A clean pair of nitrile gloves should be worn at each sample site to minimise potential contamination problems.

Most sample bottles are required to be filled completely, so that there is no airspace in the bottle. This should be done very carefully, particularly if there is acid preservative in the bottle, and the bottle should be filled to overflowing prior to replacing the cap.

Note: Sample bottles that have been supplied from an external laboratory may contain preservatives and therefore should not be rinsed or submerged in the water body.

Field Filtration

Some samples (all samples being sent for metals analysis) require field-filtration. The analytical laboratory can typically provide the filtration equipment, which often consists of a syringe and a set of disk filters.

The standard procedure for syringe filtration is as follows:

- Draw an aliquot of the sample into the syringe from the water body or sample collection container taking care to maintain an air gap between the base of the plunger and the sample to minimise contact and potential contamination
- Dispense aliquot to waste to rinse syringe. Repeat
- Draw an aliquot of the sample into the syringe taking care to maintain an air gap between the base of the plunger and the sample to minimise contact and potential contamination
- Affix appropriate filter unit to syringe (between 0.4 and 0.5 μm) and dispense into laboratory sample container
- Re-seal laboratory sample container.

Storage and Transport

Samples should be stored according to the preservation procedures summarised from AS/NZS 5667.1:1998. Generally, samples are stored on ice (or ice-bricks) in an esky for transport to the laboratory. Depending on holding times and how long it will take for samples to the delivered to the laboratory, it may be necessary to freeze some of the samples. The appropriate method and period of storage is dependent on the analyte of interest and must be adhered to so that representative results from analysis are obtained. While sample preservation will limit degradation, dispatch to the laboratory should occur as soon as practicable, ideally on the same day they were collected.

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Attachment 5: Surface Water Monitoring and Aquatic Ecology Survey Baseline Report (Hydrobiology 2021)

IRON BRIDGE: SURFACE WATER MONITORING & AQUATIC ECOLOGY BASELINE REPORT

LATE WET 2019 TO LATE WET 2021

FMG IRON BRIDGE (AUST) PTY LTD

VERSION 1.2

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OCTOBER 2021

THIS COMPANY IS REGISTERED FOR GST.

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	P21012	Version 1.2

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PROJECT SUBTITLE	Late Wet Season 2019 to Late Wet Season 2021
PROJECT MANAGER	Phil Whittle
FILENAME	P21012 FMG Iron Bridge Aquatic Ecology Baseline Report v1.2

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Version 1.1	Phil Whittle Sorcha Cronin-O'Reilly	Phil Whittle	Phil Whittle	22/9/2021
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FILENAME	DESCRIPTION	ISSUED TO	ISSUED BY
P21012 FMG Iron Bridge Aquatic Ecology Baseline Report v1.2	Version 1	Ying Yu	Phil Whittle

GLOSSARY OF ACRONYMS

Acronym	Definition
ANZG	Australian and New Zealand Guidelines for fresh and marine water quality
BRUV	Baited Remote Underwater Video- a sampling method for fish
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DSIAR	Diatom Species Index for Australian Rivers
EC	Electrical Conductivity
EPT	Ephemeroptera, Plecoptera, Trichoptera: three macroinvertebrate orders that comprise a biotic index
FMGIB	FMG Iron Bridge (Aust) Pty Ltd
N	Nitrogen
NTU	Nephelometric Turbidity Units
P	Phosphorous
QA/QC	Quality Assurance/Quality Control
SO4	Sulphate
SPC	Specific Conductivity (conductivity normalized to 25°C)
TDS	Total Dissolved Solids
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids

Contents

tables

figures

1. INTRODUCTION

This report presents the findings of the baseline aquatic ecology monitoring program of surface water pools at the Iron Bridge Project between December 2019 and June 2021.

1.1 BACKGROUND

Hydrobiology WA Pty Ltd (Hydrobiology) conducted an aquatic ecology baseline monitoring program of surface water pools to support the baseline development and approvals of the Iron Bridge Magnetite Project (the Project) in the Pilbara region of Western Australia on behalf of FMG Iron Bridge (Aust) Pty Ltd (FMGIB). The managing entity for the Project is IB Operations Pty Ltd (Iron Bridge), a joint venture company between FMGIB and Formosa Steel IB Pty Ltd.

1.2 OBJECTIVES

The objectives of the aquatic ecology survey are the following:

- Establish baseline aquatic ecology conditions at selected surface water pools, which will support future assessments of impacts potentially resulting from the Project.
- Implementation of the Iron Bridge Surface Water Management Plan (FMG, 2020).
- Inform the Site 12 Pool Water Quality and Hydrological Regime Investigation (Hydrobiology, 2020) and provide technical input to the Site 12 Pool Water Quality and Quantity Management Plan (FMG, 2020).

2. METHODOLOGY

2.1 SITE LOCATIONS

The Project is located 110 km south of Port Hedland in the Pilbara region and incorporates the North Star and Glacier Valley Magnetite ore bodies. The aquatic ecology survey was conducted at six surface water pools at Iron Bridge within the Turner and Strelley/Shaw River catchments (Figure 2-1) and is situated within the Chichester IBRA bioregion and the Grassland climate class. Hydrological data was additionally collected from surface water creeks at Iron Bridge. A map of the survey sites for aquatic ecology is provided in Figure 2-2, including catchment areas for each site. Study site catchment areas and coordinates are provided in Table 2-1.

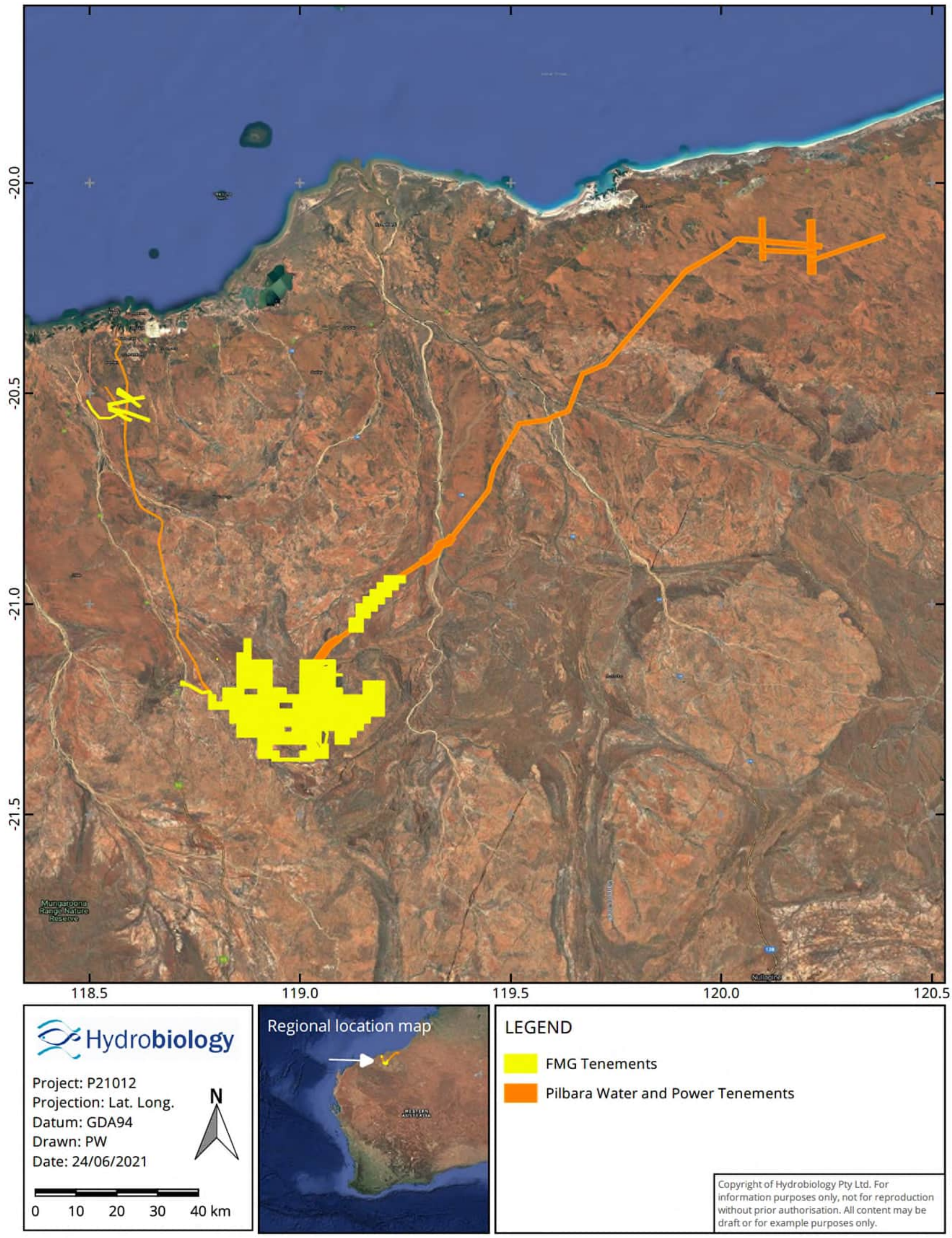


Figure 2-1 Regional study location area map showing project tenements

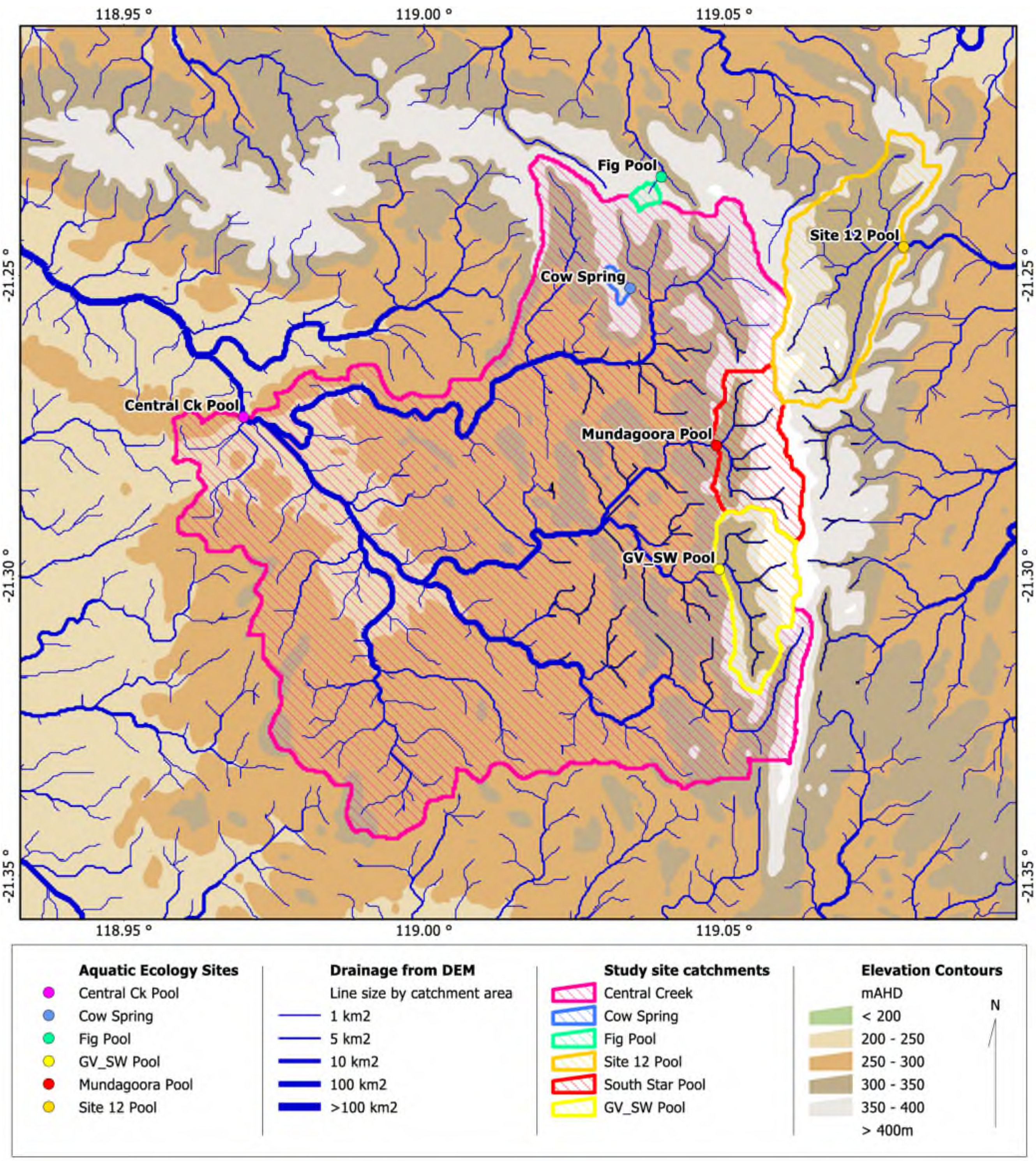


Figure 2-2 Study site catchments and drainage lines

Table 2-1. Summary of study sites included in the aquatic ecology and surface water monitoring survey for the late wet and late dry season for 2020, and the late wet season 2021, including catchment areas and coordinates (GDA94, UTM 50K)

Site Name	Catchment area (km^2)	Northing	Easting
Fig Pool	0.16	711668	7650632
Mundagoora Pool[1]	3.3	712558	7645667
Site 12 Pool	7.6	716248	7649263
Cow Spring	0.15	711103	7648587
Central Creek Pool	85.1	704385	7646299
GV Pool[2]	3.3	712580	7643386

[1] Mundagoora Pool was previusly named South Star Pool

[2] GV Pool was first sampled in the late wet season 2021.

2.2 MONITORING TIMING

Surface water level logger installations, water sampling and initial inspections of several sites were completed in December 2019 (Late Dry 2019). Aquatic ecology sampling for five pools (Fig Pool, Mundagoora Pool, Site 12 Pool, Cow Spring and Central Creek was first initiated in May 2020 (Late Wet 2020). Subsequent surveys were completed at these sites in December 2020 (Late Dry 2020) and May-June 2021 (Late Wet 2021). An additional site, SW_GV Pool, was added in December 2020 (Late Dry 2020) with a site inspection and the installation of a water level and conductivity logger. This site (GV_SW Pool) was first surveyed for aquatic ecology in May-June 2021 (Late Wet 2021).

The late wet season baseline aquatic ecology surveys are conducted between May and June. Collecting baseline data during this period captures conditions when the aquatic food web is established, and early life stages of some aquatic organisms are present, which enables effective characterisation of the ecosystem health. The timing of baseline data collection aims to align with the water quality sampling periods for the assessment period, being the wet and drying season.

The late wet season baseline conditions are expected to show greater species diversity and abundance relative to dry season conditions when stressors (such as high temperature and salinity) are typically greater and result in declining ecosystem health. Capturing the seasonal variability is expected to allow for a more accurate assessment of baseline conditions and variability, which will inform surface water management.

Table 2-2 provides the key dates and seasons for the aquatic ecology and surface monitoring survey.

Table 2-2 Summary of the key sampling dates and seasons for the aquatic ecology and surface monitoring survey

Season	Year	Dates	Sites
Late Dry	2019	17 Dec-19 December	Installation of loggers, water sampling and site inspections. No Aquatic Ecology sampling.
Late Wet	2020	29 May – 2 June	Fig Pool, Mundagoora Pool, Site 12 Pool, Cow Spring, Central Creek
Late Dry	2020	8-13 December	Fig Pool, Mundagoora Pool, Site 12 Pool, Cow Spring, Central Creek
Late Wet	2021	21-28 May	Fig Pool, Mundagoora, Site 12 Pool, Cow Spring, Central Creek, GV Pool

2.3 WATER QUALITY AND HYDROLOGICAL MONITORING

2.3.1 IN-SITU SAMPLING

Water level, temperature and conductivity loggers were installed in each pool to continuously monitor the effects of rainfall, the rate of drying, and evapo-concentration effects. Insitu Aquatroll CTD data loggers were installed in Site 12 Pool, Fig Pool and Mundagoora Pool from December 2019 and currently remain in situ. Further Insitu Aquatroll CTD data loggers were installed in Cow Spring Pool and Central Creek Pool in May 2020 and currently remain in situ. An additional logger was installed in GV_SW Pool in December 2020 and remains active. All loggers were downloaded during each survey, including most recently in June 2021.

In addition to the permanently deployed loggers, a calibrated YSI DSS Pro water quality sonde was used to collect in situ measurements from all sites where sufficient water was present during field surveys. Measurements were collected following the 'Field sampling guidelines: A guideline for field sampling for surface water quality monitoring programs' procedure for physical parameter sampling (Department of Water, 2009 pg. 13). In-situ measurements were collected before all other activities to ensure that no disturbance to water quality was caused by sampler activity. The following field parameters were collected; temperature (°C), pH, oxidation reduction potential (mV), dissolved oxygen, specific conductivity (µs/cm), salinity (ppt) and turbidity (NTU).

2.3.2 SURFACE WATER QUALITY

Water samples were collected following the 'Field sampling guidelines: A guideline for field sampling for surface water quality monitoring programs' (Department of Water, 2009) procedure for direct sampling. Water samples were collected by submerging the sample containers in the water at the waters' edge with the sampler on the bank to minimise disturbance. Powder-free nitrile gloves and laboratory prepared bottles were used to avoid potential sources of contamination. Unpreserved sample containers were rinsed three times with sample water before retaining a representative sample, and preserved bottles were filled from a pre-rinsed syringe. Samples for dissolved metals analysis were syringe filtered within 1 minute of collection through 0.45 µm membrane filters using 50 mL polyethylene disposable syringes.

Upon collection, samples were immediately placed on ice in a dedicated esky and then transferred to a fridge at the earliest convenience. For delivery to ALS Australia, samples were packed in clean coolers with ice bricks. All bottles and filtering equipment were prepared by NATA-accredited ALS, Perth. Samples were sent to a NATA accredited laboratory for analysis for parameters which allowed for a broad characterisation of the examined environments. The parameters are identified in Appendix A.

Water quality samples were also delivered to the Stable Isotope Laboratory, West Australian Biogeochemistry Centre, University of Western Australia for isotope analysis. Samples were analysed for δ2H and δ18O, using an Isotopic Liquid Water and Continuous Water Vapour Analyser Picarro 2130i and followed the procedure of Skrzypek and Ford (2014).

2.3.3 SEDIMENT QUALITY

Sediment samples were collected following the 'Handbook for Sediment Quality Assessment' procedures for the collection of surface sediment (Simpson *et al.*, 2005). Surface sediment was collected from the top 5 cm of sediment and homogenised in a bowl before transferring to sterile jars. Powder-free nitrile gloves and laboratory prepared jars were used to avoid potential sources of contamination. Samples were stored on ice in a dedicated esky and transferred to a fridge at the earliest convenience. For delivery to ALS Australia, samples were packed in clean coolers with ice bricks. Samples were sent to a NATA accredited laboratory to analyse parameters, including total metals, major ions, total organic carbon, total nitrogen and total phosphorous. The specific parameters are identified in Appendix B.

2.4 AQUATIC ECOLOGY MONITORING

2.4.1 MONITORING PARAMETERS

Aquatic ecology monitoring parameters were selected following the ANZG process (ANZG, 2018) for selecting relevant ecological indicators of water quality through establishing environmental values and identifying conceptual impact mechanisms. These indicators are algal (diatom/phytoplankton) communities, macrophyte communities, macroinvertebrate communities and fish communities. The selection of these four communities provides multiple lines of evidence and spans multiple trophic levels and phyla, which is recommended by ANZG (2019) in order to capture the variable impact of ecosystems stressors and detect, for example, impacts of bioaccumulation and biomagnification. Algae, macroinvertebrates, fish and macrophytes typically underpin the food web in pools, providing habitat and/or food sources for a diversity of native species including terrestrial or semi-aquatic organisms that may utilise the pool such as reptiles (e.g. Pilbara olive python), avian fauna and amphibians (Halse et al. 2001).

2.4.2 FISH AND DECAPOD CRUSTACEANS

2.4.2.1 SAMPLING

Fish and decapod communities were sampled to collect data on higher-order organisms with relatively long life spans, which is useful for assessing bioaccumulation and biomagnification effects, interannual survivability and reproduction. Evidence of reproduction was sought (*i.e*. presence of juveniles) to detect sub-lethal effects impacting reproduction or vulnerable size classes.

Fish and decapod crustaceans were sampled using fyke nets and traps. Two trap types, box traps and bait traps, were used to collect a more representative sample of size classes present at a site (Osawa et al. 2015). Fyke nets were 4 m long, 1 m diameter, 4 m wings, with a 4 mm mesh size and 150 cm diameter entry hole. Bait traps were 0.4 m long, 0.25 m wide and 0.25 m high, with a 5 mm mesh size and 30 mm diameter entry holes. Box traps were 0.6 m long, 0.45 m wide and 0.2 m high, with a 10 mm mesh size. Traps were baited with a 50/50 ratio of cat food biscuits and whiting based burley. At each pool, one fyke net, two bait traps, and two box traps were set for overnight an average of 12 hours (maximum 19 hours). Traps were set along the length of the pools, predominantly in bank habitats with high structural complexity (e.g. macrophytes, woody debris, root masses), where abundance was likely to be highest.

After two rounds of sampling (Late Wet 2020 and Late Dry 2020) it was decided that the box traps were not providing useful data as they rarely caught fish and those that were caught were not representative of the counts in the fyke nets, or fish abundance observable within the pools. The use of traps was discontinued for future surveys, and fyke nets are used as the primary measure of fish abundance and diversity for this program.

Following capture, the first 30 individuals of each species were randomly selected for subsampling to reduce handling stress on the entire catch. Subsampled individuals were counted, measured (total length and standard length) and weighed. The remaining individuals were counted and allocated to one of four length classes based on standard length (SL) (*i.e.* <30 mm, 30 – 60 mm, 60 – 90 mm and >90 mm). All fish were kept in aerated tubs immediately after capture, prior to being measured and were immediately released near the collection point after processing.

As a secondary measure of fish abundance and species presence at each site, Hydrobiology utilised baited remote underwater video traps (BRUVS). Baited underwater GoPro 5 cameras were deployed in suitable habitats at each site, and the video was set to record for 10 minutes.

2.4.2.2 ANALYSIS

Fish abundance at each site was compared for each season. Catch per unit effort (CPUE) was used as a measure of abundance and was defined as the species total catch divided by the soak time in hours. Fish were grouped into standard length classes, and length frequency (%) figures were constructed for each species at each site across the three seasons. Juvenile presence was defined as the presence of smaller size classes that are below the size at sexual maturity described in the relevant literature (based on wild populations).

Where standard length was recorded for subsampled fish, length distribution box and whisker plots were constructed for each species at each site across the three seasons. Independent t-tests and analysis of variance (ANOVA) were used to assess any significant differences in the mean standard length for each species at all sites across the three seasons.

Fish abundance on BRUV footage was recorded using a common metric MaxN, the maximum number of fish per species on a single video frame.

2.4.3 MACROINVERTEBRATES

2.4.3.1 SAMPLING

Macroinvertebrates are a commonly used bioindicator for assessing a variety of environmental issues. ANZG (2019) recommends macroinvertebrate monitoring to assess changes in biodiversity and changes in ecosystem processes of water bodies due to contaminant inputs. The taxonomic groups sensitive or tolerant to declines in water quality are well known and the presence and abundance of these taxa are used to score the water condition of surface water pools.

Macroinvertebrate sampling followed the procedures of 'Western Australia AUSRIVAS sampling and processing manual' (van Looij, 2009). Samples were collected using a 250 µm mesh pond net, 35 cm by 25 cm opening, a 30 cm depth (tail) and a 150 cm handle. The net was rinsed and checked for holes between each site. Two samples were collected from each pool. Due to the pool's small size, two replicates from the same habitat (i.e. macrophyte, pool) was not possible for all pools without risking re-sweeping the extent of the previous sweep. Therefore, samples were obtained from different habitats for most pools. Sites were sampled by sweeping the net starting at the downstream end of the 10 m sampling area and moving upstream while collecting the sample, aiming to sample all the different sub-components of the habitat and at different depths. The contents of the net were then rinsed into labelled sterile containers using 70%

ethanol for preservation. Samples were transported to Stream Macroinvertebrate Identification for identification and enumeration.

Specimens in each sample were laboratory picked following the AusRivAS methods. Samples were identified to family level, where possible. A 10% error margin is allowed for the identifications and enumerations of macroinvertebrates (as required for AusRivAS macroinvertebrate identification accreditation). Any taxa that could not be identified (usually due to their immature stage or deterioration/damage) were recorded at a higher taxonomic level (i.e. Order). Taxa were recorded as present if the head was present in the sample (provided it appeared to be alive at the time of collection). This is common with Ephemeroptera, Zygoptera and Oligochaeta, which are often damaged at the time of collection and only part of the specimen is retained in the sample. Empty (dead) Gastropoda shells are not recorded as being present. Specimens were preserved in a solution of 70% methylated spirits, 5% Glycerol and 25% water and retained for QA/QC purposes at Hydrobiology Perth.

2.4.3.2 ANALYSIS

Several indices were derived from the macroinvertebrate data and are described below as per Negus *et al.* (2013) and Chessman (2003). Each of these indices was qualitatively assessed for changes in values among sampling occasions.

Total abundance – The number of individual macroinvertebrates collected in a sample, which can provide insights into the biological productivity, population health or carrying capacity of an ecosystem.

SIGNAL 2 Index - The SIGNAL index (Stream Invertebrate Grade Number - Average Level) was developed for the bioassessment of water quality in rivers in Australia. It is calculated by grading each macroinvertebrate family based upon the level of its sensitivity to various pollutants. The grades applied range from 1 (tolerant) to 10 (sensitive; Chessman, 2003) and a weight is applied to each taxa depending on its abundance. The SIGNAL 2 score for a sample is calculated by averaging the weighted sensitivity grades of the macroinvertebrate families collected. The version applied here is SIGNAL version 2.iv, SIGNAL 2 Scores suit both family and order-class-phylum identification (Chessman, 2003).

EPT taxa richness - The number of aquatic macroinvertebrate families collected from three orders of aquatic insects: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Macroinvertebrates belonging to these three orders are considered sensitive to changes in their environment and therefore EPT is often used to assess water body conditions. Sensitivity would generally be indicated by a decrease in EPT in the presence of changed environmental conditions; however, increases can occur depending on the nature of the impacts that are present.

Taxa richness - The number of aquatic macroinvertebrate taxa collected in a sample. This index is used as a common measure in many monitoring programs. The use of taxa richness is based on the premise that with changes in the condition of a site, the taxa richness will increase or decrease from the baseline condition. Increases or decreases will depend on the nature of the threats that are influencing the ecosystem.

Additionally, the taxonomic composition of the community was also assessed to see how abundances of individual taxa vary among sampling events. Note that the taxonomic classification level of taxa (e.g. genus, family, order) varies as the taxa are identified to the lowest practical level, with some groups harder to identify to lower levels than others (e.g. Ostracoda).

2.4.4 DIATOMS AND PHYTOPLANKTON

2.4.4.1 SAMPLING

Diatoms (single-celled algae with siliceous cell walls) are effective indicators for ecological change in freshwater systems (Gale, 2015). Diatoms are an important component of the riverine algae community and are commonly used for assessing water quality based on the tolerance of species present to pollution (Oeding and Taffs, 2017). Artificial substrates called periphytometers were used to collect living diatoms over a specified time. Two periphytometers each containing 10 microscope slides were deployed at each of the pools. The substrates were left immersed for an average of four weeks to enable diatom communities to establish, reflecting the ambient water quality. On retrieval, the 10 slides from each artificial substrate were scraped into a small, labelled sample container and preserved with 70% ethanol. They were then submitted to the laboratory for taxonomic identification to species level and enumeration. Dr John Tibby of the University of Adelaide was engaged as the sub-consultant for the taxonomic identification and enumeration.

Water samples were taken from the survey sites and submitted to Dalcon Environmental to analyse a full count phytoplankton profile for each pool. Following the Dalcon Environmental recommended sampling protocol, 1.25 L of water was collected from each site from the mid-water column. Phytoplankton samples were preserved with Lugol's Iodine and chilled on ice for the duration of transport.

2.4.4.2 ANALYSIS

The most widely used biotic indices in Australia, DSIAR score (Diatom Species Index for Australian Rivers score), was derived to quantify diatom ecology at the pools. The DSIAR score estimates water quality by the relative abundance of diatom species sensitive to water quality stressors, where a higher DSIAR score represents higher water quality (Chessman *et al.*, 2007). Total count per sample for each species of planktonic phytoplankton and diatoms is also presented.

2.4.5 MACROPHYTES

Macrophytes (aquatic plants) are sensitive indicators of ecosystem health and can be used to assess when physico-chemical thresholds are reached (e.g. turbidity blocking photosynthesis of submerged macrophytes or impacts of sedimentation) (Barko *et al.*, 1982) and the abundance and spatial distribution of heavy metals in aquatic environments (Cardwell *et al.*, 2002). They play a fundamental role in aquatic systems by, for example, reducing erosion of stream banks, increasing dissolved oxygen levels, providing a food source and mediating food web dynamics by providing habitat structural complexity (Warfe and Barmuta, 2006).

Macrophyte sampling followed the AusRivAS guidance (van Looij, 2009). Macrophyte surface area coverage of emergent, submerged and floating macrophytes (Figure 2-3) was visually estimated across the pool habitat and defined as isolated, scattered, in beds or choking the stream as per the 'Field Sampling and Habitat Assessment Sheet 2006 v.14'. Macrophytes included those which were out of the water but in the active channel. Specimens were photographed and samples collected and preserved in 70% ethanol for subsequent confirmation of taxonomic identification and retained. Macrophytes were identified to the species level where possible.

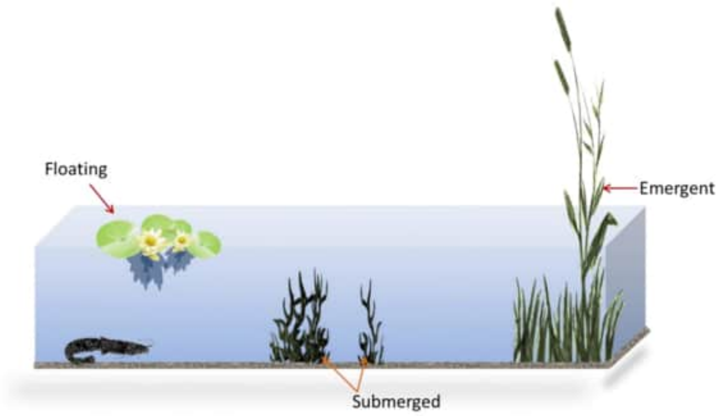


Figure 2-3 Schematic of floating, submerged and emergent macrophytes (DES, 2018).

3. RESULTS

This section presents the findings of the hydrology and aquatic ecology surveys conducted between December 2019 (Late Wet 2019) to June 2021 (Late Wet 2021). The results are presented as distinct chapters for each site to reflect that the surface water pools should not be directly assessed relative to other pools but rather to the temporal patterns of the individual pool. For example, each pool has different hydrology, size and habitats, and the methods used are not spatially uniform (i.e. macroinvertebrate sampling of different habitat types between pools).

3.1 SITE 12 POOL (IB_SW_POOL12_01)

Site 12 Pool is part of a series of shallow pools that lie to the east of the Project on a small tributary to the upper Six Mile Creek. It is connected to both surface water and groundwater sources over the hydrologic cycle, typically sustained by groundwater until the local groundwater level drops below the pool base level over the late dry season. The pool is frequently perennial, though has been known to dry out following small wet seasons. During the late wet season sampling it is a fresh-brackish, predominantly bedrock habitat that supports fish, macroinvertebrates, algal communities, macrophytes and riparian vegetation (Figure 3-1).

3.1.1 WATER QUALITY AND HYDROLOGY

Water quality sampling included physico-chemical parameters, metals analysis and major ions to characterise the surface water system. Stable isotope analysis at Site 12 Pool and bore NS-0664 was also conducted to inform the connectivity of surface water and groundwater. A logger recorded conductivity, temperature and water level on a 3-hourly basis at Site 12 Pool between December 2019 and May 2020.

Site 12 Pool is a shallow bedrock supported natural habitat with a 7.6 km^2 catchment area (Figure 3-3) with typically low rainfall and infrequent high rainfall events largely driven by storm and cyclonic activity. The water quality experiences high seasonal variability due to the climatic conditions of the region, with the greatest variability recorded following rainfall events.

The water quality was predominantly clear (mean turbidity = 2.5 NTU), slightly alkaline (mean pH = 8.5) and a magnesium-bicarbonate ($Ca/Mg\text{-}HCO_3$) dominated water type with low sulphates (SO_4) (Figure 3-4; Appendix A). However, it is expected that during surface water flow events the turbidity temporarily increases. Similarly, during rainfall events, the typically slightly brackish pool (1,100-1,300 µS/cm) would become temporality extremely fresh (<100 µS/cm).

Figure 3-1 Photographs of Site 12 Pool during the late wet season (June 2020; top) and late dry season (Dec 2019; bottom).

Figure 3-5 and Figure 3-6 display a high-resolution water level, salinity (conductivity) and temperature logger record from Site 12 Pool for December 2019 to June 2021 (two wet seasons). The rapid change in conductivity after rainfall events is evident with one minor inflow at the start of the 2019-20 wet season that partially flushed and filled the pool as well as four major inflows that displayed flooding peaks and complete pool flushing. A similar pattern of four flushing events was also observed in the 2020-21 wet season (Figure 3-6). This preliminary baseline data indicates that the pool is sustained by groundwater (until the local groundwater level drops below the pool level) and is periodically flushed with fresh surface water flows after rainfall events. The ratio of Site 12 Pool volume against inflow volume is presented in *Site 12 Pool Water Quantity Assessment and Management* (FMG, 2020). It takes approximately 2 – 3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred. Comparison of the nearby groundwater levels at the Site 12 Groundwater monitoring bore (NS-0664) with the rainfall and flow in the Site 12 Pool is provided in Figure 3-7. This data suggests that the groundwater level recedes at around 3 cm per week over the dry season, reaching the a level below which groundwater no longer maintains the Site 12 Pool towards the end of the dry season.

Site 12 Pool is a larger habitat area relative to other North Star pools, comprising a series of isolated pools spanning approximately a 650 m reach and 1266 m^2, and likely has greater downstream connectivity relative to other pools in the Iron Bridge area. Most pools are shallow, with the deepest being approximately 2.5 m. The total volume of the pools is estimated to be 2,532 m^3 based on an average depth of 2 m. This is a small volume relative to the inflow volume; for example, the 1EY post-development estimated inflow is substantially higher (54,198 m^3) (FMG, 2020). Recorded water levels were a maximum of ~0.6 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded. The rapid falling stage after large flow events indicates there is little retention capacity in the system beyond the pool spill point.

Analysis of the stable isotopes $\delta^{18}O$ and $\delta^{2}H$ in Site 12 Pool and bore NS-0664 indicated that the isotope ratios for the surface water within Site 12 Pool and the upstream monitoring bore (NS-0664) were consistently different, with the groundwater being substantially more depleted, particularly for the late dry season (Dec 2019) sampling event. It is likely that some degree of evaporation along the groundwater inflow to the pool, and within the pool system itself, is creating an enriched signature relative to the deeper groundwater (NS-0664) which is more representative of large rainfall event recharge. The December 2019 isotope enrichment in the Site 12 Pool is evidence that at this stage “fresh” or deep groundwater recharge was at a minimum and evaporative isotopic enrichment was a dominant process. The most depleted isotopic ratio of the dataset was observed at the Site 12 groundwater monitoring bore (NS-0664) following the large 2020/21 wet season. This may indicate that the source of the groundwater at the site was relatively recent rainfall during this period. There are preliminary indications that the groundwater at the Site 12 Pool monitoring bore is more similar to a rainwater isotopic composition after the wet season, moving towards the evaporation line in the late dry.

Although the pool is sustained by groundwater for the majority of the dry season, it has been recorded as completely dry in recent years (2015, 2016 and 2020 dry seasons) following low rainfall and groundwater recharge wet seasons (BOM 2020). The more recent observations noted it did not completely dry out in 2019 (Plate 1). The pool naturally drying out or experiencing substantially lower water levels would be expected to impact significantly on the ecological health of Site 12 Pool due to evapo-concentration increasing environmental stressors (e.g. salinity) and lower water levels reducing available habitat. It is noted that visual observations in the late dry 2019 indicated there were no fish in the pool. However, after a drying event in mid November 2020 (late dry), the pool retained all three fish species within several weeks of re-wetting in December 2020. This indicated that the pool ecological response to drying is variable depending on antecedent conditions. It is unknown if the larger pools downstream of the monitoring location dry out at the same frequency as the monitoring location. These are not accessed regularly due to heritage restrictions.

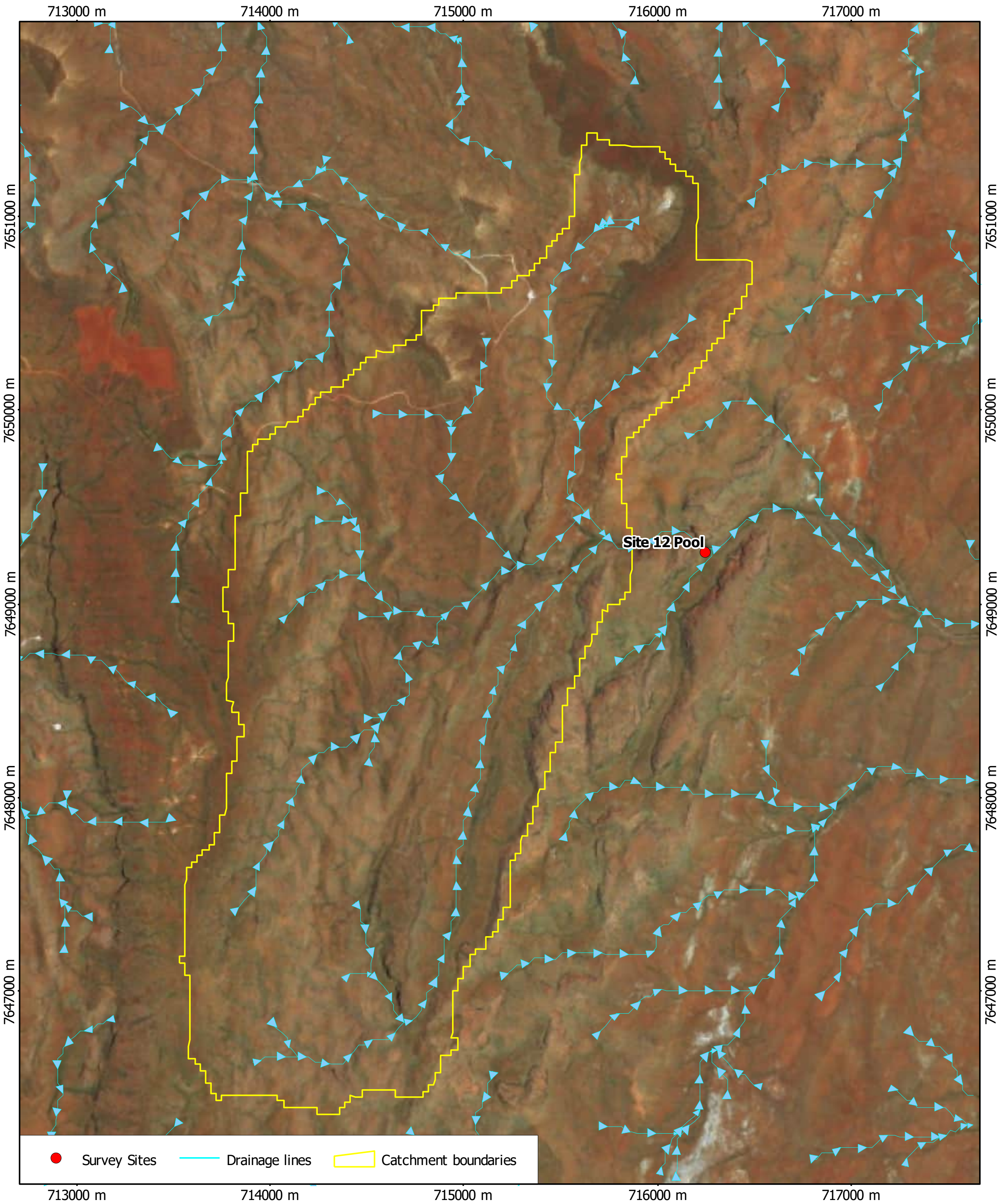


Figure 3-3 Site 12 Pool catchment area

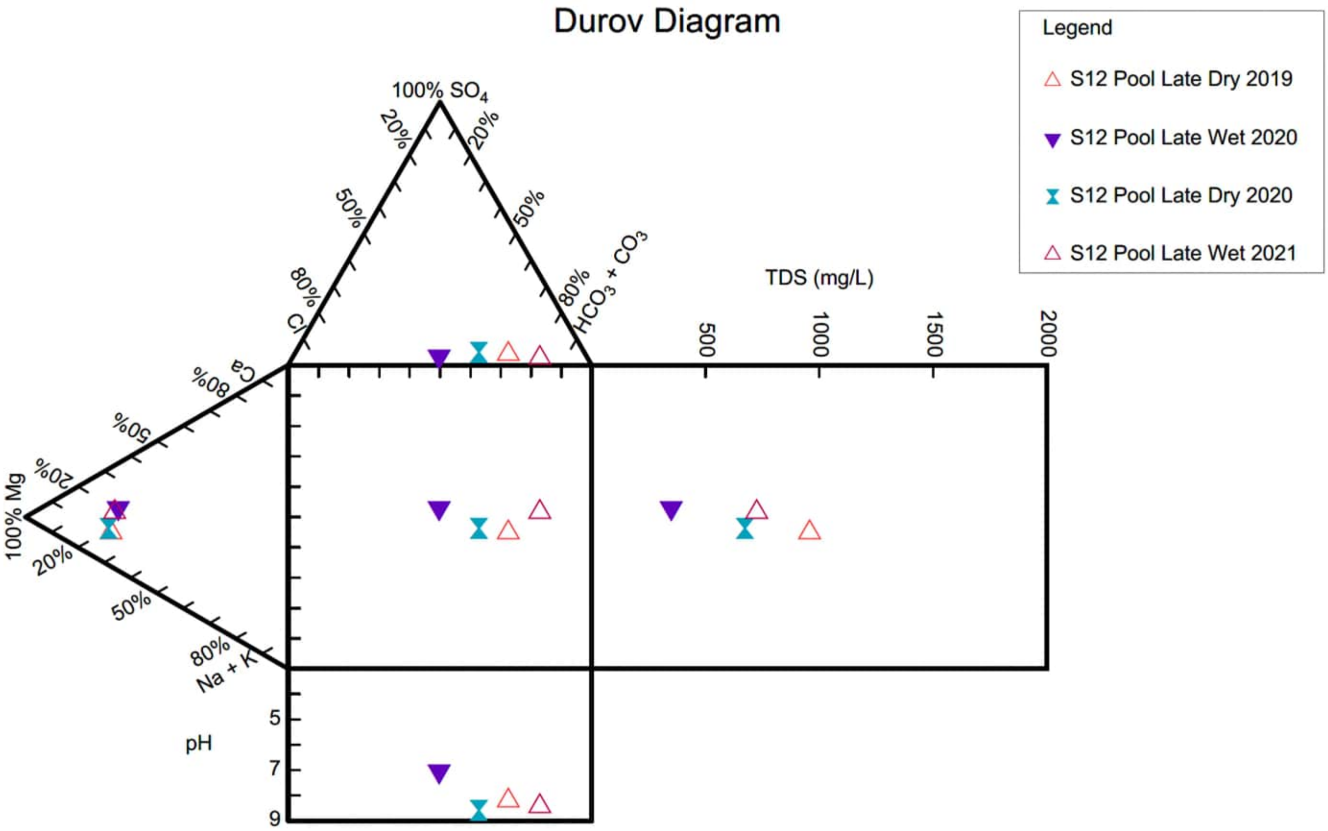


Figure 3-4 Durov diagram illustrates Site 12 Pool is a magnesium-bicarbonate (Ca/Mg-HCO_3) dominated water type. It is fresh-brackish, alkaline (481 mg/kg $CaCO_3$) with low sodium, chloride and sulphate (SO_4).

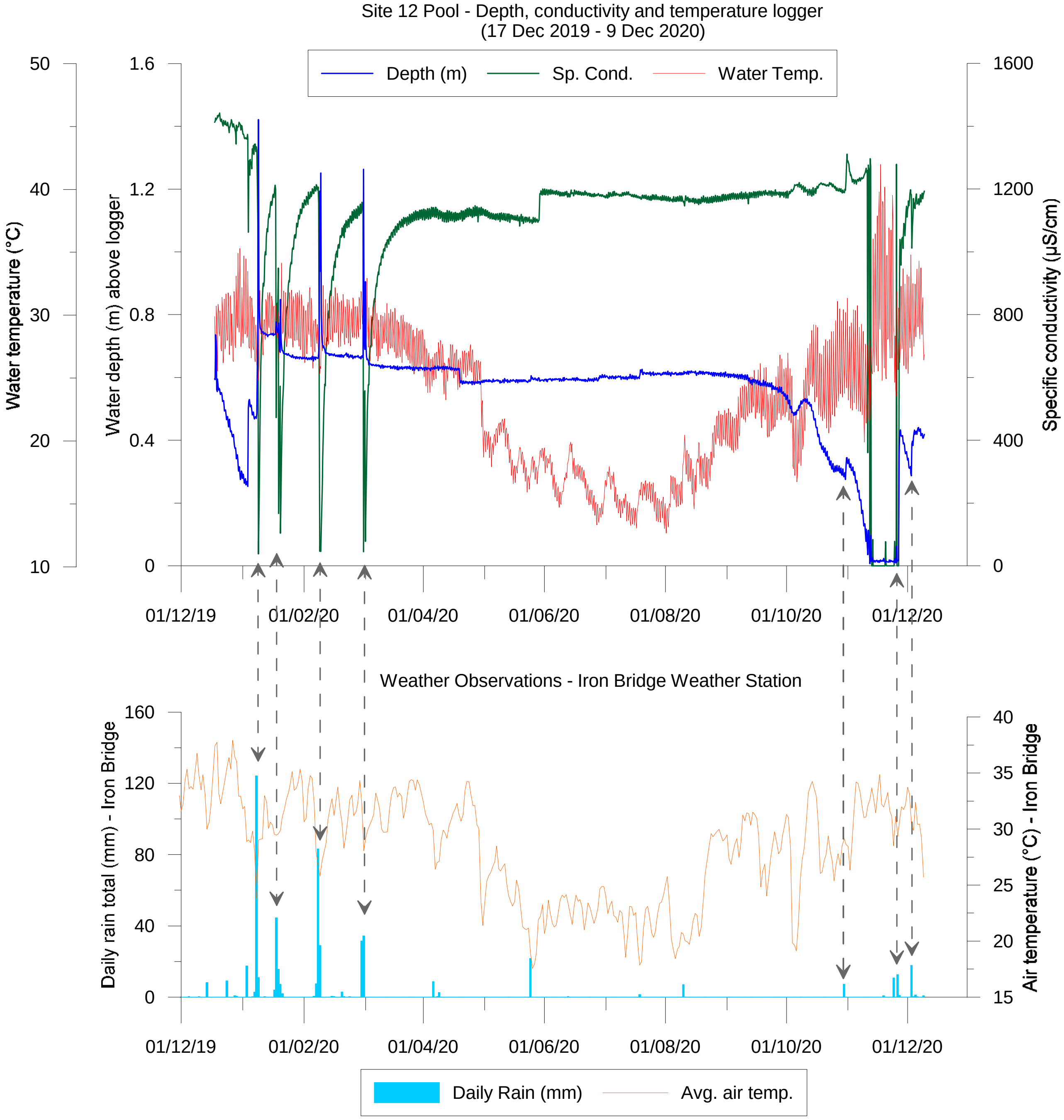


Figure 3-5 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below).

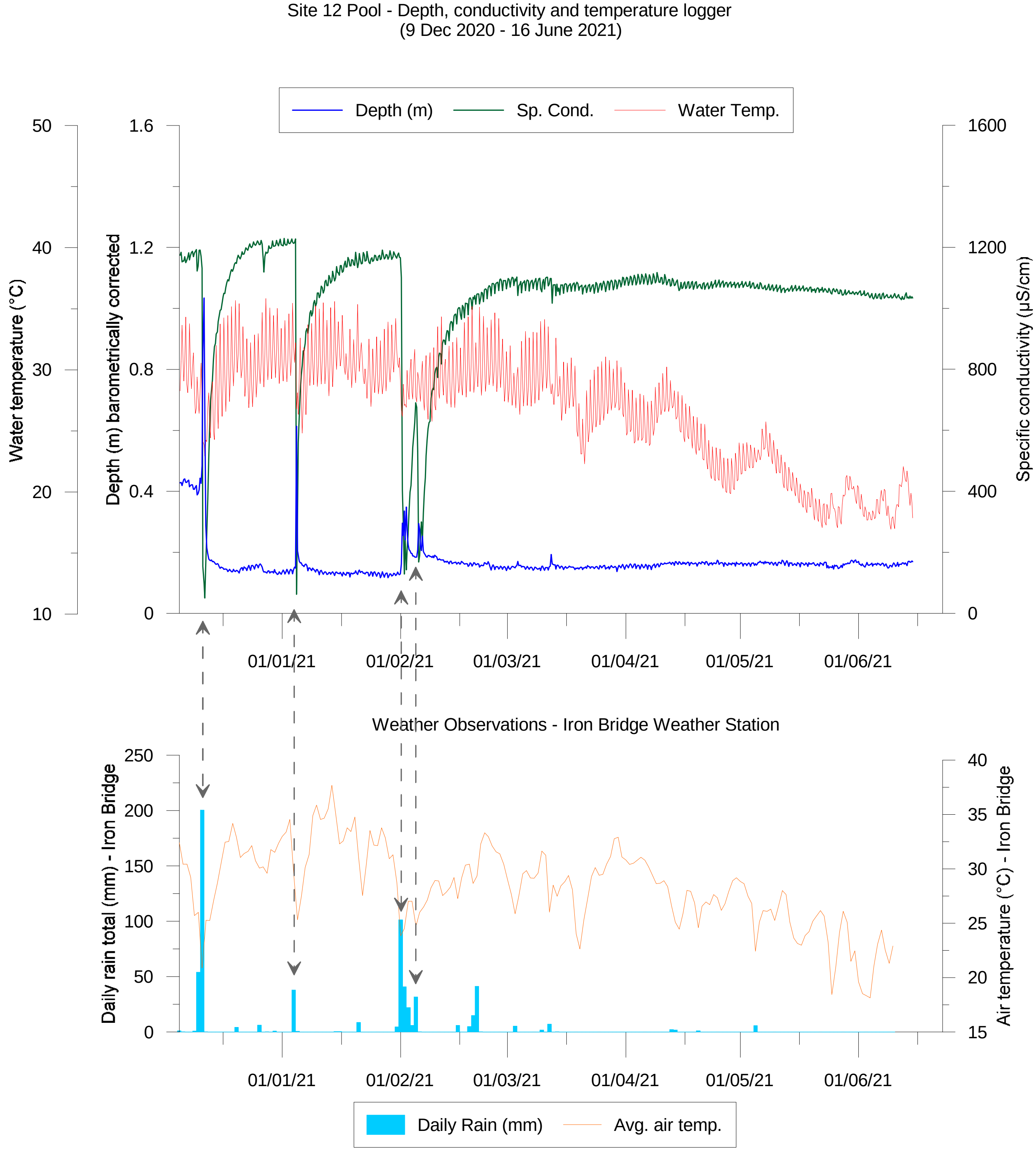


Figure 3-6 Site 12 Pool depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Wet-mid Dry season 2021

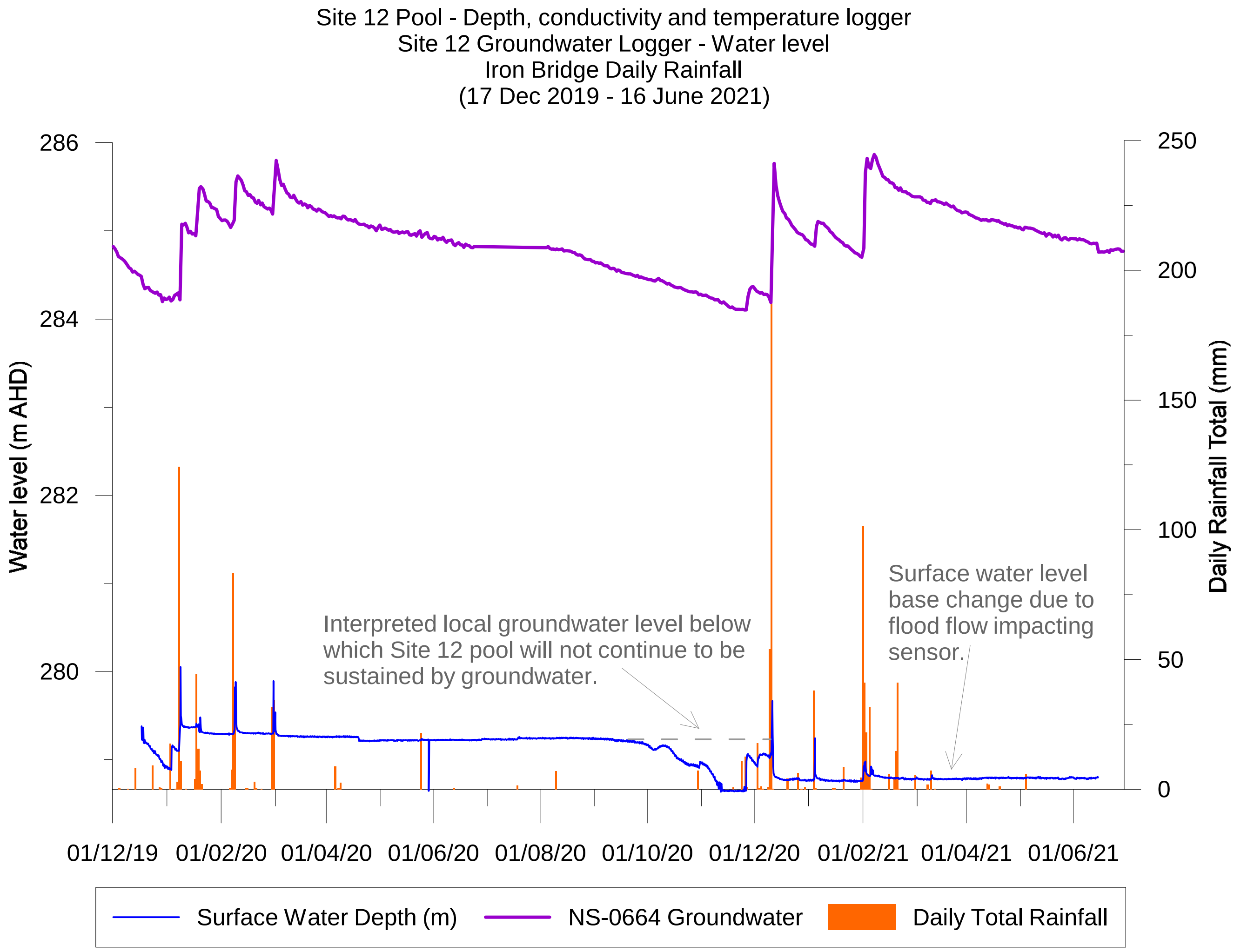


Figure 3-7 Comparison of surface water levels in Site 12 Pool and groundwater levels within the upgradient monitoring bore (NS-0664).

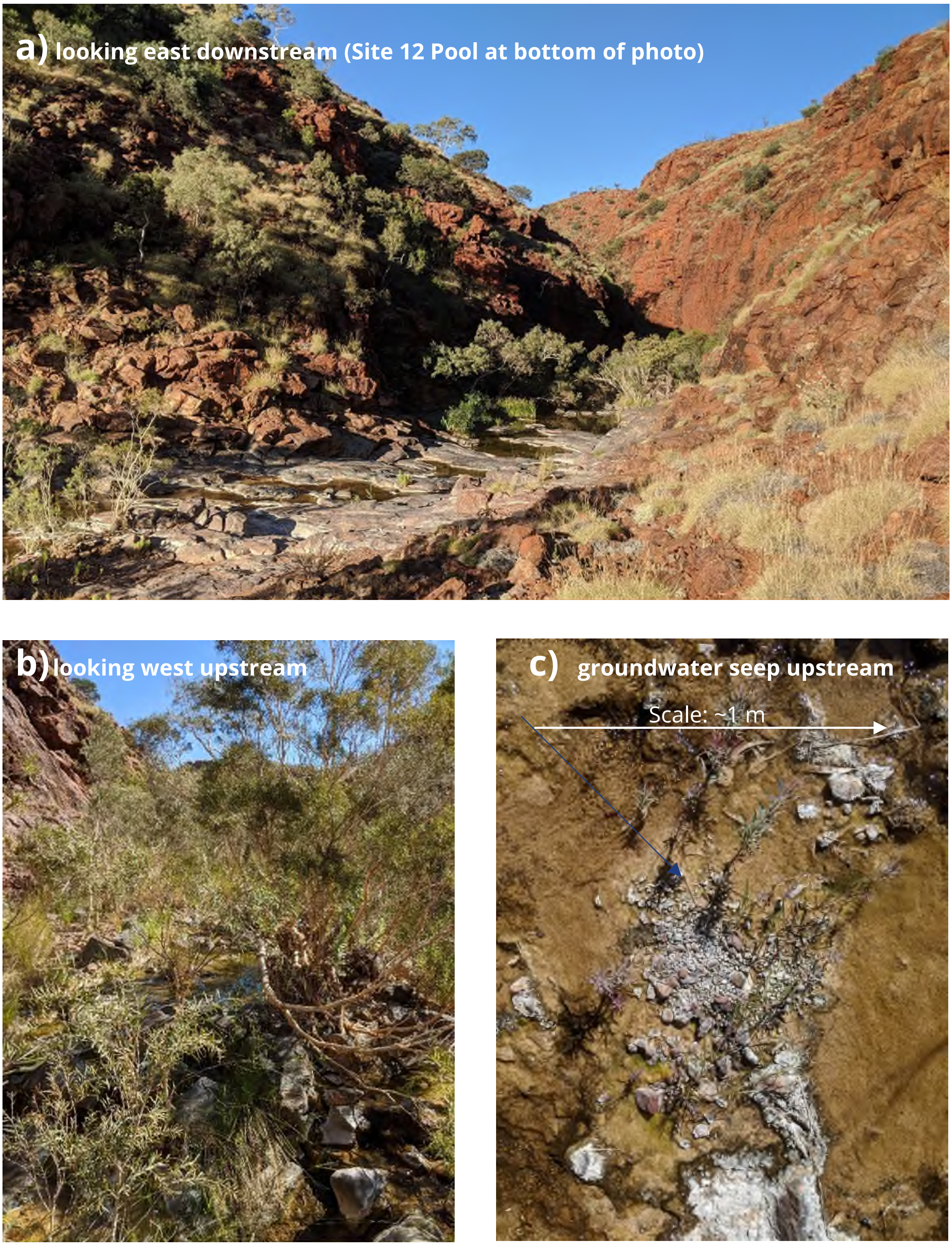


Plate 1 Site 12 Pool hydrological characteristics including; a) high flows over a steeper gradient of bedrock habitat b) confined creek line supporting riparian vegetation and c) sustained groundwater flow

3.1.2 SEDIMENT QUALITY

Table 3-1 provides the surface sediment quality at Site 12 Pool across the three seasons sampled. Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium and nickel concentrations exceeded the DGV (80 and 21 mg/kg respectively) and the GV-high (370 and 52 mg/kg, respectively). Chromium and nickel both naturally occur at high concentrations across the Project area and were similarly above DGVs at most other surveyed surface water pools in the Project area.

Table 3-1. Summary of sediment quality analytical results for Site 12 Pool. Concentration for each analyte and analyte group described for late wet season 2020 (June 2020), late dry season (December 2020) and late wet season (May 2021). Bolded values denote results above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Total Soluble Salts	mg/kg	**408**	**-**	**402**
Moisture Content (Dried @ 105-110°C)	%	**28.6**	**20.9**	**25**
Total Alkalinity as CaCO3	mg/kg	**71**	**329**	**26**
Bicarbonate Alkalinity as CaCO3	mg/kg	**67**	**265**	**26**
Carbonate Alkalinity as CaCO3	mg/kg	**4**	**65**	**253**
Acidity	mg/kg	**4**	**<5**	**<5**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**20**	<10	<10
Chloride (by Discrete Analyser)	mg/kg	**30**	**30**	**20**
Calcium	mg/kg	**50**	**40**	**30**
Magnesium	mg/kg	**60**	**90**	**60**
Sodium	mg/kg	**40**	**40**	**6**
Potassium	mg/kg	<10	<10	<10
Mercury (FIMS)	mg/kg	<0.1	-	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	**520**	**200**	**80**
Total Nitrogen as N	mg/kg	**520**	**200**	**80**
Total Phosphorus as P	mg/kg	**73**	**61**	**56**
Reactive Phosphorus as P	mg/kg	<0.1	<0.1	<0.1
Total Organic Carbon	%	**0.18**	**0.29**	**0.2**
Total Metals by ICP-AES				
Arsenic	mg/kg	<5	**-**	**6**
Barium	mg/kg	**50**	**-**	**70**
Beryllium	mg/kg	<1	-	<1

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Boron	mg/kg	<50	-	<50
Cadmium	mg/kg	<1	-	<1
Chromium	mg/kg	**384**	-	**492**
Cobalt	mg/kg	**23**	-	**36**
Copper	mg/kg	**23**	-	**37**
Iron	mg/kg	**32,800**	**41,200**	**49,400**
Lead	mg/kg	<5	-	<5
Manganese	mg/kg	**561**	-	**894**
Nickel	mg/kg	**179**	-	**246**
Selenium	mg/kg	<5	-	<5
Vanadium	mg/kg	**48**	-	**65**
Zinc	mg/kg	**26**	-	**44**

3.1.3 FISH

Fish, decapods and non-fish vertebrates were sampled with a combination of nets/traps and underwater video (BRUVs). Table 3-2 and Figure 3-9 to Figure 3-14 present the fish species, abundance, and size distribution.

Three native omnivorous fish species were observed in Site 12 Pool across the three seasons: *Melanotaenia australis* (western rainbowfish), *Leiopotherapon unicolor* (spangled perch) *and Neosilurus hyrtlii* (Hyrtl's catfish).

Melanotaenia australis was the dominant species in all three seasons (Table 3-2). Figure 3-9 demonstrates the frequency of each length class for *M. australis* for the three seasons. Predominately, the *M. australis* observed were adults (~50 mm) and estimated to be over 3 months old. In the Late Dry 2020 and Late Wet 2021, smaller fish (<30 mm) were observed, indicating the presence of juveniles at the site (Figure 3-9).

The larger size distribution of *L. unicolor* and *N. hyrtlii*, ranging from juveniles to adults over a year old, more clearly indicates interannual survival of these species and demonstrating evidence of successful wet season or post-wet season reproduction. However, these species may aestivate (*L. unicolor*) or persist in downstream environments rather than at Site 12 Pool throughout the drier months and migrate upstream to the pool during wet season connective flows. For example, fish were abundant and clearly visible without sampling during the Late Wet 2020 survey, though were not observed during the previous years' late dry season site inspection (December 2019). Similarly, Site 12 Pool was the only pool of five pools surveyed at North Star where *N. hyrtlii* has been recorded (Figure 3-18), which may be due to the connectivity to downstream creeks and rivers. This species exhibits spawning migration into tributaries and the tendency to inhabit riverine habitats more frequently than off-channel lentic habitats (Pusey, B., Kennard, M., & Arthington, 2004).

Further surveys will clarify the role of environmental stress and connectivity in determining fish presence. For example, whether extended dry season conditions result in decreased fish, or low wet seasons restrict connectivity and therefore fish movement.

Burrowing toadlets (*Uperoleia sp.*), a genus that typically inhabits rocky creeks, were observed in the tadpole phase during December 2019 though were not observed during wet season sampling. This finding may be due to the breeding season occurring earlier and only the semi-aquatic adult stage being present at the time of sampling, which was not targeted by sampling methods.

While baited marron/box traps were used to target decapod crustaceans, none were collected or observed.

Table 3-2. Summary of fish species observed at Site 12 Pool with number of fish for each size class sampled in the Late Wet 2020, Late Dry 2020 and Late Wet 2021. CPUE (catch per unit effort) calculated for each species and sampling date

Species	Size class (mm)	Late Wet (2020) Fish Count	CPUE[1]	Late Dry (2020) Fish Count	CPUE[1]	Late Wet (2021) Fish Count	CPUE[1]
Melanotaenia australis		**196**	**12.6**	**111**	**7.1**	**25**	**1.61**
	0 – 30	0		7		6	
	30 – 60	84		18		16	
	60 – 90	112		86		3	
Neosilurus hyrtlii		**37**	**2.4**	**50**	**3.2**	**10**	**0.6**
	60 – 90	16		4		4	
	>90	21		46		6	
Leiopotherapon unicolor		**24**	**1.5**	**52**	**3.3**	**20**	
	0 - 30	0		0		2	
	30 – 60	7		5		12	
	60 – 90	10		32		5	
	> 90	7		15		1	
Total		**257**	**16.6**	**213**	**13.7**	**55**	**3.5**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 15.5 hours.

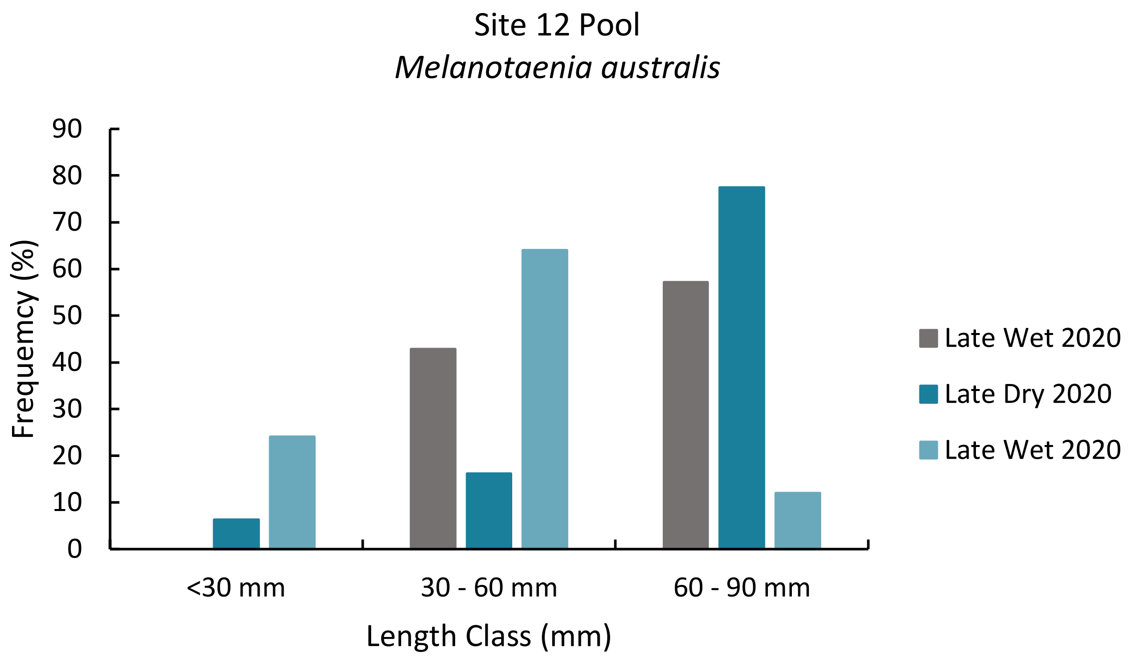


Figure 3-9. Frequency (%) of occurrence for each length class (SL, mm) of *Melanotaenia australis* sampled in Site 12 Pool in the Late Wet 2020, Late Dry 2020 and Late Wet 2021.

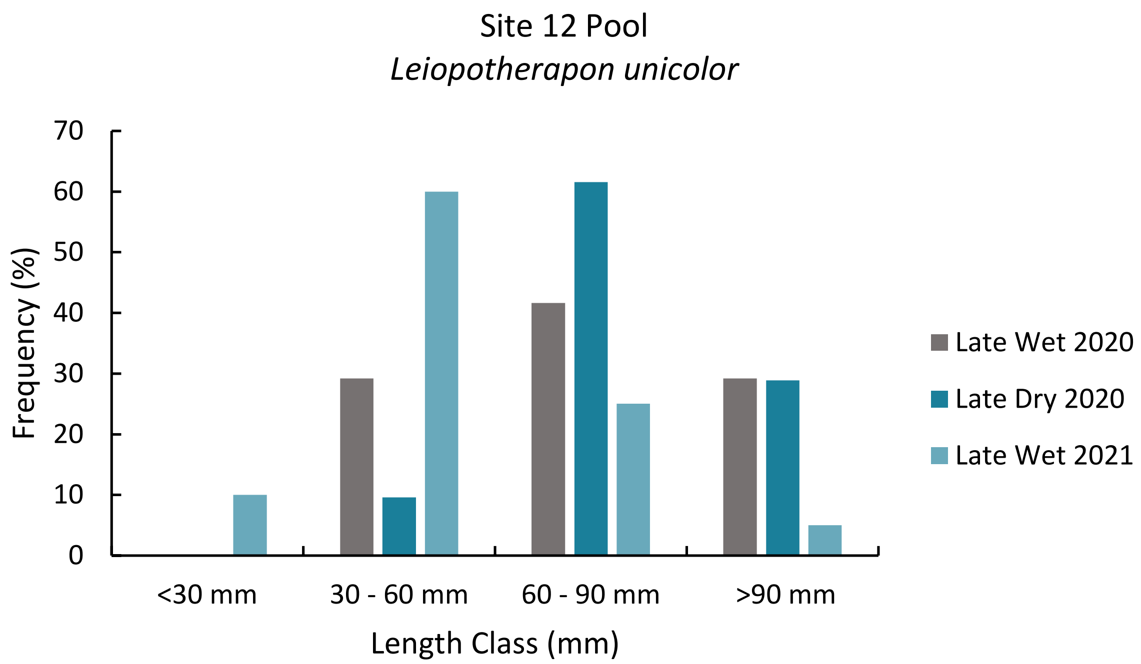


Figure 3-10. Frequency (%) of occurrence for each standard length class (SL, mm) of *Leiopotherapon unicolor* sampled in Site 12 Pool in the Late Wet 2020, Late Dry 2020 and Late Wet 2021.

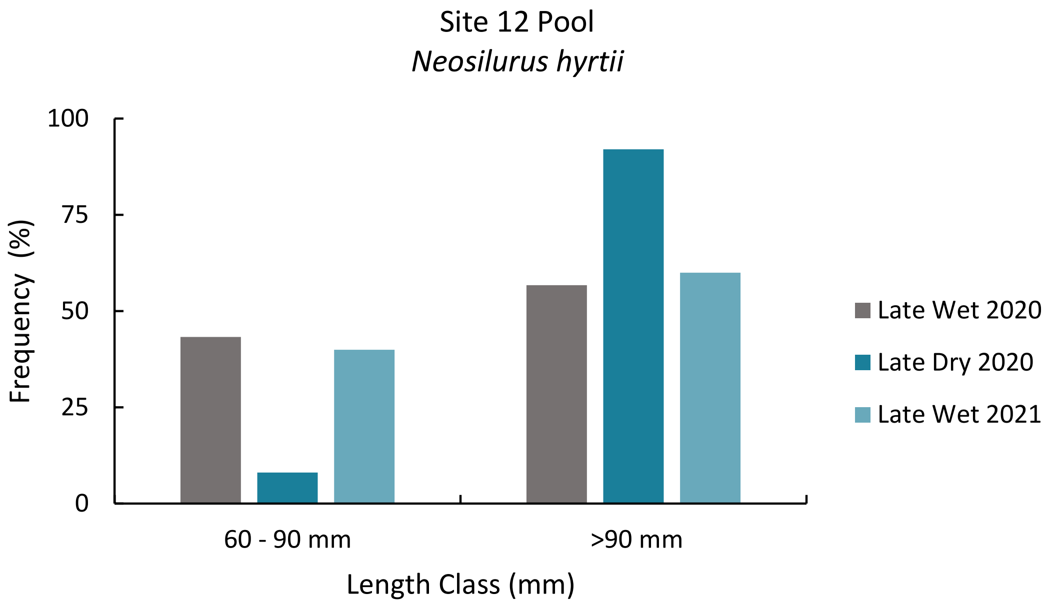


Figure 3-11. Frequency (%) of occurrence for each length class (SL, mm) of *Neosilurus hyrtlii* sampled in Site 12 Pool in the Late Wet 2020, Late Dry 2020 and Late Wet 2021.

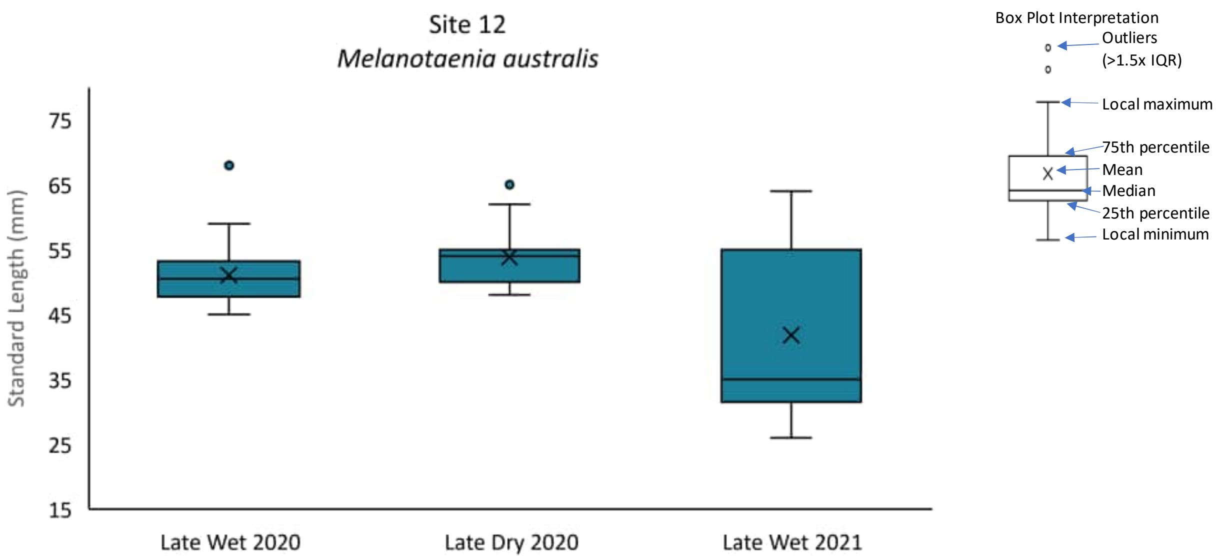


Figure 3-12. Distribution of standard length (SL, mm) of *Melanotaenia australis* sampled in Site 12 Pool in the Late Wet 2020, Late Dry 2020 and Late Wet 2021.

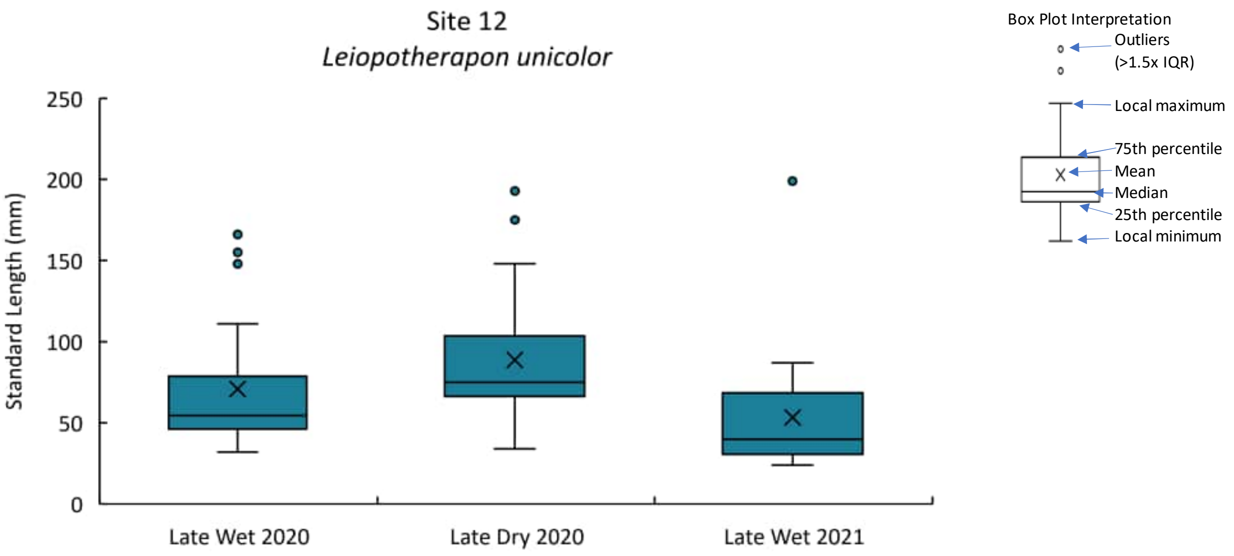


Figure 3-13 Distribution of standard length (SL, mm) of *Leiopotherapon unicolor* sampled in Site 12 Pool in the late wet 2020 (June 2020), late dry (December 2020) and late wet 2021 (May 2021).

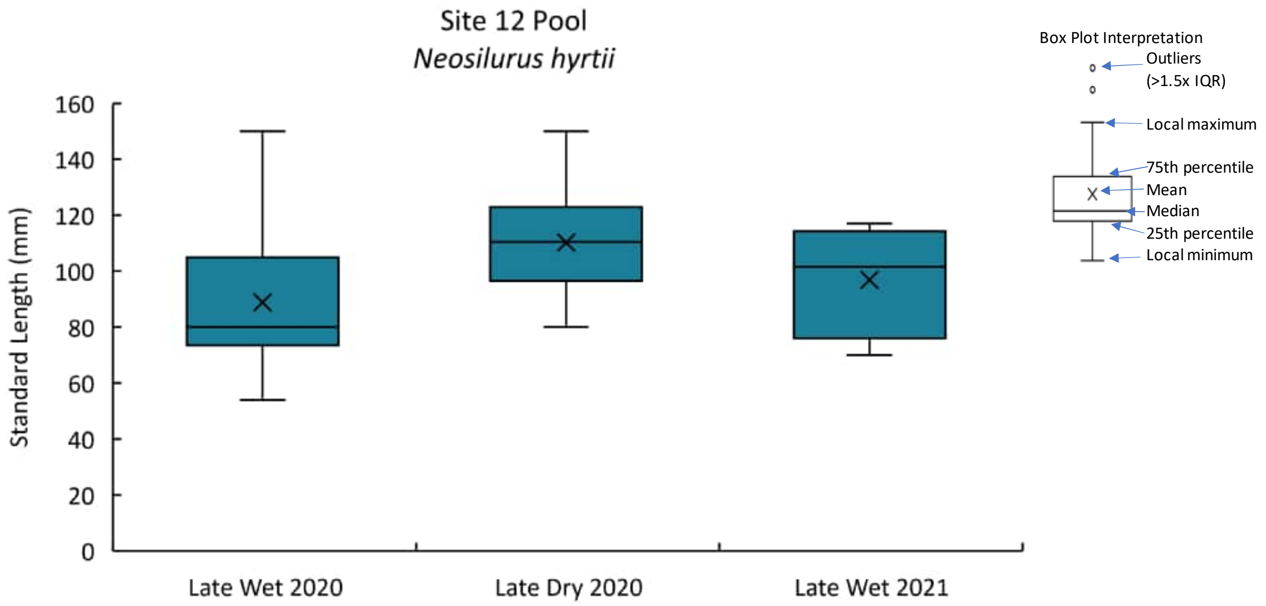
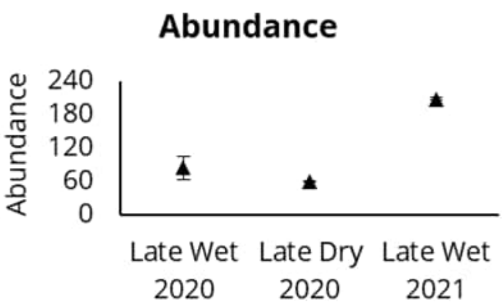


Figure 3-14 Distribution of standard length (SL, mm) of *Neosilurus hyrtlii* sampled in Site 12 Pool in the late wet 2020 (June 2020), late dry (December 2020) and late wet 2021 (May 2021).

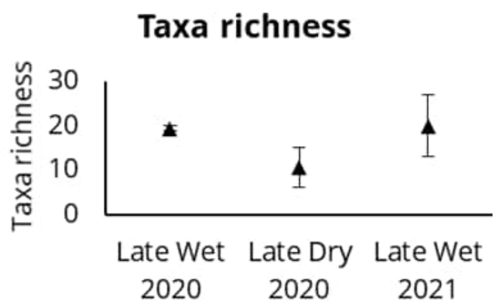
3.1.4 AQUATIC MACROINVERTEBRATES

Figure 3-15 presents the total abundance, taxa richness, EPT richness and SIGNAL2 scores for Site 12 Pool in the late wet seasons of 2020 and 2021, and the late dry season of 2020. The key findings were as follows:

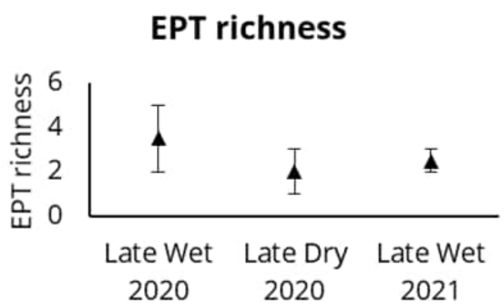
- Average macroinvertebrate abundance was two times greater in the latest wet season during 2021 (209 individuals) than those recorded in the wet (84 inds.) and dry (61 inds.) season of 2020 (Figure 3-15a).
- Taxa richness was similar in both late wet seasons with 20 taxa present, while a lessor 10 taxa were recorded during the late dry season of 2020 (Figure 3-15b).
- The number of taxa belonging to the sensitive Ephemoptera, Plecoptera and Trichoptera oders was sligthly higher in the Late Wet season of 2020 (EPT richness = 3.5), with similar measures in the Late Dry season and Late Wet season of 2020 and 2021, respectively (EPT richness = 2-2.5; Figure 3-15c).
- SIGNAL2 scores ranged from 2.8 to 3.6 among sampling events (Figure 3-15d), indicating the community is consistently dominated by tolerant macroinvertebrate families.



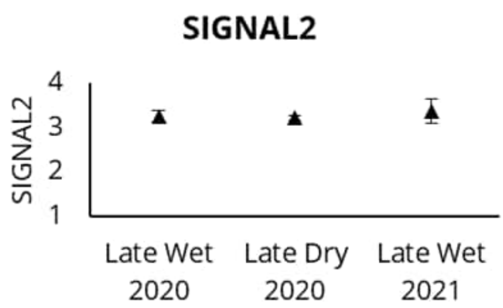
a) Total abundance at Site 12 Pool



b) Taxa richness at Site 12 Pool



c) EPT richness at Site 12 Pool



d) SIGNAL2 scores at Site 12 Pool

Figure 3-15 Macroinvertebrate indices for Site 12 Pool – Late Wet 2020, Late Dry 2020 and Late Wet 2021

The abundance of taxa for the three seasonal surveys is provided in Figure 3-16 and shows taxa ranging from the the most abundant (left) to the least abundant (right) along the x-axis. Briefly, the non-biting midge of Tanypodinae, oligochaete worms, and biting midge larvae of Ceratopognidae were much more abundant in the most recent 2021 wet season than the previous seasons. In contrast, the non-biting midge Chironominae was similarly abundant in all sampling events. Mites and ticks belonging to the Acarina were similarly abundant during both wet seasons, with a decline in the dry season of 2020. Some macroinvertebrates, such as chironomids and oligochaetes, can increase in abundance following freshwater flow events such as flooding in wetlands (e.g. McInerney et al. 2017), which may explain increased abundances of such taxa in the latest wet season when greater rainfall levels were recorded.

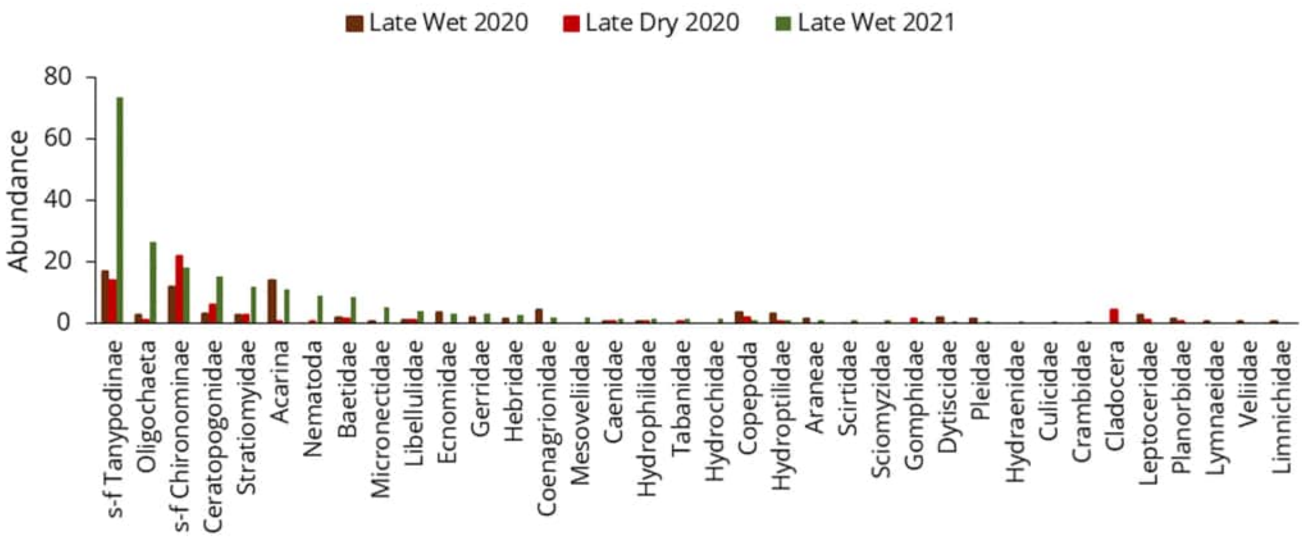


Figure 3-16 Average abundances of all macroinvertebrate taxa at Site 12 Pool in the Late Wet season of 2021 and the Late Wet and Late Dry season of 2020, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.1.5 DIATOMS AND PHYTOPLANKTON

3.1.5.1 DIATOMS

The Late Wet 2020 and Late Wet 2021 results are presented. The Late Dry 2020 diatom samples were not analysed as there was a major flood event during the four-week sampler deployment time and, therefore, the samples were not considered representative or useful. Two replicates of diatom samples were collected from Site 12 Pool during each survey and species, abundance and biotic indices were recorded. Overall, a total of 26 diatom species were recorded (Table 3-3) across the two replicates and two seasonal sampling rounds. The most abundant species in all replicates and surveys was *Mastogloia smithii*, followed by *Achnanthidium minutissimum*. The Late Wet 2021 round indicated a higher diversity and abundance than the previous wet season with a doubling of the species richness and abundance. Figure 3-17 illustrates the mean abundance (diatom count per replicate) of diatom species recorded at Site 12 Pool.

The tolerance to environmental stress for Site 12 Pool is reflected in the moderate sensitivity DSIAR scores (52 to 55 across the replicates and seasonal surveys). In Site 12 Pool, there was a large number of teratological ("deformed") forms.

Table 3-3. Summary of diatom total count per species, average abundance and DSIAR score for Site 12 Pool collected in Late Wet 2020

Taxon name	**Late Wet 2020**		**Late Wet 2021**	
Replicate	**Rep 1**	**Rep 2**	**Rep 1**	**Rep 2**
Achnanthidium exiguum	2			
Achnanthidium minutissimum	4	24	44	24
Amphora spp.		6		
Brachysira vitrea	4	8		4
Caloneis silicula		4		
Cymbella spp				2
Diploneis parma				4
Epithemia gibba				8
Eunotia arcus				12
Eunotia bilunaris	8	10	18	
Eunotia incisa		2		
Eunotia tenera			4	
Fragilaria acus			22	
Fragilaria capucina var gracilis			2	
Mastogloia elliptica			12	
Mastogloia smithii	42	112	232	116
Navicula gregaria			2	
Navicula lanceolata			2	
Nitzschia filiformis			2	
Nitzschia frustulum			4	
Nitzschia pumilla			2	
Pinnularia spp.			2	
Planothidium frequentissimum			4	
Surirella elegans			2	
Tryblionella calida			2	
Ulnaria ulna			18	34
Total Count	**60**	**166**	**374**	**204**
Species Richness	**5**	**7**	**17**	**8**
DSIAR Score	**55**	**54**	**52**	**53**

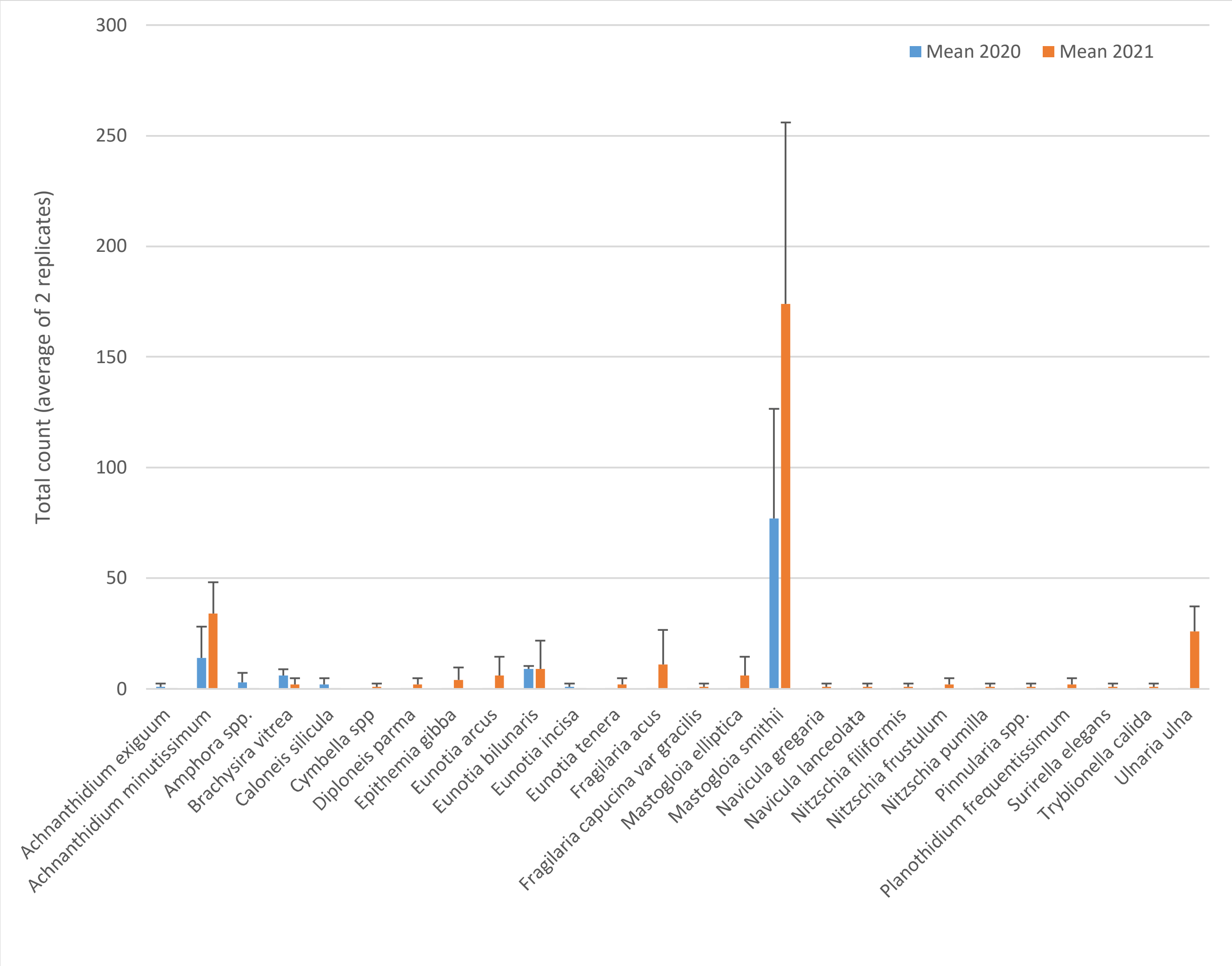


Figure 3-17. Average species abundance (diatom count per replicate) for diatoms sampled at Site 12 Pool in the Late Wet 2020 and Late Wet 2021. Standard deviation denoted by error bars.

3.1.5.2 PHYTOPLANKTON

As noted above, in the Late Dry 2020 sampling, the Diatom samplers (periphytometers) did not record meaningful data, as such, water samples were taken from the site to analyse a full phytoplankton profile for the site. This was repeated in the Late Dry 2021 survey for completeness and comparison of results.

Five classes of phytoplankton were identified at Site 12 Pool in Late Dry 2020, the most abundant being Dinophyceae (Dinoflagellates) at 72.8%, with two genera being observed *Gonyaulax sp.* and *Peridinium sp.* The second most abundant phytoplankton class was Cryptophyceae at 17%, with the genus *Cryptomonas sp.* having the highest contribution in this class. *Cryptomonas spp.* are always found in freshwater and function like diatoms. Cyanobacteria (blue-green algae) contributed 5.67% of the overall phytoplankton abundance. Chlorophyceae (green algae) and Bacillariophyceae (diatoms) had the lowest abundance at Site 12 Pool (Table 3-4).

Minimal algal cells were identified in the samples taken in Late Wet 2021 at Site 12 Pool; the only genus observed was *Navicula spp.* (Diatoms) (Table 3-4). This potentially indicates that late dry conditions are favourable for phytoplankton growth at this site, with moving water during the wet season not allowing the development of water column algal populations.

Table 3-4 Summary of phytoplankton analytical results for Site 12 Pool sampled in Late Dry 2020 and Late Wet 2021, abundance (cells L^{-1}) and percentage contribution (%), limit of reporting 10 cell L^{-1}.

Taxon	Late Dry 2020		Late Wet 2021	
	Abundance	***%***	***Abundance***	***%***
Bacillariophyceae	**5200**	**2.27**	**20**	**100**
Amphora spp	400	0.28	0	0
Navicula spp.	1200	0.85	20	100
Nitzschia spp.	1200	0.85	0	0
Synedra spp.	400	0.28	0	0
Chlorophyceae	**3200**	**2.27**	**0**	**0**
Closterium spp.	1200	0.85	0	0
Cosmarium spp.	2000	1.42	0	0
Cryptophyceae	**24000**	**17**	**0**	**0**
Chroomonas spp.	2400	1.7	0	0
Cryptomonas spp.	21600	15.3	0	0
Cyanobacteria	**8000**	**5.67**	**0**	**0**
Chroococcus spp.	1600	1.13	0	0
Planktolyngbya spp.	6400	4.53	0	0
Dinophyceae	**102800**	**72.8**	**0**	**0**
Gonyaulax spp.	42800	30.31	0	0
Peridinium spp.	60000	42.49	0	0

3.1.6 MACROPHYTES

A diverse range of native flora was observed within Site 12 Pool. These comprised aquatic species and groundwater-dependent species. These species are likely not surface water inflow dependent, as the pool refills with groundwater within 2 – 3 weeks following flushing events.

During all surveys (Late Wet 2020, Late Dry 2020 and Late Wet 2021), a total of seven macrophyte species were observed belonging to five families (Table 3-5). Macrophytes observed at Site 12 Pool included Bulrush reeds (*Typha sp.*), sedges (*Cyperus sp.*), two charaphytes (*Nitella sp.* and *Chara sp.*), as well as two submerged macrophytes (*Vallisneria sp.* and *Myriophyllum sp.*)(Figure 3-18). Table 3-5 summarises the macrophyte species observed at Site 12 Pool. No substantial changes in macrophyte composition were observed at the Site 12 Pool over the three surveys (Late Wet 2020, Late Dry 2020 and Late Wet 2021). A slight decrease in the abundance of both submerged and emergent macrophytes in the Late Wet 2021 compared to the Late Wet 2020 was noted, though no changes were substantial enough to alter the categorical abundance classification.

The types and species of macrophytes present in a system are indicators of water quality and ecological health. The abundance and diversity of macrophytes at Site 12 Pool plays a key role in nutrient dynamics, indicates that water quality parameters (e.g., turbidity, salinity) have not reached levels that interfere with macrophyte growth and development and provides habitat structure and refuges to organisms. For example, the macrophyte habitat and its' structural complexity likely provide refuge to the *M. australis* (western rainbowfish) from predation by adult *L. unicolor* (spangled perch).

Table 3-5. Summary of macrophyte species abundance, with family name and common name observed at Site 12 Pool during sampling in the Late Wet 2020, Late Dry 2020 and Late Wet 2021.

Common name	Species name	Late Wet 2020 Abundance[1]	Late Dry 2020 Abundance[1]	Late Wet 2021 Abundance[1]
Ribbon weed	*Vallisneria sp.*	Isolated	Isolated	Isolated
Charophytes	*Nitella sp*., *Chara sp*.	Isolated	Isolated	Isolated
Clubrush	*Schoenoplectus sp.*	Isolated	Isolated	Isolated
Sedges	Cyperaceae	Isolated	Isolated	Isolated
Bulrush	*Typha sp.*	Isolated	Isolated	Isolated

[1] Abundance based on *Western Australia AUSRIVAS field sampling and habitat assessment sheet (*DoW, 2009).

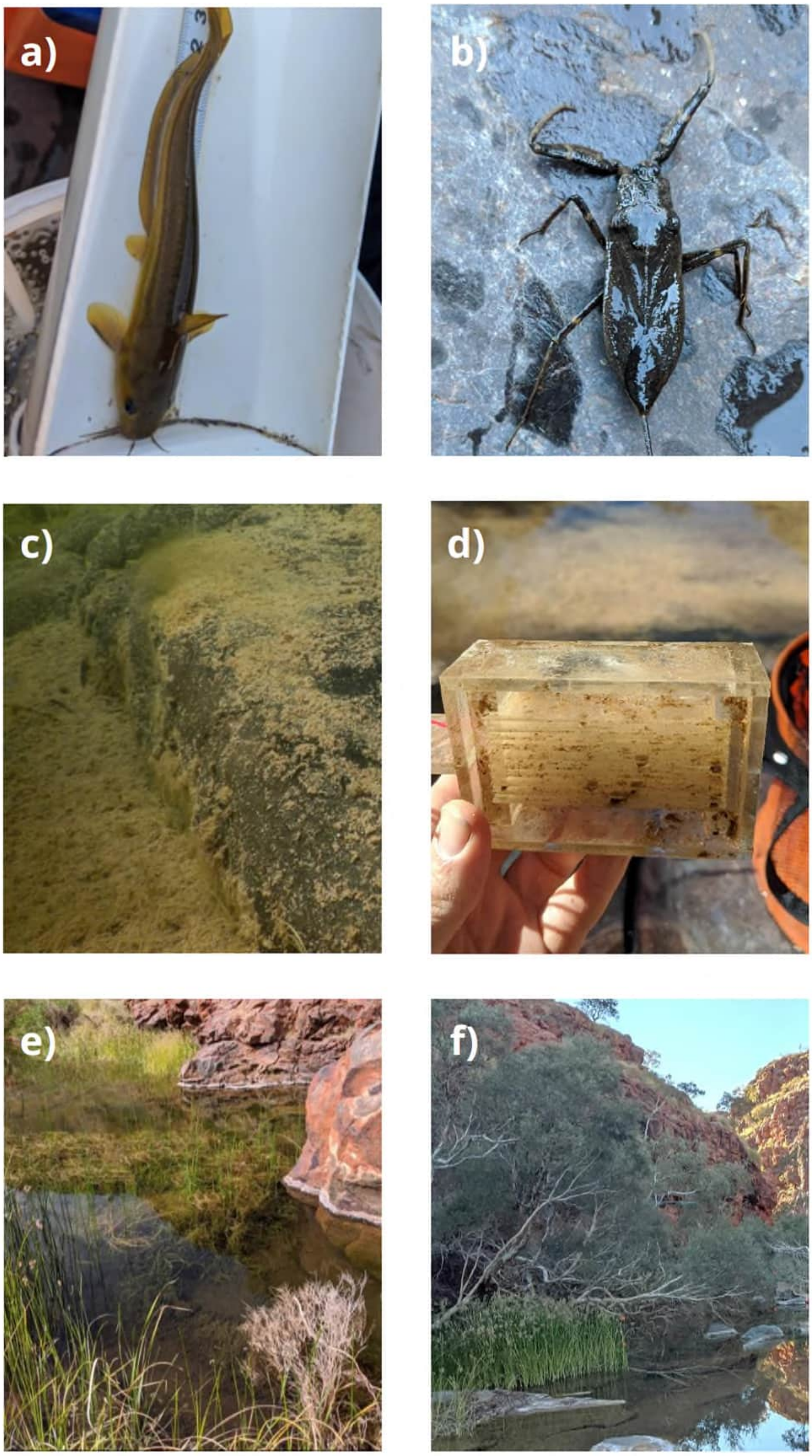


Figure 3-18 Site 12 Pool aquatic ecology. a) *Neosilurus hyrtlii* found at Site 12 Pool and no other surveyed pools; b) Belostomatidae, a giant water bug that typically hunts amongst macrophytes; c) bedrock covered in benthic algae; d) periphytometer used to sample diatoms shows benthic algae growth; e) and f) submerged and emergent macrophytes

3.2 FIG POOL (IB_SW_POOL_Fig)

Fig Pool is an isolated small pool that lies at the base of a rockface (Figure 3-19) with a small catchment area of 0.16 km^2 (Figure 3-20). It is characterised by stable water levels maintained by fresh groundwater. A relatively low abundance and diversity of aquatic flora and fauna inhabit the pool, likely due to it being naturally acidic. For example, fish and macrophytes are absent in the pool. It is a bedrock dominated habitat with the primary structural complexity provided by the roots of *Melaleuca leucadendra* (paperbark tree) roots.

Figure 3-19 Fig Pool is a small, acidic pool that lies below a rockface and is surrounded by *Melaleuca leucadendra* (paper bark tree) of which the roots are a dominant feature.

3.2.1 WATER QUALITY AND HYDROLOGY

Water quality sampling results, including physio-chemical parameters, metals analysis, major ions, and stable isotope analysis to characterise the surface water system and its connectivity to groundwater are presented in Appendix A. Figure 3-21 and Figure 3-22 display a high-resolution water level, salinity (conductivity) and temperature logger record from Fig Pool for the wet seasons of 2019/2020 and 2020/2021 respectively.

Fig Pool is a small (~20 m^3), shallow pool with water quality that varies minimally between seasons. The pool is largely sustained by groundwater and was periodically flushed with fresh surface water flows after rainfall events. It takes approximately 1 week for the groundwater to displace the surface water flows once a flushing event has occurred. Conductivity was typically fresh (~200 µS/cm) except during a surface water flow event when it would become extremely fresh (<20 µS/cm). Water levels were a maximum of ~0.06 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded. The minimal change in water level indicates the pool remained approximately at its spill point level throughout the logging period. Due to the small catchment area (0.16 km²) and the gradient of Fig Pool's upstream and downstream environment, it is likely the pool has very limited connectivity to surface drainage.

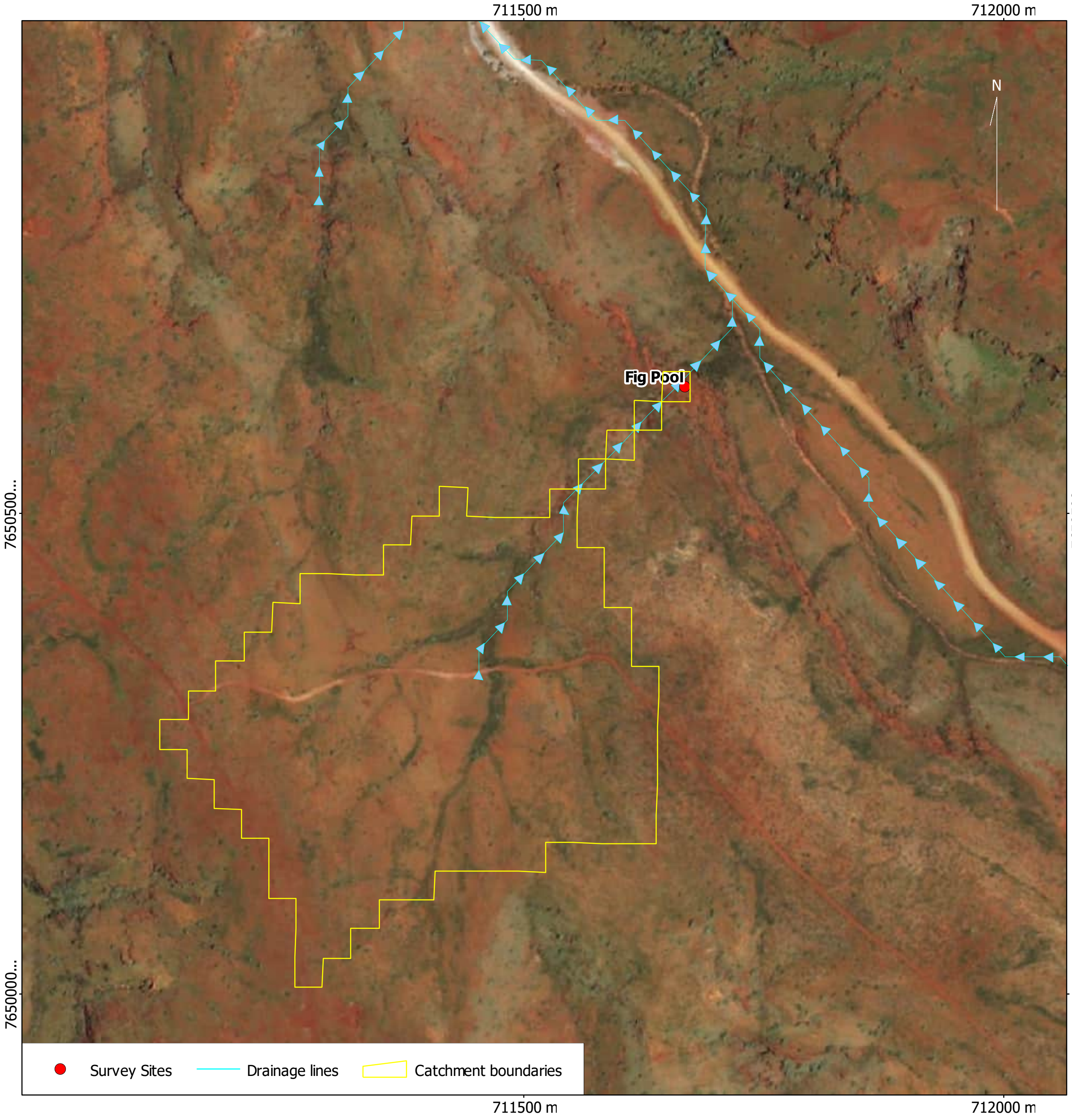


Figure 3-20 Fig Pool catchment area (0.16 km²)

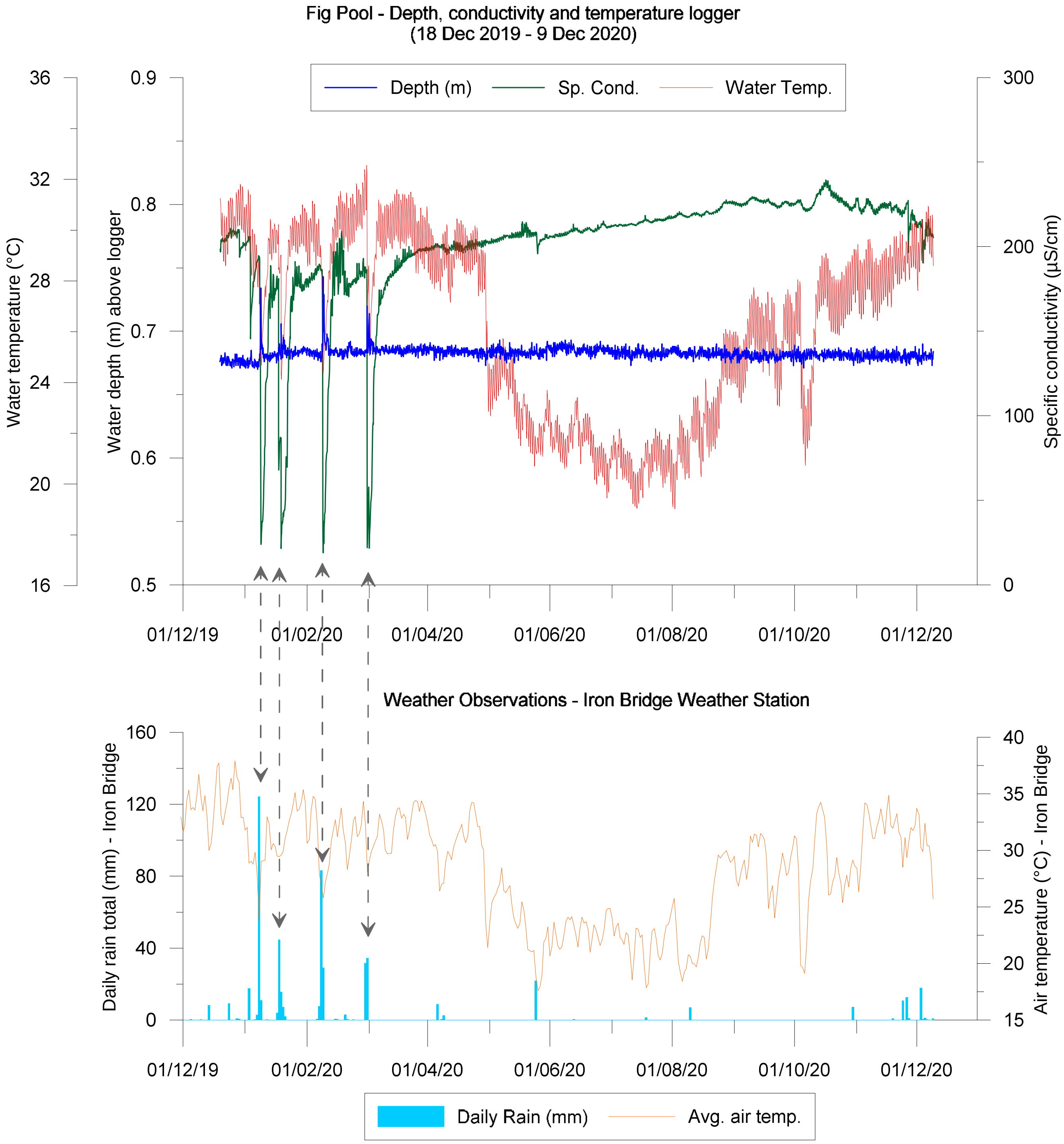


Figure 3-21 Fig Pool depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Wet-Dry season 2020.

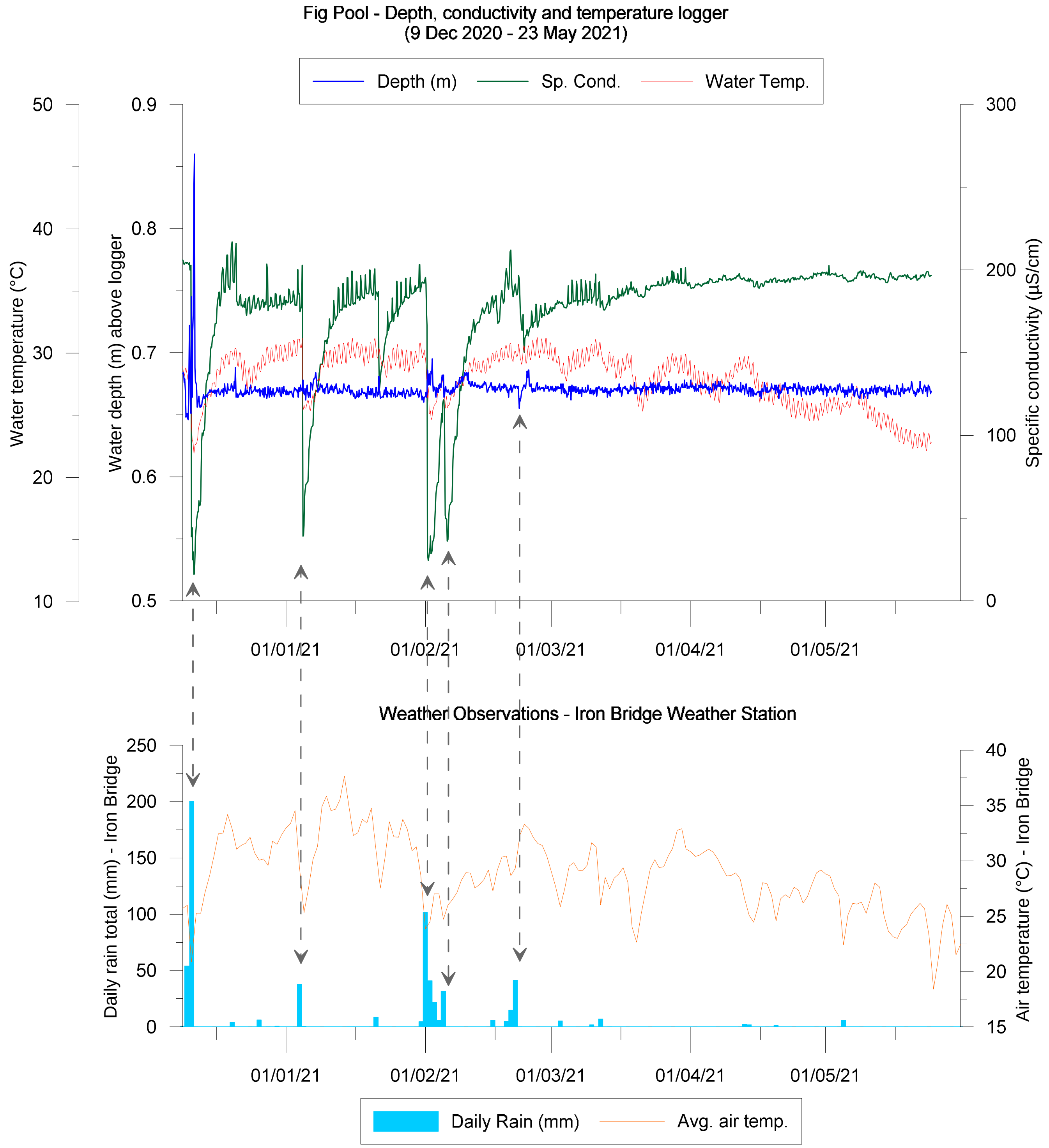


Figure 3-22 Fig Pool depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Wet-mid Dry season 2021.

3.2.1.1 WATER CHEMISTRY

The major ion balance at Fig Pool was remarkably stable over the four sampling events (Late Dry 2019, Late Wet 2020, Late Dry 2020 and Late Wet 2021). The water quality was clear (turbidity = <1 NTU NTU), acidic (pH = 3.4) and a sodium sulphate dominated water type (Figure 3-23). Although the pH at this site is low, the acidity levels are only moderate to low (16 mg/L as $CaCO_3$). Observations at the site would indicate that the low pH based on spot samples (no pH logger is installed) is potentially due to the lack of buffering capacity in the low conductivity water and is likely to be controlled by the Fe(II)/Fe(III) redox couple at a pH of ~3.5. This is potentially mediated by biological processes in the root mats which surround the pool (e.g. root zone Fe(II) oxidation).

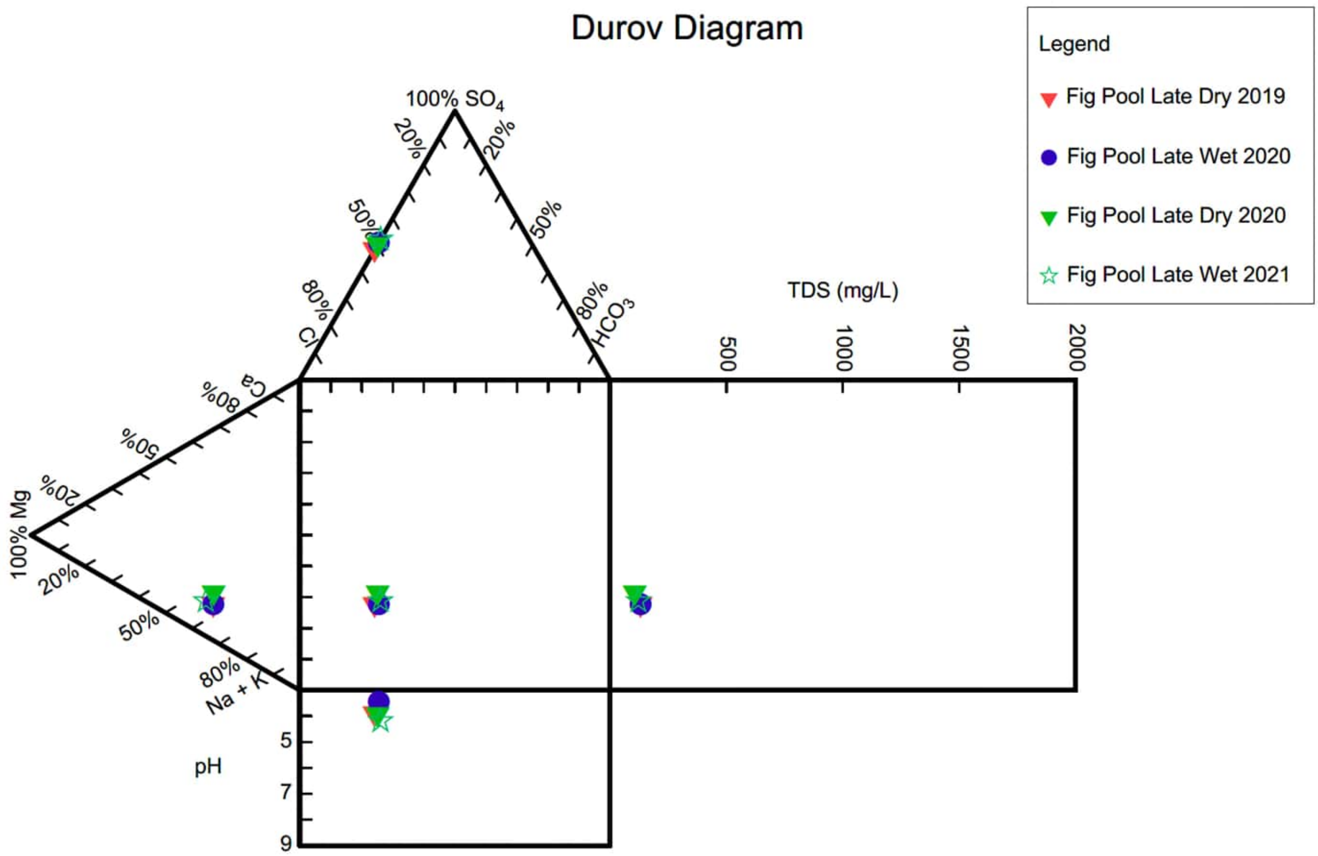


Figure 3-23 Durov diagram illustrates Fig Pool is a sodium-sulphate dominated water type. It is fresh, highly acidic pool with low total dissolved solids (TDS).

3.2.2 SEDIMENT QUALITY

Table 3-6 provides the surface sediment quality at Fig Pool during the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys. Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentrations exceeded the DGV (80 mg/kg) though not the GV-high (370 mg/kg). Chromium naturally occurs at high concentrations across the Project area and were similarly above DGVs at most other surveyed surface water pools in the Project area.

Table 3-6. Summary of sediment analysis at Fig Pool sampled in late wet season 2020 (June 2020), late dry season 2020 (December 2020) and late wet season 2021 (May 2021).

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Total Soluble Salts	mg/kg	**248**	**-**	**384**
Moisture Content (Dried @ 105-110°C)	%	**-**	**38.3**	**37**
Total Alkalinity as CaCO3	mg/kg	**2**	**<5**	**<5**
Bicarbonate Alkalinity as CaCO3	mg/kg	**2**	**<5**	**<5**
Carbonate Alkalinity as CaCO3	mg/kg	<1	<5	<5
Acidity	mg/kg	**14**	**166**	**1000**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**120**	**160**	**150**
Chloride (by Discrete Analyser)	mg/kg	<10	**40**	**60**
Calcium	mg/kg	**30**	<10	<10
Magnesium	mg/kg	<10	10	10
Sodium	mg/kg	**10**	**40**	**12**
Potassium	mg/kg	**10**	**30**	**10**
Mercury (FIMS)	mg/kg	<0.1	-	**0.2**
Nitrite + Nitrate as N (Sol.)	mg/kg	<0.1	<0.1	**0.2**
Total Kjeldahl Nitrogen as N	mg/kg	**1110**	**1670**	**3030**
Total Nitrogen as N	mg/kg	**1110**	**1670**	**3030**
Total Phosphorus as P	mg/kg	**60**	**223**	**310**
Reactive Phosphorus as P	mg/kg	<0.1	<0.1	<0.1
Total Organic Carbon	%	**0.30**	**3.60**	**3.08**
Total Metals by ICP-AES				
Arsenic	mg/kg	<5	-	**12**
Barium	mg/kg	**10**	**-**	**40**
Beryllium	mg/kg	<1	-	<1
Boron	mg/kg	<50	-	<50
Cadmium	mg/kg	<1	-	<1
Chromium	mg/kg	**143**	-	**127**
Cobalt	mg/kg	<2	-	**2**
Copper	mg/kg	**8**	**-**	**24**
Iron	mg/kg	**58500**	**90200**	**64600**
Lead	mg/kg	<5	-	<5

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Manganese	mg/kg	**94**	**-**	**39**
Nickel	mg/kg	**6**	**-**	**12**
Selenium	mg/kg	<5	-	<5
Vanadium	mg/kg	**27**	**-**	**53**
Zinc	mg/kg	**5**	**-**	**8**

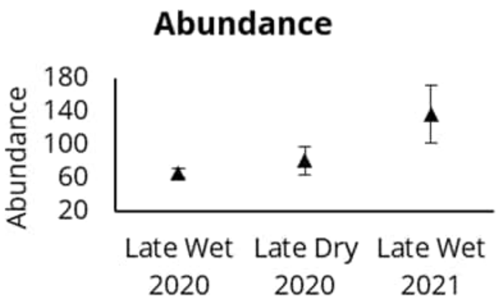
3.2.3 FISH

Fish, decapods, and non-fish vertebrates were sampled with a combination of nets/traps and BRUVs over three surveys (Late Wet 2020, Late Dry 2020 and Late Wet 2021). No fish were collected by fyke nets, traps or BRUVs and no fish have been observed to inhabit the pool across the three seasons. Similarly, no other vertebrates (e.g. tadpoles, frogs or snakes) have been observed at the pool. It is noted that organisms that are generally highly visible (e.g. fish) would have been readily observable if they inhabited the pool due to the small size of the pool, shallowness, and water clarity. The low pH of this pool (pH 3-4), as well as restricted connectivity, is likely to be controlling the absence of fish at this location.

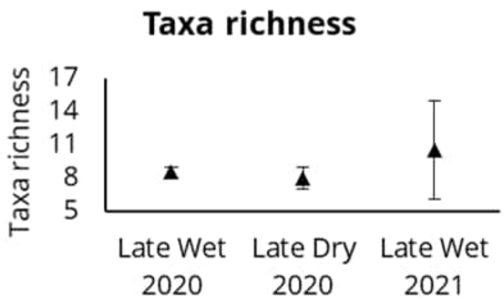
3.2.4 AQUATIC MACROINVERTEBRATES

Figure 3-24 presents the total abundance, taxa richness, EPT richness and SIGNAL2 scores for Fig Pool in the late wet seasons of 2020 and 2021, and the late dry season of 2020. The key findings were as follows:

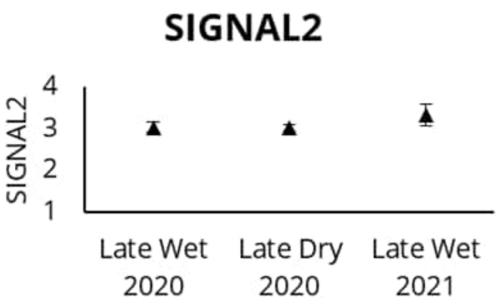
- Total abundance and taxonomic richness increased from 2020 to 2021 (Figure 3-24a,b), with abundances and number of taxa increasing to 138 and 11, respectively, in the Late Wet season of 2021. In contrast, 66 to 81 invertebrates of around 8 different taxa were present in 2020.
- There was only one individual of the Leptoceridae sampled from the Trichoptera oder in Late Wet 2021, with no families belonging to the pollution sensitive Plecoptera or Ephemeroptera sampled at any time (EPT richness ≤ 1; not plotted).
- The SIGNAL2 score was 3.02 for 2020, with a slight increase to 3.33 in the late wet season of 2020. These scores considered with an EPT richness of 1, indicates that a mostly tolerant macroinvertebrate community resides in Fig Pool.



a) Total abundance at Fig Pool



b) Taxonomic richness at Fig Pool



c) SIGNAL2 scores at Fig Pool

Figure 3-24 Macroinvertebrate indices for Fig Pool – Late Wet 2020, Late Dry 2020 and Late Wet 2021.

The abundance of taxa for the three seasonal surveys is provided in Figure 3-25 and shows taxa ranging from the the most abundant (left) to the least abundant (right) along the x-axis. The non-biting midge of the Chironominae, dragonflies of the Libellulidae and water striders of the Veliidae were much more abundant in the latest Late Wet season of 2021 in comparison to previous seasons, while damselflies of the family Coenagrionidae were more abundant in the Late Wet season of 2020. Some macroinvertebrates, such as chironomids and oligochaetes, can increase in abundance following freshwater flow events such as flooding in wetlands (e.g. McInerney et al. 2017), which may explain increased abundances of such taxa in the latest wet season when greater rainfall levels were recorded.

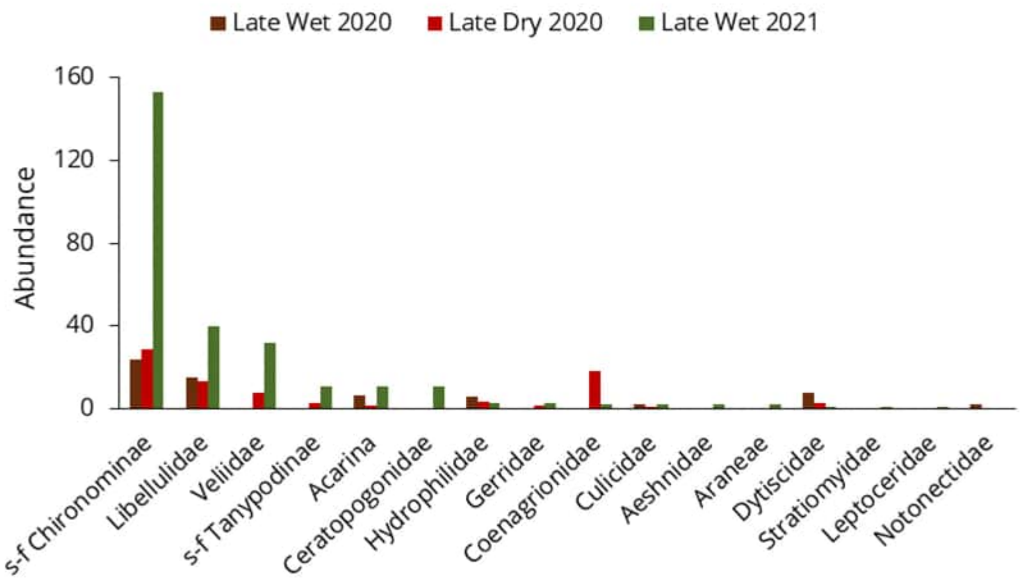


Figure 3-25 Average abundances of all macroinvertebrate taxa at Fig Pool in the Late Wet season of 2021 and the Late Wet and Late Dry season of 2020, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.2.5 DIATOMS AND PHYTOPLANKTON

No diatom species were detected at Fig Pool across the two seasonal surveys to date (Late Wet 2020 and Late Wet 2021) by quantitative artificial substrate sampling. This indicates that the water conditions did not enable reproduction of diatoms during the sampling timeframe because none colonised the new artificial substrates. A DSIAR score could not be calculated. The Late Dry 2020 diatom samples were not analysed as there was a major flood event during the four-week sampler deployment time and therefore the samples were not considered representative or useful.

In the Late Dry 2020, an analysis of the phytoplankton abundance was conducted at Fig Pool. Overall, phytoplankton abundance at Fig Pool was low. Three classes of phytoplankton were observed with the most abundant being Chlorophyceae (Green Algae, 88%), with diatoms (Bacillariophyceae) at 8% and least abundant was Euglenophyceae (4%) (Table 3-7). Water samples from Fig Pool collected in May 2021 (late wet season) did not yield any algal cells, this finding was not unusual due to the previous low abundance of phytoplankton and similar results in the late wet season of the previous year.

Table 3-7 Summary of phytoplankton analytical results for Fig Pool sampled in late dry season (2020), abundance (cells L^{-1}) and percentage contribution (%), limit of reporting 10 cell L^{-1}. Samples taken from Fig Pool in late wet season 2021 did not yield any phytoplankton results.

Taxon	Late Dry 2020		Late Wet 2021	
	Abundance	**%**	**Abundance**	**%**
Bacillariophyceae	**200**	**8**	**-**	**-**
Microtabella spp	100	4	-	-
Navicula spp.	100	4	-	-
Chlorophyceae	**2200**	**88**	**-**	**-**
Cosmarium spp. (O)	2200	88	-	-
Euglenophyceae	**100**	**4**	**-**	**-**
Trachelomonas spp.	100	4	-	-

3.2.6 MACROPHYTES

Across the three seasons that Fig Pool was surveyed, no macrophytes species were observed. The natural acidity (pH = 3.4) at Fig Pool is likely to be the cause for the absence of macrophytes (Section 3.2.1 Water Quality and Hydrology). A considerable proportion of Fig Pool is bordered by *Melaleuca spp*. with extensive root mats, which likely provided habitat structural complexity typically provided by macrophytes (Figure 3-26). The fauna visible in Fig Pool, such as Dytiscidae (dive beetles), Hydrophilidae (water scavenger beetles) and Chironominae (midges) were noted to be inhabiting the root mats.

Figure 3-26 Fig Pool ecology. a) and b) root mats of *Melaleuca* spp extend into Fig Pool; c) and d) microscope slide used as artificial colonising habitat for diatoms appears stained by iron deposits and no algal growth; d) periphytometers to sample diatoms placed on root mats and leaf litter; e) and f) macroinvertebrate sampling found low abundance and diversity with predominantly tolerant taxa collected.

3.3 MUNDAGOORA POOL (GV_SW_POOL_Mundagoora_SS)

Mundagoora Pool has a catchment area of approximately 3.3 km^2, draining two similarly sized basins (to the northeast and southeast; Figure 3-28). Discharge from the pool flows to Cockatoo Creek and the Turner River (see Figure 2-2). The likely permanent nature of the pool provides habitat to an abundance of fish, macroinvertebrates, and extensive beds of macrophytes and established riparian vegetation (Figure 3-27). Some key features of this pool are:

- The inflow is over a steep rock face (waterfall).
- The outflow is over a sill with little variation in pool height over wet/dry season (controlled by the sill level).
- It is a clear water pool dominated by submerged vegetation/algae and abundant fish (common species, not endangered).
- Downstream of the pool is dominated by dense emergent vegetation (reeds and sedges), which extends down a shallow braided channel downstream for several hundred metres from the pool.
- The pool contains a hard bottom (rock) at the inflow point, likely to be scoured out (removal of deposited sediments) during high-flow events.

Figure 3-27 Mundagoora Pool is a permanent pool with extensive macrophyte beds and riparian vegetation.

3.3.1 WATER QUALITY AND HYDROLOGY

Figure 3-29 and Figure 3-30 display a high-resolution water level, salinity (conductivity) and temperature logger record from Mundagoora Pool for the wet seasons of 2019/2020 and 2020/2021 respectively.

Mundagoora pool is a relatively deep permanent pool located at the base of an intermittent waterfall, which appears to only flow during high rainfall events. The pool water level is controlled by a sill at the downstream edge. Water levels remain relatively consistent within the pool with the exception of short duration peaks during high rainfall events (Figure 3-29 and Figure 3-30). Mundagoora Pool appears to be largely sustained by groundwater; however, it was periodically flushed with fresh surface water flows after rainfall events. It takes approximately 3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred. Conductivity was typically very slightly brackish (~850 µS/cm) except during a surface water flow event when it would become extremely fresh (<50 µS/cm). Water levels were a maximum of ~0.6 m above the pool overflow levels during high-flow events, typically lasting less than 24 hours before flows receded. Water temperature within the pool was responsive to atmospheric temperature changes (Figure 3-29 and Figure 3-30).

Mundagoora Pool is a clear water pool with low turbidity (0.71 NTU), low salinity (870 µS/cm) and moderate oxygenation (5.61 mg/L). No metals were recorded above ANZG (2018) and were predominantly below detection limits. Nutrients were low, with Total Nitrogen at 0.5 mg/L and Total Phosphorus at 0.01 mg/L. Dissolved organic carbon (DOC) was moderate at 4 mg/L. See Appendix A for complete water quality data.

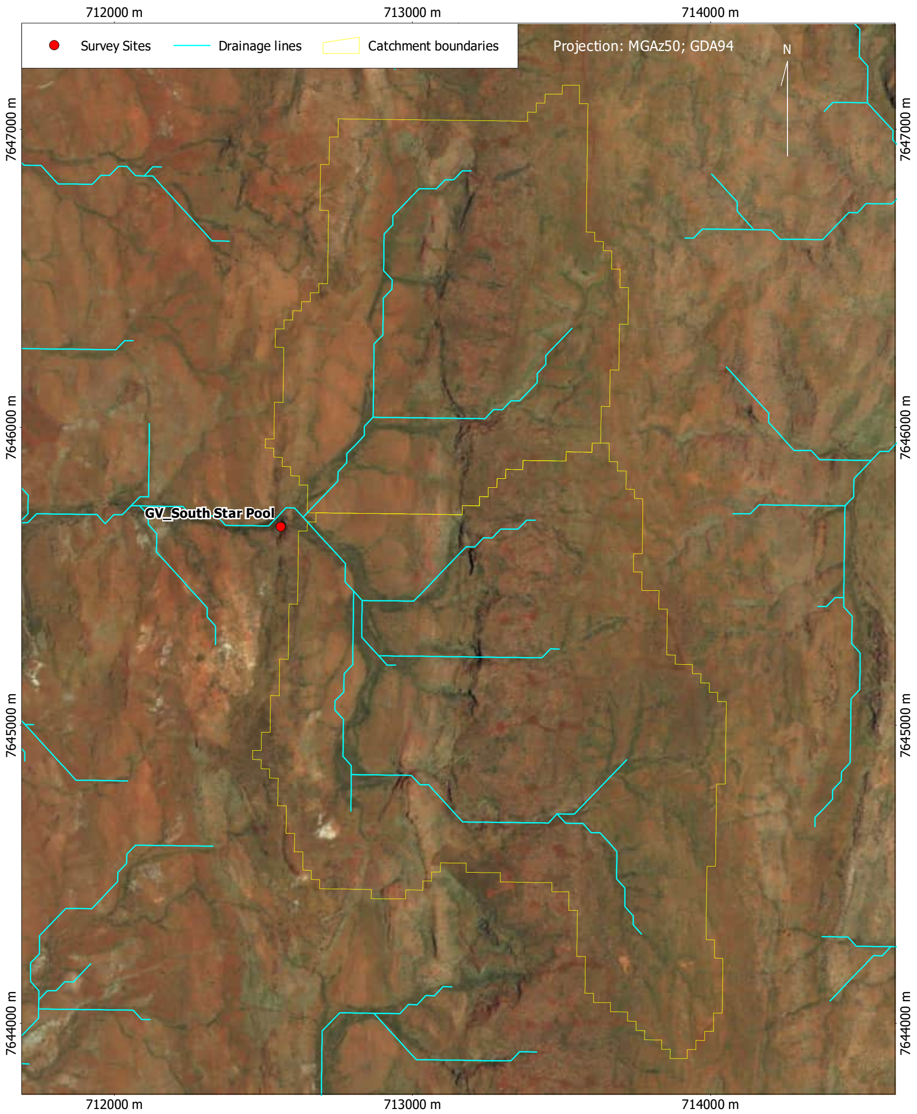


Figure 3-28 Mundagoora Pool catchment (3.3 km^2)

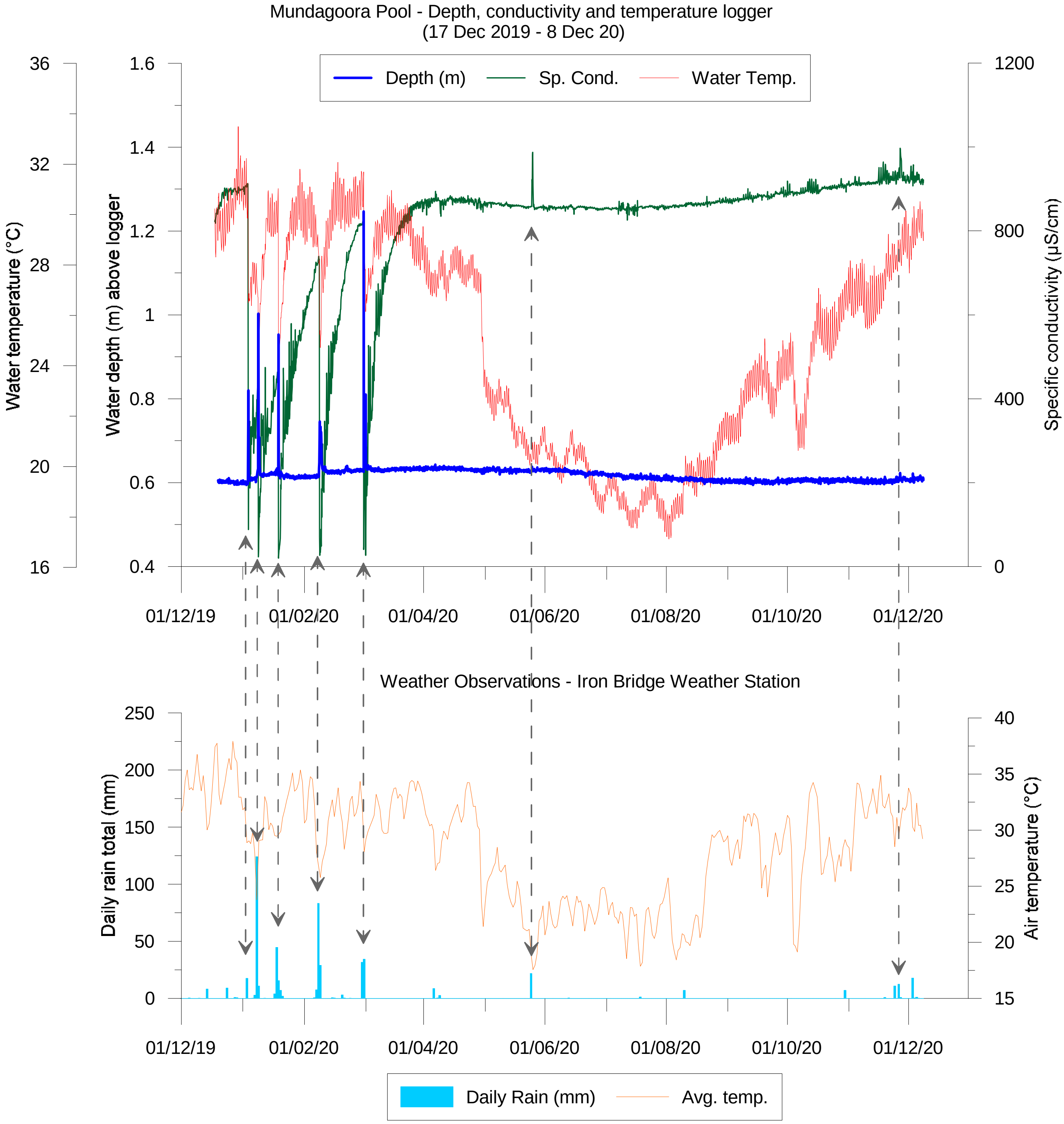


Figure 3-29 Water level, temperature and conductivity (salinity) at Mundagoora Pool – Wet-Dry Season 2020

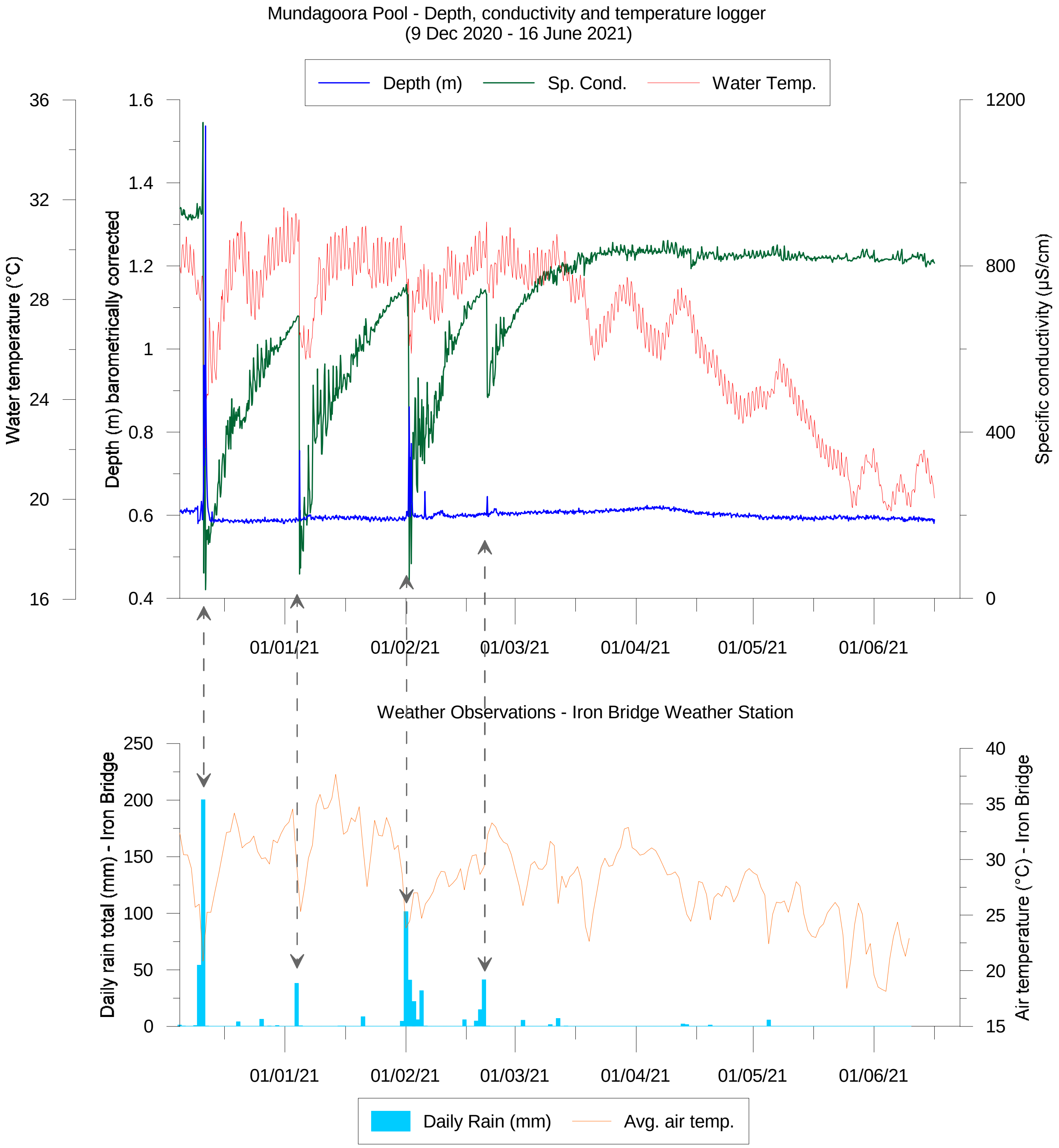


Figure 3-30 Water level, temperature and conductivity (salinity) at Mundagoora Pool – Wet – mid Dry Season 2021

Figure 3-31 provides a Durov plot displaying the major ion balance of Mundagoora Pool over four sampling events. It can be seen that the water quality is relatively stable over the four seasonal sampling events with a slightly alkaline pH. Cations are evenly distributed between Calcium, Magnesium and Sodium+Potassium with anions dominated by carbonates.

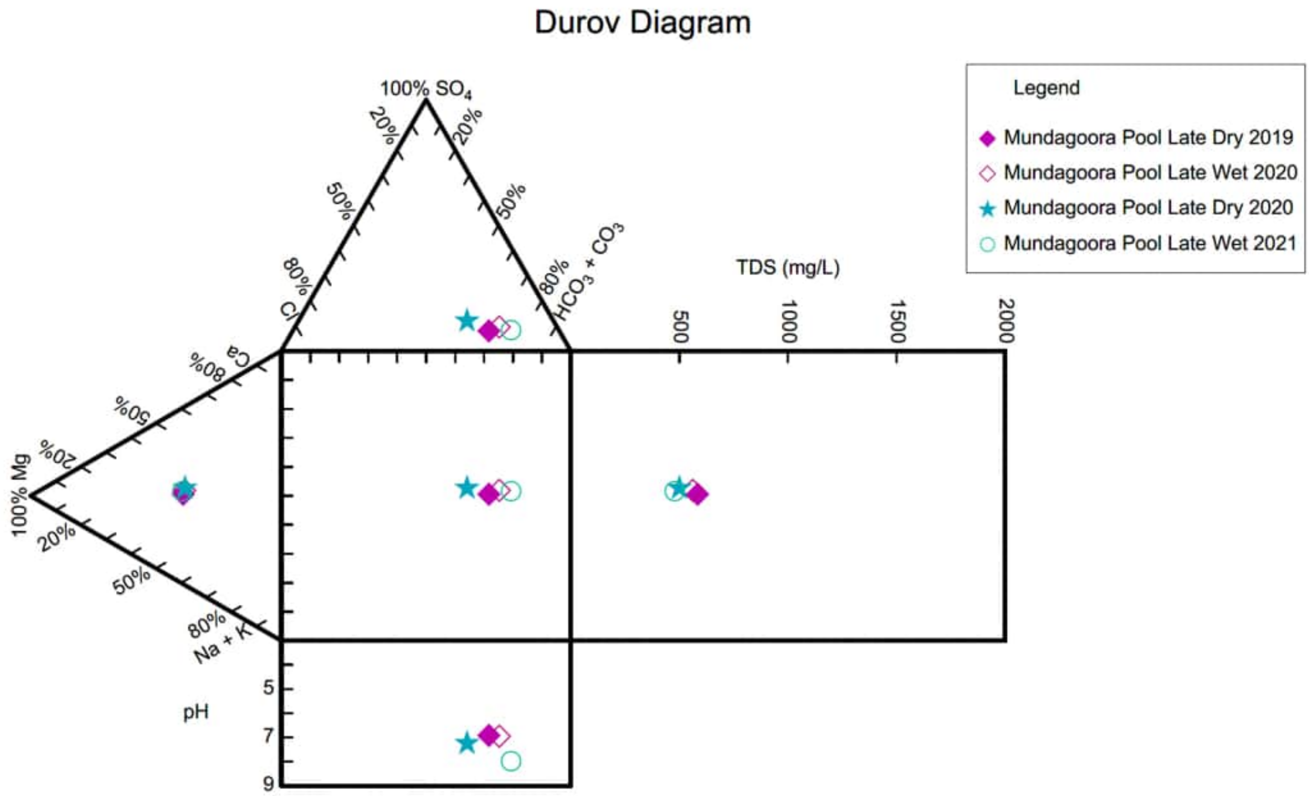


Figure 3-31 Durov diagram illustrates the Mundagoora Pool major ion distribution.

3.3.2 BATHYMETRY

Mundagoora Pool was surveyed in May 2020 using a down beam and side-scan sonar system attached to a remote-control boat. The maximum depth of the pool is approximately 3.5 m with the average depth 1.9 m (Figure 3-32). The volume of the pool has been calculated at 448 m^3. The deepest section (3-3.5 m) is in the basin below the waterfall/rock face to the east with a shallower sill to the west at ~1 m deep (Figure 3-32 to Figure 3-36). The pool is 25 m in length (north-south) and 15 m at its widest point (east-west). The base of the pool is dominated by hard rock with gravel/sediments to the west at the pool overflow point.

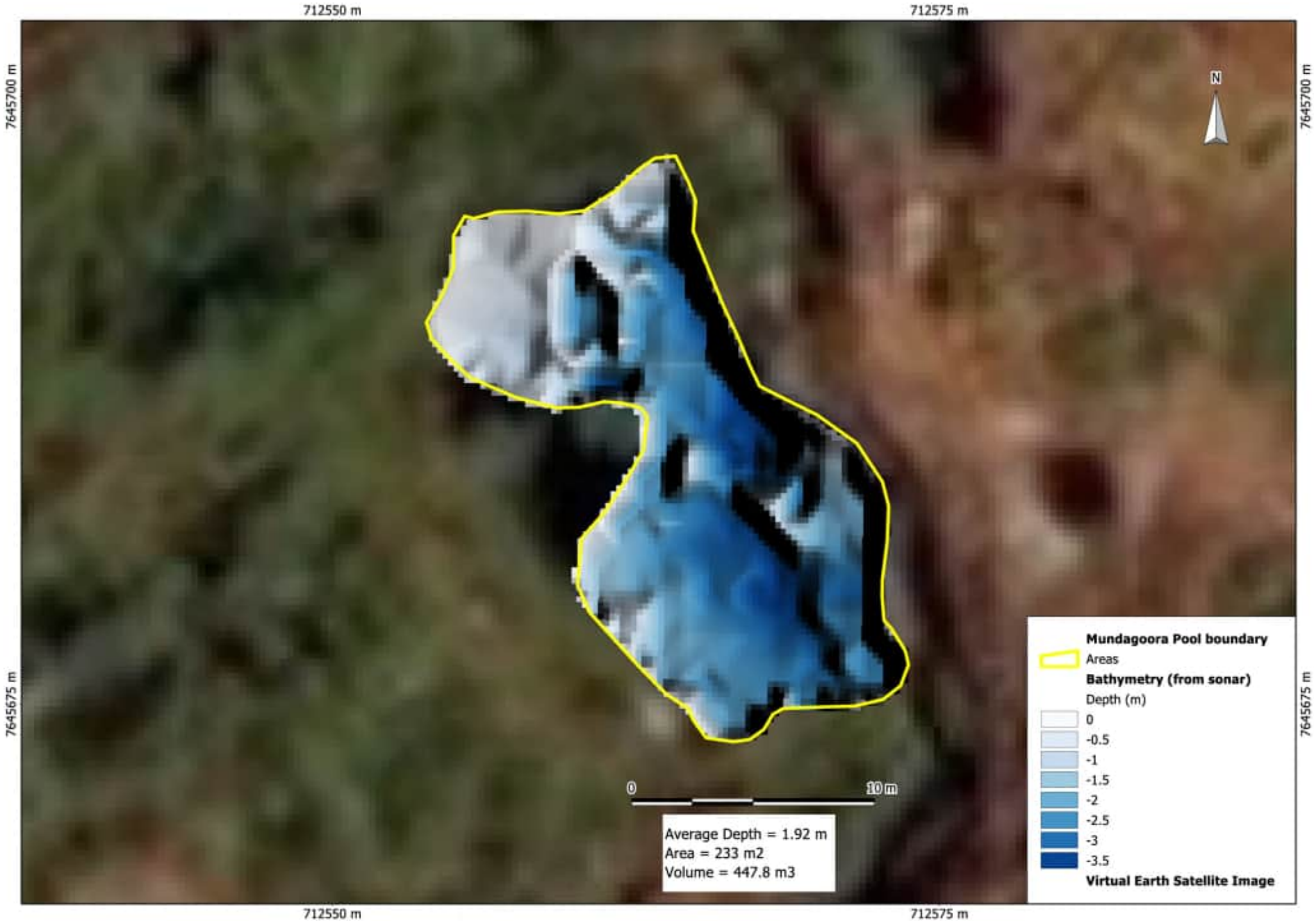


Figure 3-32 Bathymetry of Mundagoora Pool

Figure 3-33 Cross-section of deep southern portion of Mundagoora Pool (East-West)

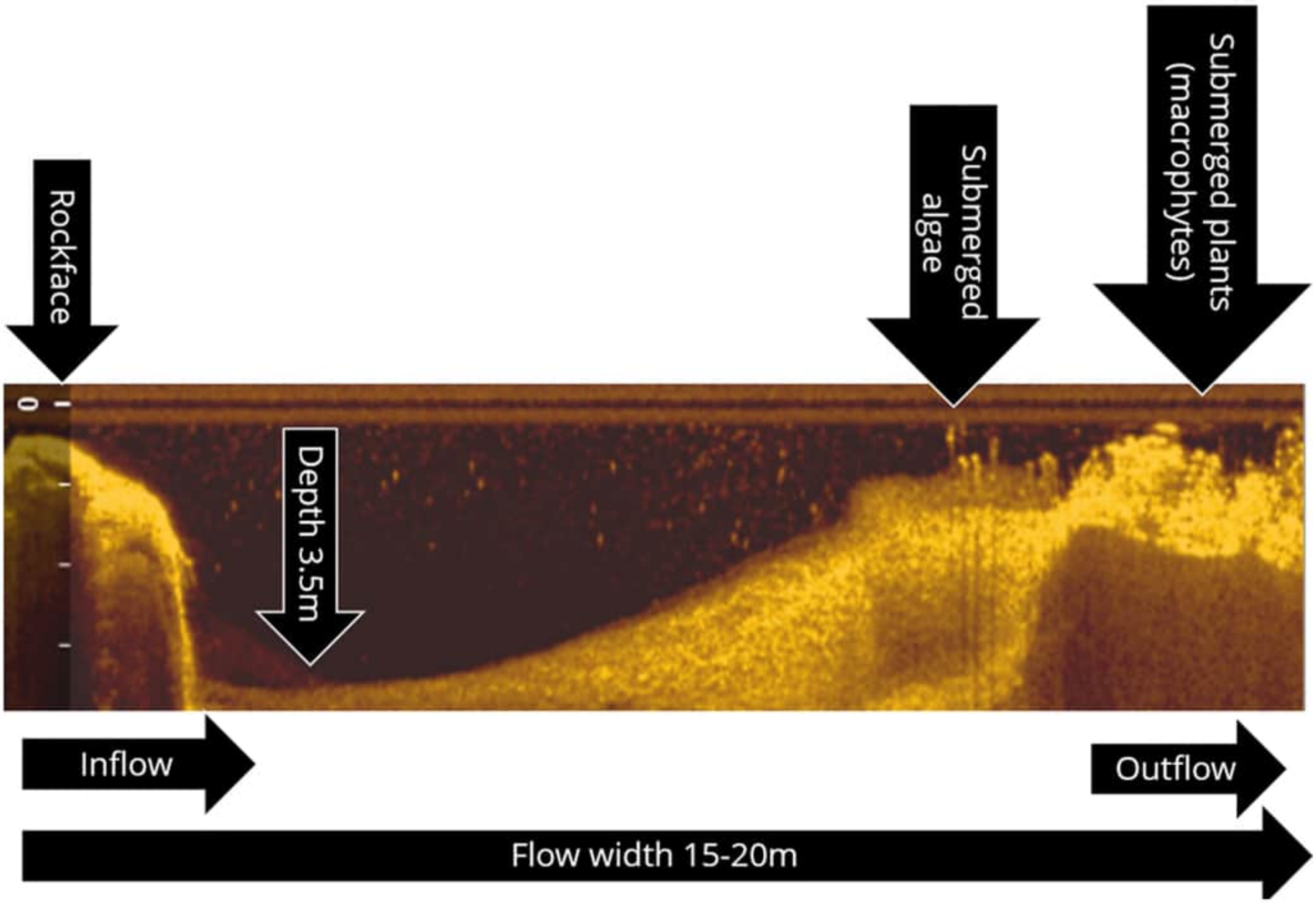


Figure 3-34 Sonar cross-section of Mundagoora Pool showing habitat features

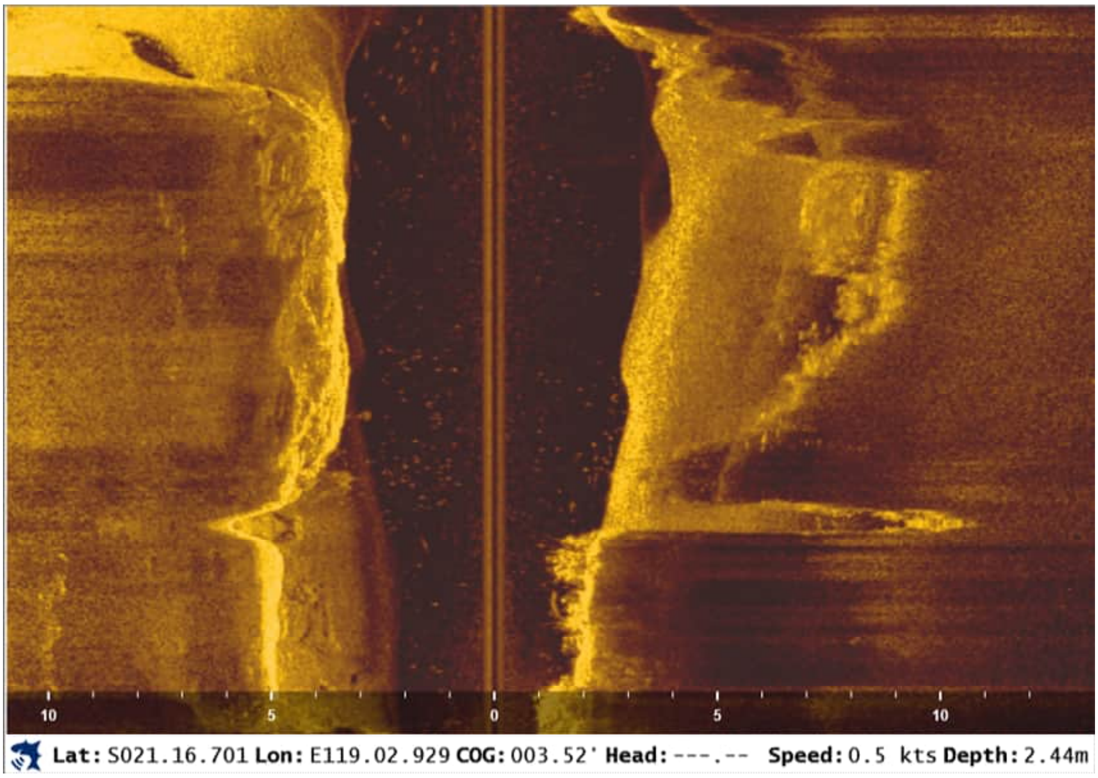


Figure 3-35 Side-scan sonar bathymetry: - cross-section north-south

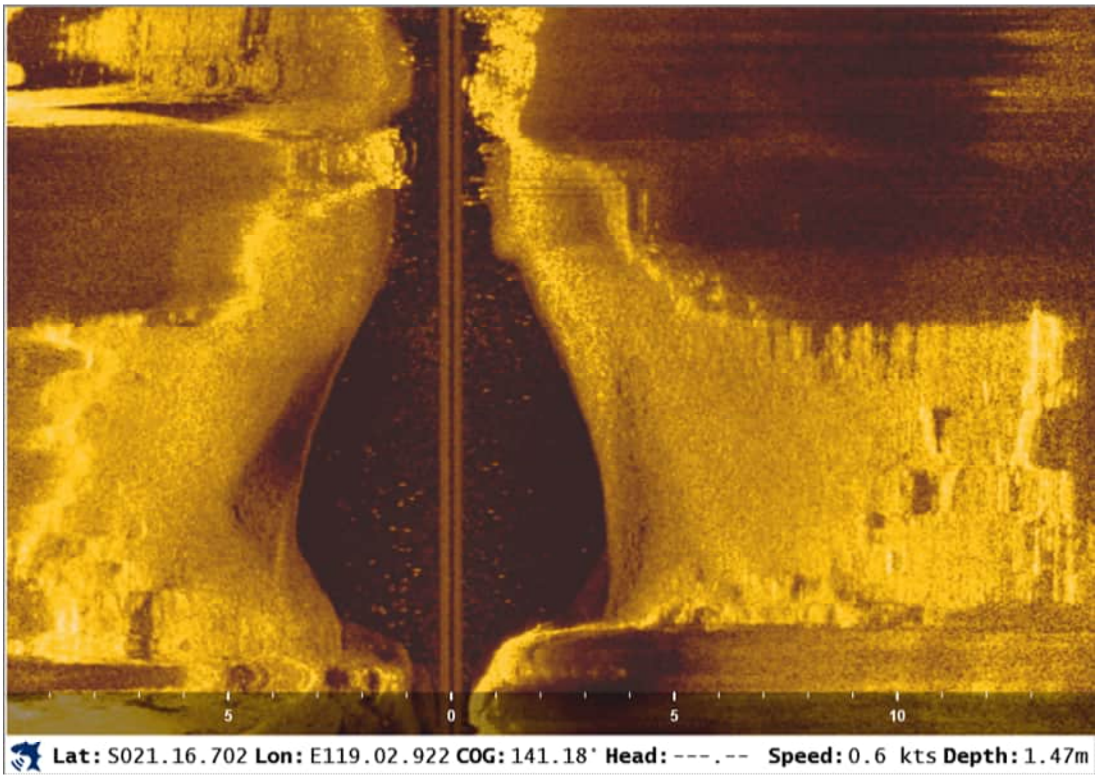


Figure 3-36 Side-scan sonar bathymetry: cross-section east-west

3.3.3 SEDIMENT QUALITY

Table 3-8 provides the surface sediment quality at Mundagoora Pool during the three seasonal surveys. Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (169 mg/kg) exceeded the DGV but not the GV-high. Nickel concentration (79 mg/kg) exceeded both the DGV and GV-high. These metals both naturally occur in high concentrations across the Project area. Alkalinity exceeded acidity in the sediments of Mundagoora Pool, indicating that there is unlikely to be an acid sulphate soil issue.

Table 3-8. Summary of sediment quality analyses for the late wet season (2020), late dry season (2020) and late wet season (2021). Bolded values denote results above the limit of reporting.

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Total Soluble Salts	mg/kg	**693**	**-**	**280**
Moisture Content (Dried @ 105-110°C)	%	**59.7**	**49.3**	**24.8**
Total Alkalinity as CaCO3	mg/kg	**77**	**104**	**<5**
Bicarbonate Alkalinity as CaCO3	mg/kg	**77**	**104**	**239**
Carbonate Alkalinity as CaCO3	mg/kg	<1	<5	**239**
Acidity	mg/kg	**12**	**53**	**62**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**80**	**70**	<10
Chloride (by Discrete Analyser)	mg/kg	**100**	**40**	**20**
Calcium	mg/kg	**220**	**30**	**30**
Magnesium	mg/kg	**110**	**20**	**20**
Sodium	mg/kg	**170**	**100**	**30**
Potassium	mg/kg	**20**	<10	<10
Mercury (FIMS)	mg/kg	**0.6**	-	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	**3950**	**1970**	**430**
Total Nitrogen as N	mg/kg	**3950**	**1970**	**430**
Total Phosphorus as P	mg/kg	**242**	**179**	**190**
Reactive Phosphorus as P	mg/kg	<0.1	<0.1	<0.1
Total Organic Carbon	%	**3.15**	**4.88**	**0.13**
Arsenic	mg/kg	**9**	**-**	**9**
Barium	mg/kg	**40**	**-**	**60**
Beryllium	mg/kg	**1**	**-**	**<1**
Boron	mg/kg	<50	-	**50**
Cadmium	mg/kg	<1	-	<1
Chromium	mg/kg	**169**	**-**	**368**
Cobalt	mg/kg	**22**	**-**	**33**

Analyte grouping/Analyte	Unit	Late Wet 2020	Late Dry 2020	Late Wet 2021
Copper	mg/kg	**52**	**-**	**67**
Iron	mg/kg	**76600**	**57000**	**114000**
Lead	mg/kg	<5	-	**6**
Manganese	mg/kg	**481**	**-**	**674**
Nickel	mg/kg	**79**	**-**	**134**
Selenium	mg/kg	**5**	**-**	**<5**
Vanadium	mg/kg	**166**	**-**	**161**
Zinc	mg/kg	**39**	**-**	**30**

3.3.4 FISH

Table 3-9 presents the fish species, catch and size distribution collected during the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys. Two fish species were present and were sampled by nets/traps and BRUVs; *M. australis* and *L. unicolor*. *M. australis* was substantially more abundant in all three seasons (Table 3-9). The highest number of *M. australis* was collected in the Late Dry 2020, with 451 fish caught, the late wet for both years had similar numbers of fish caught (213).

The majority of *M. australis* ranged between approximately 20 mm to 90 mm in total length, with very few individuals being observed > 90 mm in the late dry season (2020). Figure 3-37 displays the size distribution of measured *M. australis* individuals for each survey. Figure 3-38 displays the frequency of each size class, with the 30 – 60 mm size class being most frequent in all three seasons. In all three surveys, individuals <30 mm were observed at Mundagoora Pool, indicating a regular spawning and recruitment at the site (Pusey, B., Kennard, M., & Arthington, 2004).

Only one individual of *L. unicolor* was caught in the Fyke net in the Late Wet 2020 and three in the Late Dry 2020. No *L. unicolor* individuals were caught in the Late Wet 2020 though these were visually observed to be present in low numbers. As such, size distribution for *L. unicolor* has been pooled for the two seasons in Figure 3-39, all *L. unicolor* individuals caught within the Fyke nets were > 90 mm. The size range of *L. unicolor* observed demonstrated likely interannual survival and reproduction, with some estimated at several years old (Figure 3-43). The low abundance of *L. unicolor* was likely due to the net being placed in habitat less frequented by this species (edge/macrophytes). BRUVs directed towards open water captured a greater abundance of adult *L. unicolor*. BRUV footage in the Late Wet 2021 did not observe *L. unicolor*, potentially indicating lower abundance for this survey.

Table 3-9. Fish species, size class (SL, mm), overall count and CPUE for Mundagoora Pool

Species	Size class (mm)	Late Wet (2020)	CPUE[1]	Late Dry (2020)	CPUE[1]	Late Wet (2021)	CPUE[1]
Melanotaenia australis		**212**	**12.8**	**451**	**27.3**	**213**	**12.9**
	0 – 30	63		61		10	
	30 – 60	95		269		2020	
	60 – 90	54		100		1	
	> 90	0		21			
Leiopotherapon unicolor		**1**	**0.06**	**3**	**0.18**	**0**	**-**
	30 - 60	0		0		0	
	60 - 90	0		0		0	
	> 90	1		3		0	
Total		**213**	**12.9**	**454**	**27.5**	**213**	**12.9**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 16.5 hours.

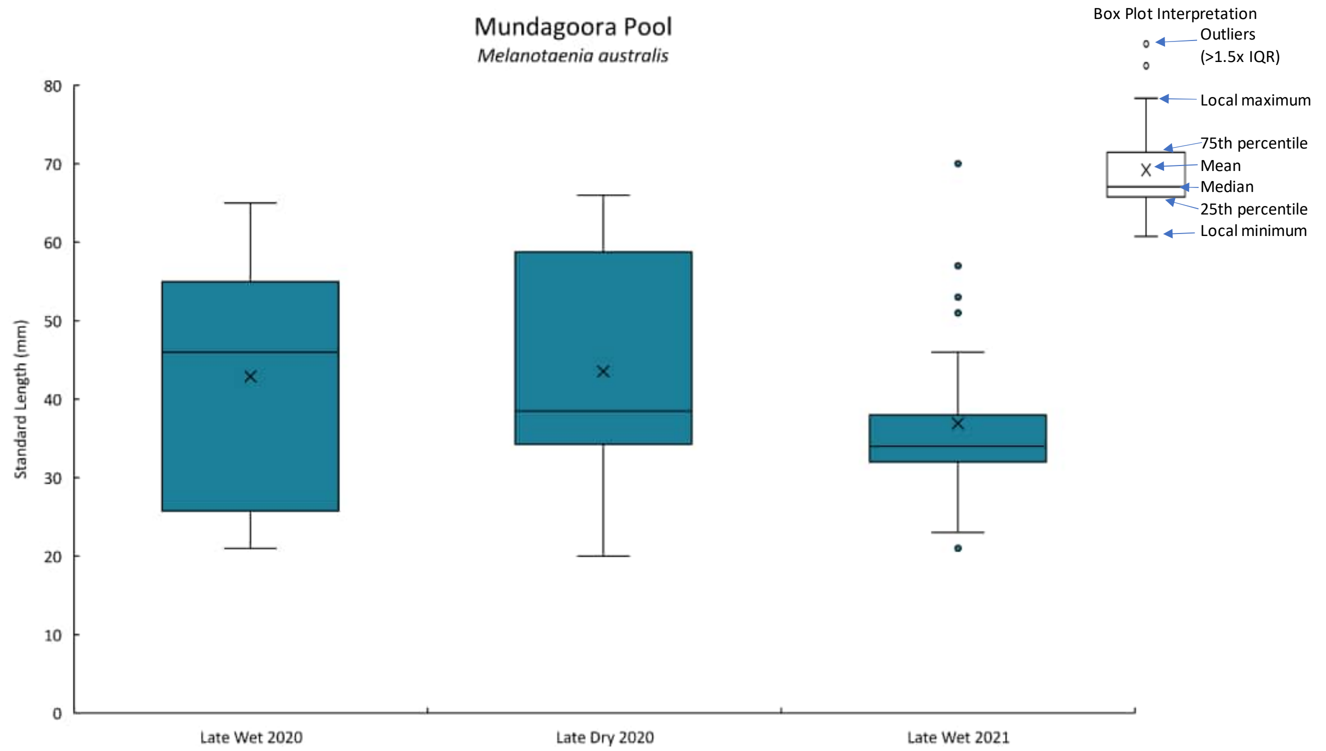


Figure 3-37. Distribution of standard length (SL, mm) for *Melatoenia australis* in Mundagoora Pool sampled with Fyke nets for the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys.

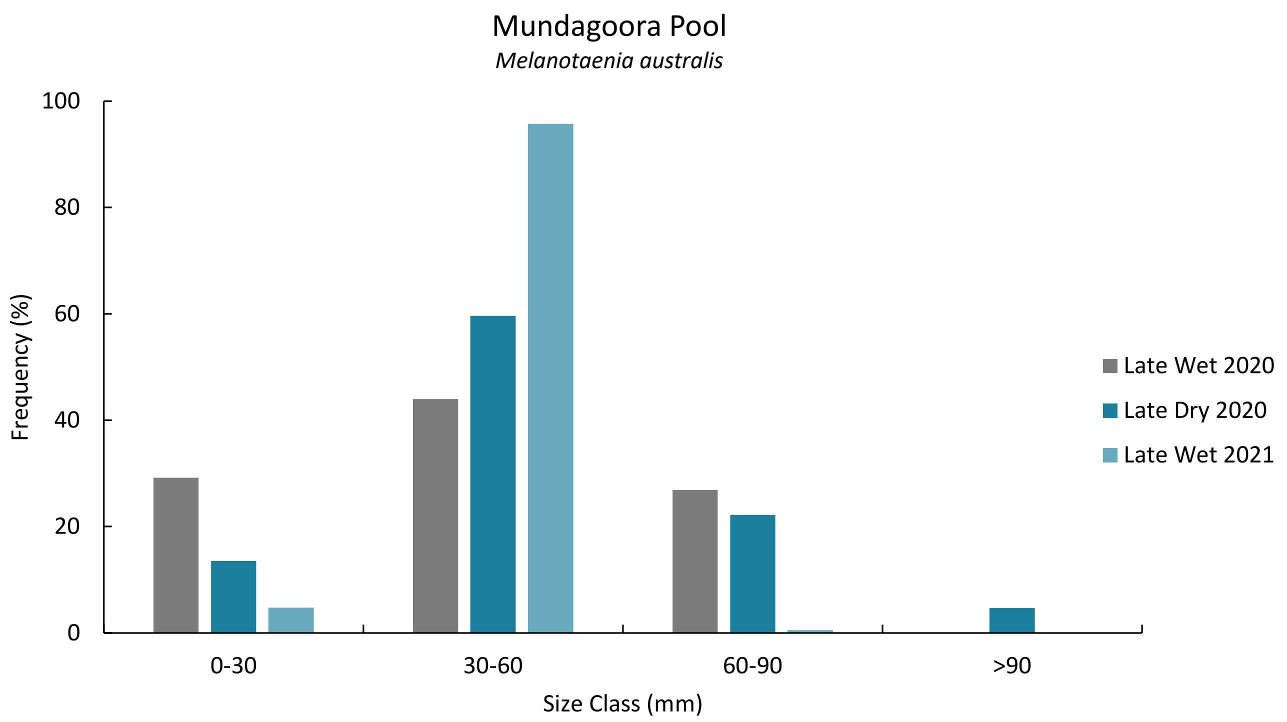


Figure 3-38. Frequency (%) of each size class (mm) for *M. australis* in Mundagoora Pool sampled with Fyke nets for the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys.

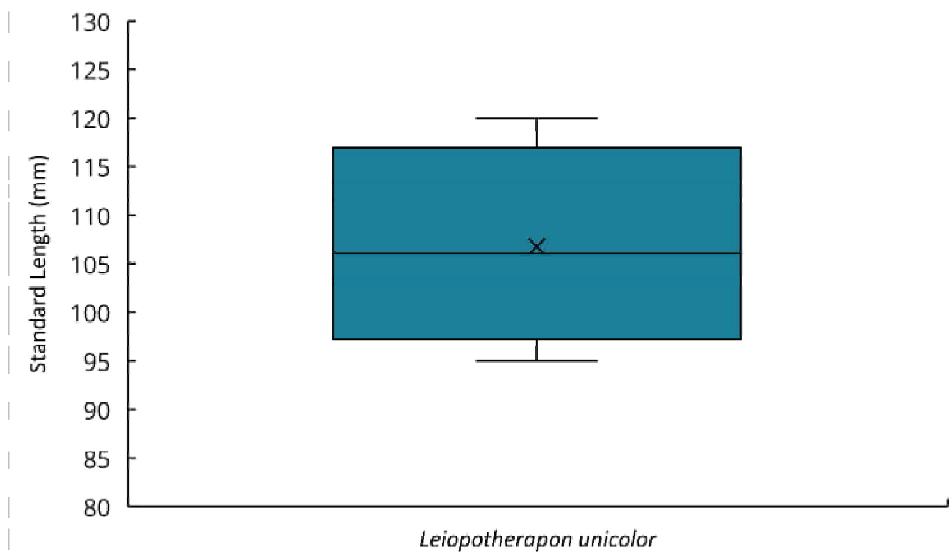
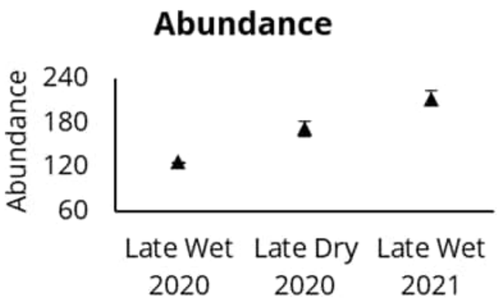


Figure 3-39. Distribution of standard length (SL, mm) for *Leiopotherapon unicolor* sampled from Mundagoora Pool in the Late Wet 2020 and Late Dry 2020 seasons.

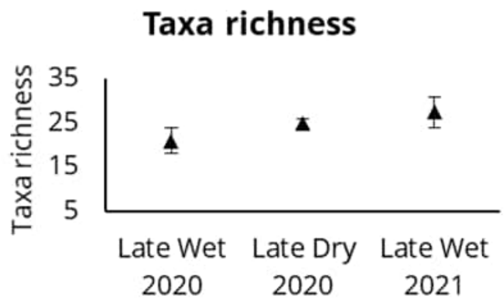
3.3.5 AQUATIC MACROINVERTEBRATES

Figure 3-40 presents the total abundance, taxa richness, EPT richness and SIGNAL2 scores for Mundagoora Pool in the late wet seasons of 2020 and 2021 and the late dry season of 2020. The key findings were as follows:

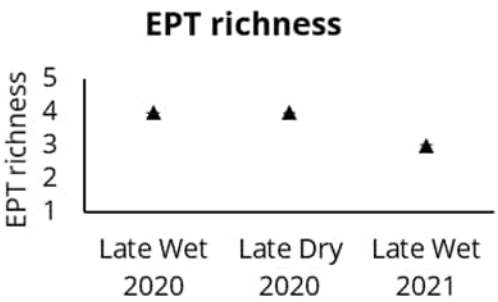
- Total abundance of aquatic macroinvertebrates gradually increased throughout the seasons, with an average of 214 individuals sampled in the recent Late Dry 2021 season (Figure 3-40a).
- Taxonomic richness remained relatively constant in comparison, with a slightly higher number of taxa recorded in the most recent season (Figure 3-40b)
- An average of four taxa belonging to the Plecoptera, Ephemeroptera and Trichoptera were found in both seasons in 2020 (EPT richness = 4) while it reduced to 3 in Late Wet 2021 (EPT richness = 3; Figure 3-40c).
- SIGNAL 2 scores were also consistent between seasons with a range of 2.8 to 3.2 (Figure 3-40d), indicating a community primarily dominated by tolerant taxa.



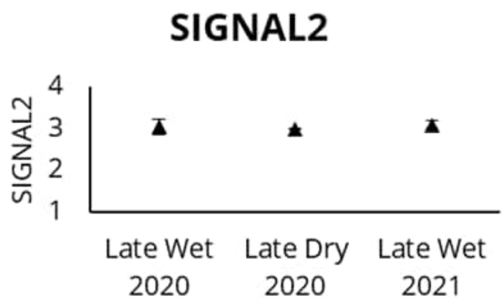
a) Total abundance at Mundagoora Pool



b) Taxonomic richness at Mundagoora Pool



c) PET richness at Mundagoora Pool



d) SIGNAL2 scores at Mundagoora Pool

Figure 3-40 Macroinvertebrate indices for Mundagoora Pool – Late Wet 2020, Late Dry 2020 and Late Wet 2021.

The taxonomic composition of the macroinvertebrate community is provided in Figure 3-41, ranging from most abundant (left) to least abundant (right) along the x-axis. There were higher numbers of the non-biting midge Tanypodinae, the biting midge Ceratopogonidae, backswimmers of the Pleidae, and oligochate worms found during the recent Late Wet 2021 survey in comparison to others. In contrast, higher abundances of the caddisfly Leptoceridae were found during the Late Dry season of 2020. Relatively similar abundances of non-biting midge of the Chironominae and Coenagrionidae damselflies were found in each sampling event. Some macroinvertebrates, such as chironomids and oligochaetes, can increase in abundance following freshwater flow events such as flooding in wetlands (e.g. McInerney et al. 2017), which may explain increased abundances of such taxa in the latest wet season when greater rainfall levels were recorded.

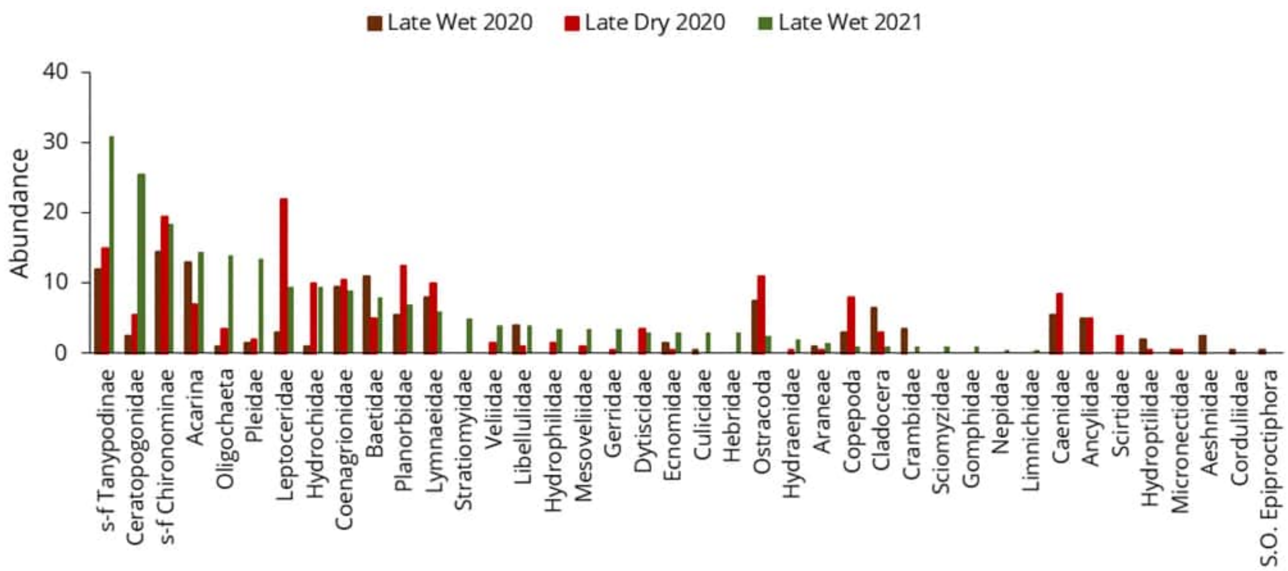


Figure 3-41 Average abundances of all macroinvertebrate taxa at Mundagoora Pool in the Late Wet season of 2021 and the Late Wet and Late Dry season of 2020, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.3.6 DIATOMS AND PHYTOPLANKTON

3.3.6.1 DIATOMS

Table 3-10 presents the Late Wet 2020 diatom species present, abundance and biotic indices as collected on Diatom plates. No data is available from the Late Dry 2020 due to flood conditions during the 4 week deployment period. The Late Wet 2021 data was not yet available at the time of reporting. Figure 3-42 shows the average count by diatom species present. A total of 17 diatom species were recorded and showed a high taxonomic diversity ranging across multiple families. The most dominant species were *Achnanthidium minutissimum* (average count=197) and *Brachysira vitrea* (average count=106) (Figure 3-42). The moderate sensitivity DSIAR scores (average DSIAR = 62.7) is associated with low levels of environmental stress and diatoms valves were relatively abundant compared to other North Star Pools.

Table 3-10. Diatom species list with count (total count per species), average abundance and DSIAR score for Mundagoora Pool surveyed in the Late Wet season 2020 and 2021.

Taxon	Late Wet 2020			Late Wet 2021		
	Replicate 1	Replicate 2	Average	Replicate 1	Replicate 2	Average
Achnanthidium minutissimum	302	92	197	14	62	38
Brachysira vitrea	48	164	106	0	124	62
Eunotia bilunaris	14	70	42	0	102	51
Navicula cryptocephala	6	0	3	16	68	42
Navicula radiosa	12	24	18	0	24	12
Encyonopsis microcephala	0	0	0	0	24	12
Brachysira styriaca	0	0	0	0	16	8
Cymbella affinis	6	8	7	0	0	0
Navicula menisculus	0	0	0	6	8	7
Navicula menisculoides	8	4	6	0	0	0
Navicula viridula	0	0	0	12	0	6
Ulnaria ulna	0	12	6	0	0	0
Cymbella spp	4	4	4	0	0	0
Eunotia naeglii	0	0	0	0	8	4
Navicula cryptotenella	0	2	1	0	8	4
Navicula lanceolata	4	4	4	0	2	1
Nitzschia palea	0	0	0	8	0	4
Eunotia incisa	0	0	0	0	6	3
Eunotia mucophila	0	0	0	0	6	3
Encyonema minutum	4	0	2	0	0	0
Fragilaria tenera	0	0	0	0	4	2
Gomphonema affine	0	0	0	0	4	2
Navicula erifuga	0	0	0	0	4	2
Navicula gregaria	4	0	2	0	2	1

Taxon	Late Wet 2020			Late Wet 2021		
Navicula leptostriata	0	0	0	0	4	2
Navicula recens	4	0	2	0	0	0
Nitzschia fonticola	0	0	0	4	0	2
Nitzschia inconspicua	0	0	0	4	0	2
Caloneis silicula	0	2	1	0	0	0
Craticula halophila	2	0	1	0	0	0
Diploneis parma	2	0	1	0	0	0
Epithemia gibba	0	0	0	0	2	1
Eunotia pectinalis	0	0	0	0	2	1
Gomphonema gracile	0	0	0	0	2	1
Karayevia clevei	0	0	0	0	2	1
Navicula spp	0	0	0	2	0	1
Navicula veneta	0	0	0	2	0	1
Total Abundance	**420**	**386**	**403**	**68**	**484**	**276**
DSIAR Score	**59.1**	**66.3**	**62.7**		**63**	

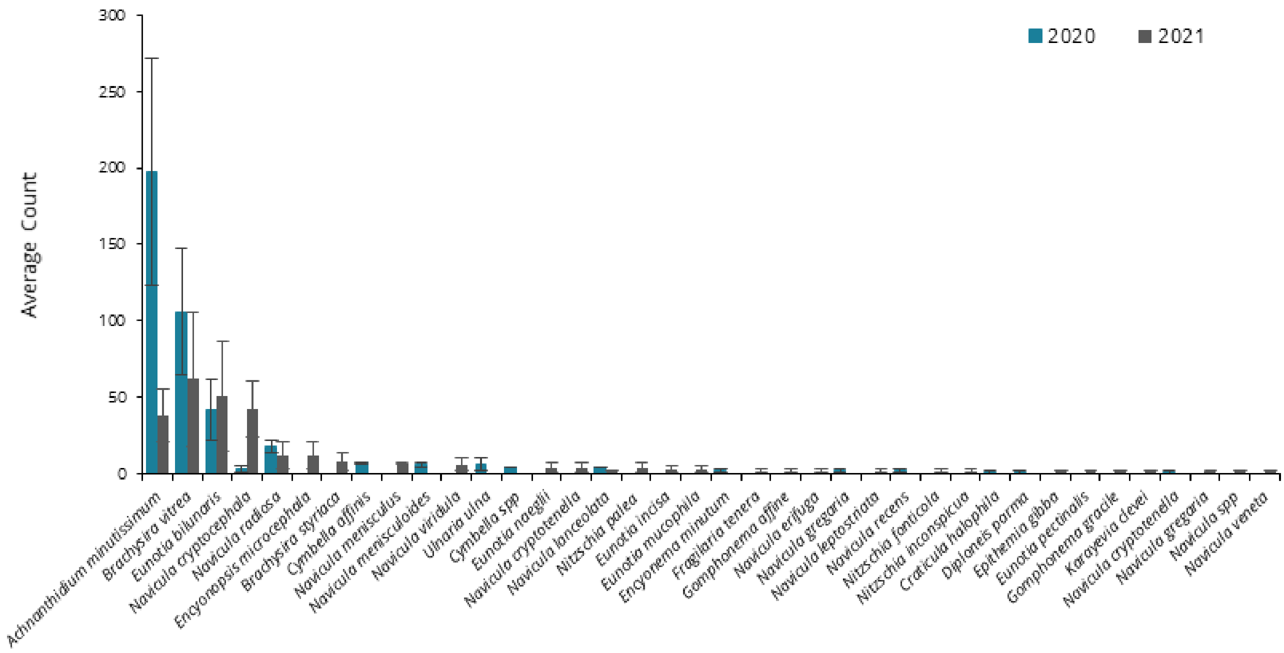


Figure 3-42. Mean abundance of diatom species recorded at Mundagoora Pool in the late wet season 2020, with error bars denoting 0.5±σ.

3.3.6.2 PHYTOPLANKTON

In the Late Dry 2020 and the Late Wet 2021, water samples were taken from Mundagoora Pool for phytoplankton taxonomy and abundance. Table 3-11 summarises the abundance of the phytoplankton taxon identified at Mundagoora Pool. Overall, 6 classes of phytoplankton with ~19 species were identified across both seasons indicating a high phytoplankton diversity. The most abundant Class were diatoms (Bacillariophyceae) for both seasons.

Table 3-11 Summary of phytoplankton analytical results for Mundagoora Pool sampled in late dry season (2020) and late wet season (2021), abundance (cells L^{-1}) and percentage contribution (%), limit of reporting 10 cell L^{-1}.

Taxon	Late Dry (2020)		Late Wet (2021)	
	Abundance	%	Abundance	%
Bacillariophyceae	**80300**	**76.11**	**70**	**63.64**
Achnanthidium sp.	35200	33.36	10	9.09
Amphora spp.	0	0	10	9.09
Cocconeis spp.	700	0.66	0	0
Cymbella spp.	300	0.28	0	0
Lyrella spp	100	0.09	0	0
Navicula spp.	19600	18.58	0	0
Navicula spp.	19600	18.58	40	36.36
Nitzschia spp.	100	0.09	0	0
Pinnularia spp.	200	0.19	0	0
Synedra spp. (O)	4500	4.27	10	9.09
Chlorophyceae	**900**	**0.85**	**40**	**36.36**
Mougeotia sp.	0	0	40	36.36
Cryptophyceae	**8800**	**8.34**	**0**	**0**
Chroomonas spp.	800	0.76	0	0
Cryptomonas spp. (O)	8000	7.58	0	0
Cyanobacteria	**8200**	**7.77**	**0**	**0**
Pseudoanabaena spp. (O) (PT)	8200	7.77	0	0
Dinophyceae	**7200**	**6.82**	**0**	**0**
Gomphonema spp.	500	0.47	0	0
Gonyaulax spp.	800	0.76	0	0
Gymnodinium spp.	1400	1.33	0	0
Peridinium spp. (O)	4500	4.27	0	0
Euglenophyceae	**100**	**0.09**	**0**	**0**
Euglena spp. (O)	100	0.09	0	0

3.3.7 MACROPHYTES

Table 3-12 presents the macrophyte species and qualitative abundance during the three season surveys at Mundagoora Pool. The key findings were as follows:

- A total of 5 macrophyte species were recorded and show a range of emergent (bulrush and sedges) and submerged (charophyte and ribbon weed) types.
- Emergent macrophytes were the dominant edge habitat, occurring in wide dense beds along the pools edge except for along the upstream eastern rockface. Submerged macrophytes occurred in scattered abundance on the bed.
- There were no significant changes noted for macrophyte presence, abundance or health over the three survey periods. There was a decrease in the abundance of emergent macrophytes in the Late Wet 2021 compared to the Late Wet 2020, though no changes were substantial enough to alter the categorical abundance classification.

Table 3-12 Macrophytes present at Mundagoora Pool

Common name	Species name	Late Wet 2020 Abundance[1]	Late Dry 2020 Abundance[1]	Late Wet 2021 Abundance[1]
Ribbon weed	*Vallisneria sp.*	Abundant	Abundant	Abundant
Charophytes	*Nitella sp., Chara sp.*	Isolated	Isolated	Isolated
Clubrush	*Schoenoplectus sp.*	Abundant	Abundant	Abundant
Sedges	Cyperaceae	Isolated	Isolated	Isolated
Bulrush	*Typha sp.*	Abundant	Abundant	Abundant

[1] Abundance based on *Western Australia AUSRIVAS field sampling sheet* (DoW, 2009).

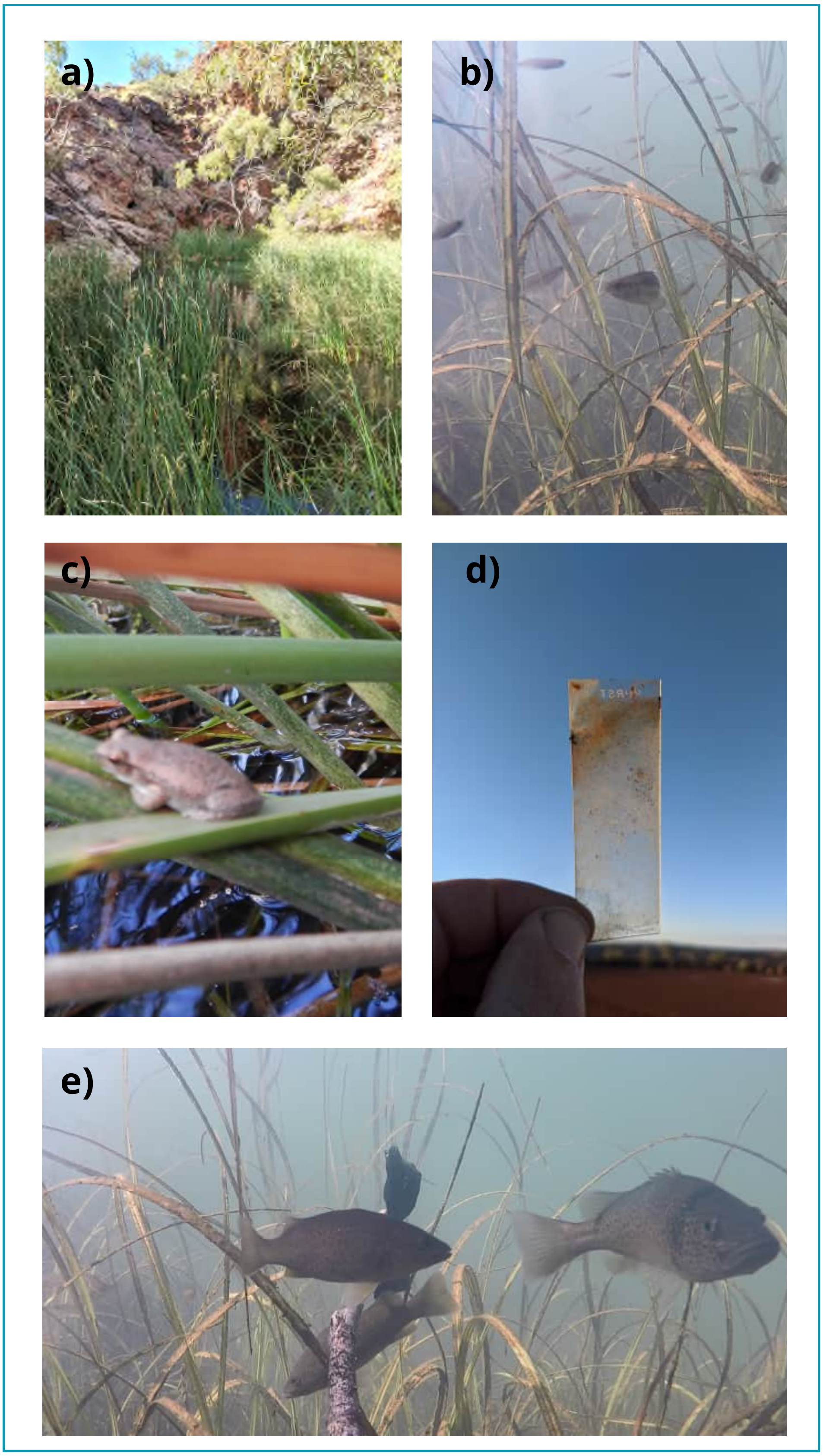


Figure 3-43 Mundagoora Pool aquatic ecology. a) emergent macrophytes forms beds at the edge of the pools; b) submerged macrophytes create important habitat for an abundance of *M. australis* and *L. unicolor*; c) frog (*Littoria rubella*) utilising the macrophyte habitat; d) abundant diatom growth on slide; e) adult *L. unicolor* observed in abundance using underwater video.

3.4 CENTRAL CREEK POOL (IB_SW_POOL_Central Ck)

Central Creek Pool is a shallow pool that lies on deep alluvial sediments on Cockatoo Creek, which experiences high flows in the wet season. The pool is predominantly sustained by surface/hyporheic water and consequently undergoes high rates of evapo-concentration and has minimal established macrophyte habitat. The water quality is relatively turbid in comparison to other North Star pools and there is evidence of cattle visitation.

In the Late Dry 2020, samples were not obtained from Central Creek as the site was dry.

Figure 3-44 Central Creek is a shallow pool on Cockatoo Creek that experiences substantial evapo-concentration and is likely a temporary pool.

3.4.1 WATER QUALITY AND HYDROLOGY

Central Creek Pool has a catchment area of 85.1 km^2, draining to Cockatoo Creek and the Turner River (Figure 3-45). The surface water level logger was installed in Central Creek Pool during the Late Wet 2020 sampling round and as such there is no direct hydrology data available for the previous wet season. However, there was a logger installed on the same creek system approximately 550 m downstream in a similar pool (MAR Cockatoo Creek; Figure 3-47) and it is considered that this represents a reasonable analogue for the hydrology of Central Creek Pool. The logger data for May 2020 to June 2021 at Central Creek Pool is provided in Figure 3-47. Central Creek Pool shows a typical Pilbara creek flooding profile driven by alluvial (hyporheic) flows. There is an initial peek water level during high-rainfall events with a longer "tail" to the peak as water levels recede, driven by discharge from upper catchment alluvial storage and groundwater. Once recharged after the first flush event, the pool water levels are maintained over the wet season, receding slowly as the alluvials dry out over the early dry season. It can be seen from Figure 3-47 that Central Creek Pool was dry by July 2020 and filled again with a major rainfall event on the 10th December 2020. The rate of recedance between flood events appears to lower as the wet season progresses, potentially in response to increase groundwater inflows to the hyporheic system of the creek.

Figure 3-45 Central Creek Pool catchment area (85.1 km^2)

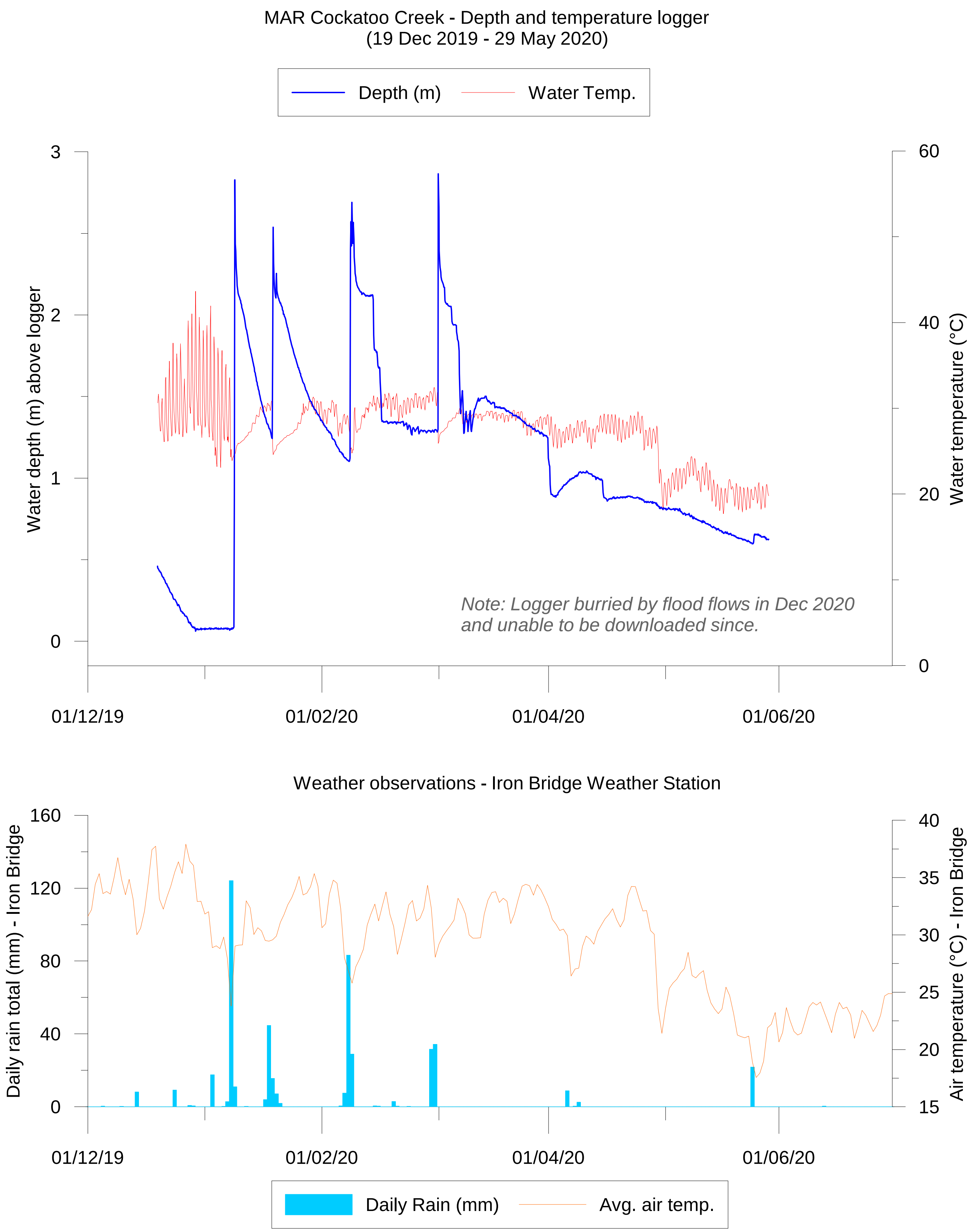


Figure 3-46 MAR Cockatoo Creek - water level logger data - Dec 2019 to June 2020

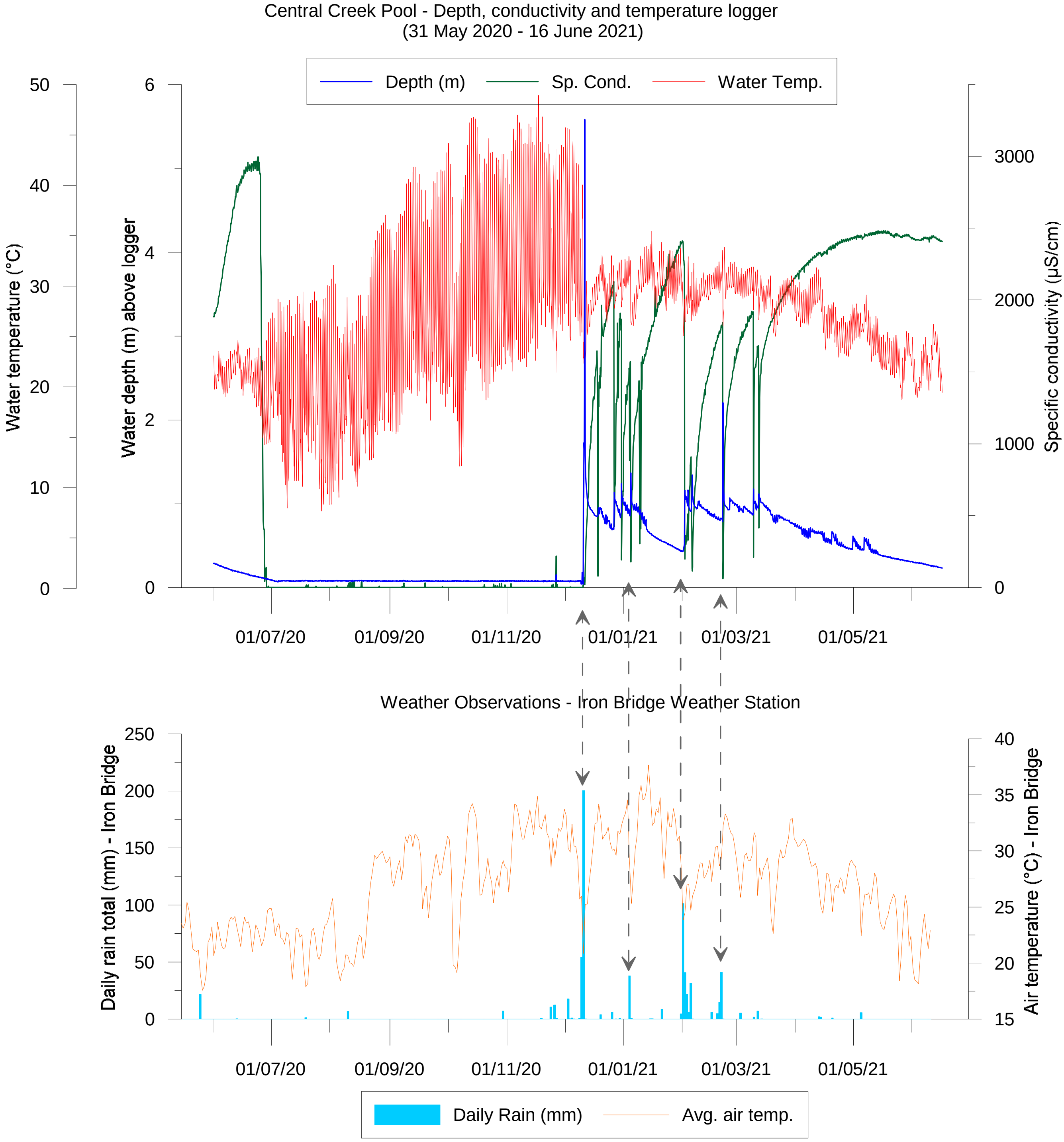


Figure 3-47 Central Creek Pool water level and temperature logger data – Late Wet 2020 – mid Dry 2021

Central Creek Pool displayed brackish salinity (2227 µS/cm conductivity) during the Late Wet 2020, likely representing evapo-concentration effects since the last major flushing event occurred in March 2020. Water quality was representative of typical Pilbara streams with near-neutral pH (7.69), low-moderate turbidity (2.54 NTU) and moderate oxygenation (92% saturation). Alkalinity was moderate-high at 406 mg/L (as CaCO3) with major ions dominated by sodium chloride (Figure 3-48). Note that Figure 3-48 also shows the MAR Cockatoo Creek results for the Late Dry 2020 as these were opportunistically obtained following the large (200 mm) rainfall event on the 10th December 2020 (see Figure 3-47). The MAR Cockatoo Creek site is 550 m downstream of Central Creek Pool on the same reach.

Dissolved arsenic levels were potentially at, or exceeding, the ANZG (2018) 99 or 95% Ecosystem Protection Levels (EPLs) at 13 µg/ however, the results represent non-speciated arsenic while the guidelines are for individual inorganic species of arsenic (III and V). No other metals or metalloids were above guideline levels.

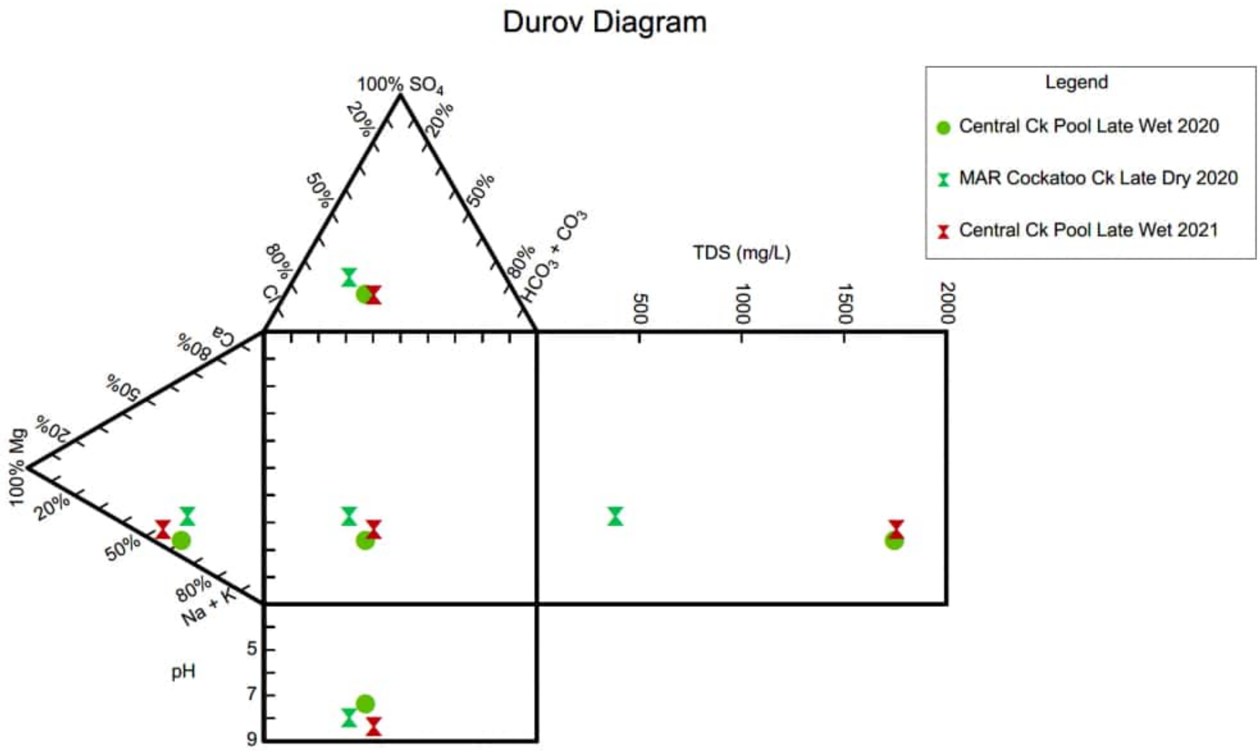


Figure 3-48 Durov diagram showing the Central Creek Pool major ion distribution.

3.4.2 SEDIMENT QUALITY

Table 3-13 provides the surface sediment quality at Central Creek Pool during the Late Wet 2020 and Late Wet 2021. Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (219-247 mg/kg) exceeded the DGV but not the GV-high. Nickel concentration (112-113 mg/kg) exceed both the DGV and GV-high. However, both chromium and nickel naturally occur in high concentrations across the Project area.

Table 3-13. Summary of sediment quality analyses for Central Creek for the late wet seasons (2020 and 2021), no analysis recorded for late dry season (2020) due to the site being dry. Bolded values denote results above the limit of reporting.

Analyte grouping/Analyte	Unit	Late Wet (2020)	Late Wet (2021)
Total Soluble Salts	mg/kg	**1,180**	**559**
Moisture Content (Dried @ 105-110°C)	%	**29.8**	**19.1**
Total Alkalinity as CaCO3	mg/kg	**120**	<5
Bicarbonate Alkalinity as CaCO3	mg/kg	**120**	**198**
Carbonate Alkalinity as CaCO3	mg/kg	<1	**198**
Acidity	mg/kg	**4**	<5
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**200**	**40**
Chloride (by Discrete Analyser)	mg/kg	**170**	**90**
Calcium	mg/kg	**40**	<10
Magnesium	mg/kg	**70**	**40**
Sodium	mg/kg	**220**	**10**
Potassium	mg/kg	**20**	<10
Mercury (FIMS)	mg/kg	<0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	**1,090**	**80**
Total Nitrogen as N	mg/kg	**1,090**	**80**
Total Phosphorus as P	mg/kg	**100**	**43**
Reactive Phosphorus as P	mg/kg	<0.1	<0.1
Total Organic Carbon	%	**1.80**	**0.18**
Total Metals by ICP-AES			
Arsenic	mg/kg	**9**	**10**
Barium	mg/kg	**40**	**30**
Beryllium	mg/kg	<1	<1
Boron	mg/kg	<50	<50
Cadmium	mg/kg	<1	<1
Chromium	mg/kg	**219**	**247**
Cobalt	mg/kg	**16**	**18**
Copper	mg/kg	**22**	**17**
Iron	mg/kg	**26,600**	**30,600**
Lead	mg/kg	<5	<5
Manganese	mg/kg	**476**	**492**

Analyte grouping/Analyte	Unit	Late Wet (2020)	Late Wet (2021)
Nickel	mg/kg	**112**	**113**
Selenium	mg/kg	<5	<5
Vanadium	mg/kg	**39**	**36**
Zinc	mg/kg	**35**	**20**

3.4.3 FISH

Fish were present at Central Creek Pool during both wet season surveys and were not present in the dry season due to the pool being dry. Two fish species were present during both wet season surveys: *M. australis* and *L. unicolor*. Both species were observed roughly equal abundance in 2020 and considerably higher numbers of *M. australis* (n = 266) were observed in 2021.

Table 3-14 presents the fish species, catch and size distribution. The two fish species present, *M. australis* and *L. unicolor,* occurred at similarly high abundances for the size of the pool. The high abundance is likely a function of the high catchability due to evaporation reducing the pool habitat and thereby increasing fish density, rather than the pool providing a preferred habitat. The high interest in bait during the BRUVs survey may indicate low food resources in the pool.

For both seasons, the size distribution of *M. australis* was similar, with the SL size ranging from Figure 3-49 displays the size-frequency for *M. australis,* notably most fish were recorded in the 30 – 60 mm size class. Only one *M. australis* individual in the <30 mm size category was observed for both seasons, indicating minimal juvenile abundance in this site. However, due to Central Creek being dry over the late dry season and similar abundances of fish in both wet seasons, breeding and recruitment likely occur in nearby water bodies that seasonally open to Central Creek.

The size range for *L. unicolor* was generally larger in the Late Wet 2020 (subsampled range SL: 32 - 174 mm) than in the Late Wet 2021 (subsampled range SL: 39 - 110 mm), with a higher frequency of juveniles present in the Late Wet 2021 (Figure 3-50). The large proportion of *L. unicolor* individuals observed in the 30 – 60 mm size class indicates a notable juvenile presence in Central Creek in both years (Figure 3-50). *Leiopotherapon unicolor* displays rapid growth in the juvenile stage, attaining a length of ~25 mm TL in under 60 days (Llewellyn, 1973). Although very young juveniles (<30 mm) were not observed during each survey, most *L. unicolor* caught were between 30 – 60 mm, indicating spawning around 2 to 3 months before the survey. Most *L. unicolor* present at Central Creek are not sexually mature, as length at maturity is typically above 60 mm TL (Llewellyn, 1973).

Table 3-14. Fish species, size class (SL, mm), total catch number and CPUE for Central Creek surveyed in late wet seasons in 2020 and 2021.

Species	Size class (mm)	Late Wet 2020 Fish Count	Late Wet 2020 CPUE[1]	Late Wet 2021 Fish Count	Late Wet 2021 CPUE[1]
Melanotaenia australis		**188**	**9.8**	**266**	**14**
	0 – 30	1		1	
	30 – 60	128		237	
	60 – 90	590		28	
	> 90	0		0	
Leiopotherapon unicolor		**214**	**11.2**	**111**	**5.8**
	30 - 60	110		79	
	60 - 90	55		19	
	> 90	49		13	
Total		**402**	**21.1**	**377**	**19.8**

1 CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 19 hours.

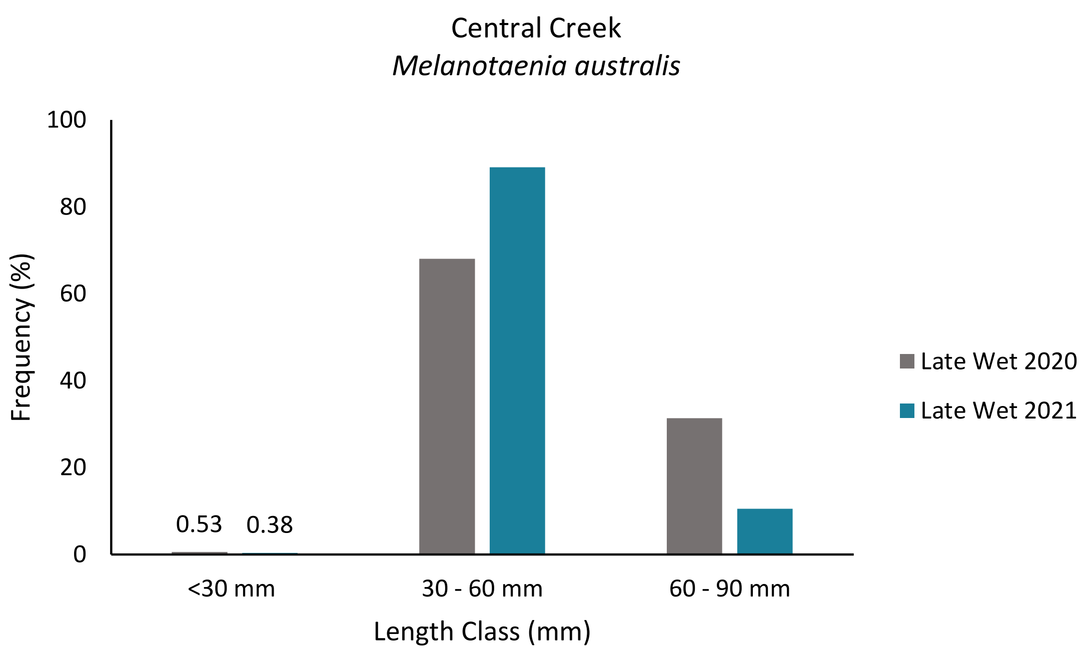


Figure 3-49. Frequency (%) of occurrence of each length class (SL, mm) *M. australis* sampled from Central Creek in the Late Wet 2020 and Late Wet 2021.

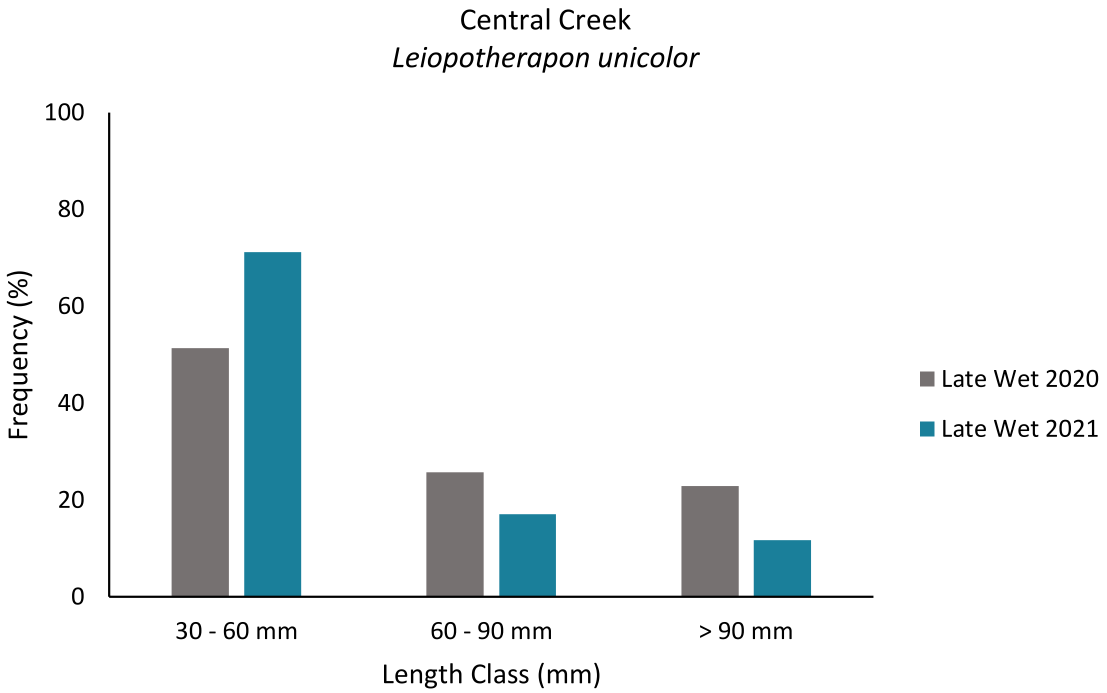


Figure 3-50 Frequency (%) of occurrence of each length class (SL, mm) for *L. unicolor* sampled from Central Creek in the Late Wet 2020 and Late Wet 2021

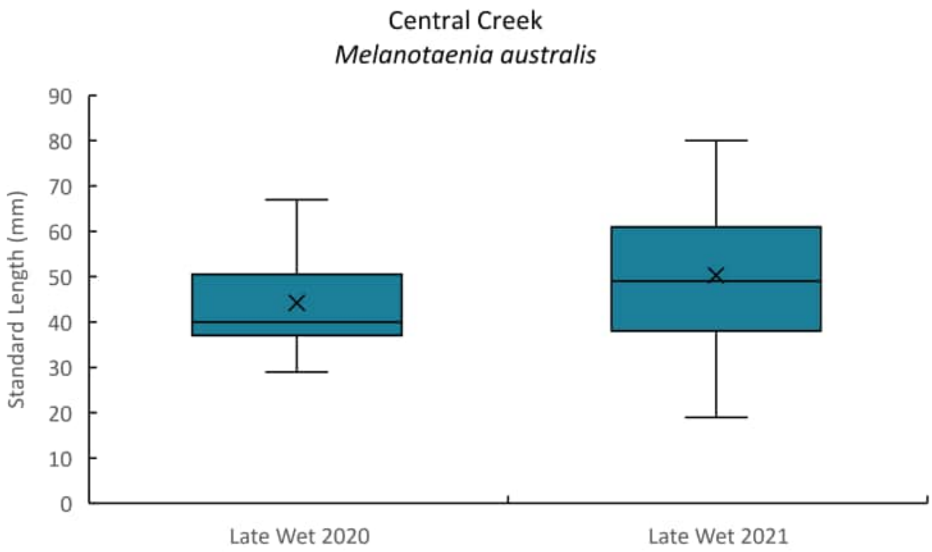


Figure 3-51 Distribution of standard length (SL, mm) of *Melanotaenia australis* sampled from Central Creek in the late wet season in 2020 (June) and 2021 (May)

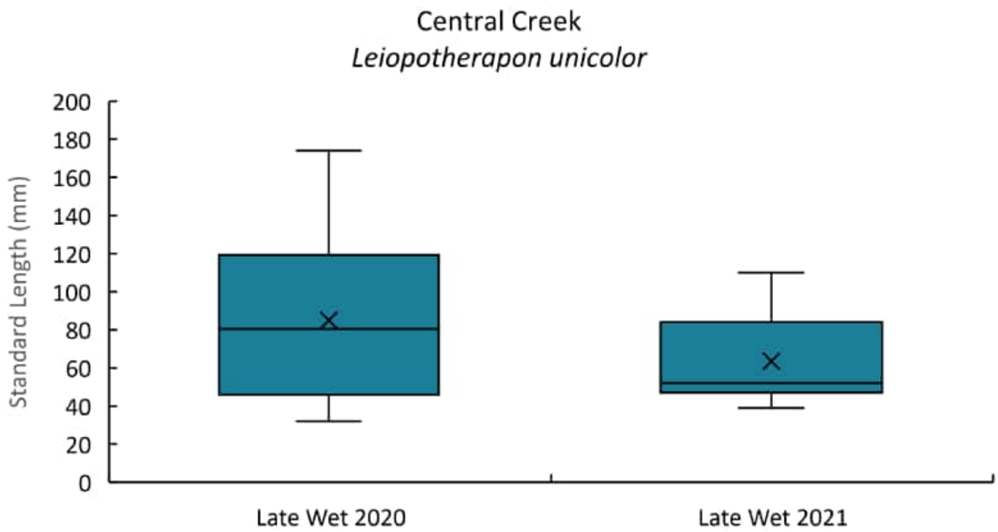


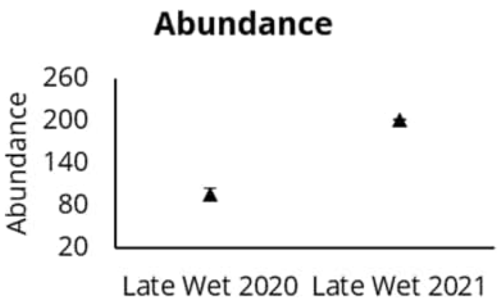
Figure 3-52 Distribution of standard length (SL, mm) of *Leiopotherapon unicolor* sampled from Central Creek in the late wet season in 2020 (June) and 2021 (May)

3.4.4 AQUATIC MACROINVERTEBRATES

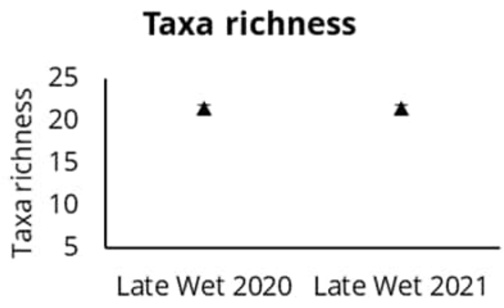
Figure 3-53 presents the total abundance, taxa richness, EPT richness and SIGNAL2 scores for the Late Wet seasons of 2020 and 2021. No data is available for the Late Dry 2020 season due to the pool being dry. The key findings from both wet seasons were as follows:

- Average abundance of macroinvertebrates doubled from 96 in the Late Wet season of 2020 to 202 in the corresponding season in 2021 (Figure 3-53a).
- Similarly, PET richness also increased from 3 to 4.5 between seasons of 2020 and 2021 (Figure 3-53c), with a total of five families recorded from the Plecoptera and Trichoptera orders.
- In contrast, taxa richness (21.5) and SIGNAL2 (3.08-3.38) scores were consistent between the Late Wet seasons (Figure 3-53b, d), indicating that Central Creek Pool can maintain a relatively stable macroinvertebrate community in the wet seasons despite its ephemeral presence.
- A low SIGNAL2 score (SIGNAL2 grade = 3) indicates predominantly tolerant taxa were collected and the system experiences associated environmental stress (Chessman, 2003).

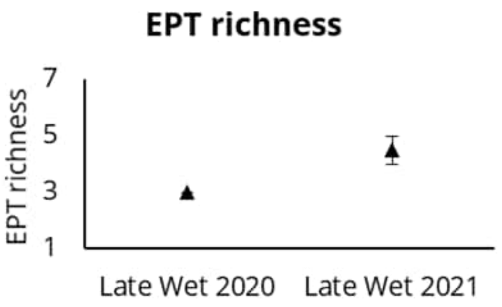
Many macroinvertebrate taxa were much more abundant in the Late Dry 2021 season than the previous Late Dry season, such as mayflies of the Baetidae and Caenidae, waterboatman of the Micronectidae, and the non-biting midge belonging to s-f Tanypodinae. In comparison, the backswimmer Pleidae, the diving beetle Dytiscidae and damselflies of the Coenagrionidae were more abundant in the Late Wet season of 2020. The increased abundances of macroinvertebrates in Late Wet 2021after a period of desiccation suggest that the community is well adapted to this drying pattern. For example, chironomids are recognised to burrow deeper into the sediments when pools dry out and can also enter a period of aestivation (i.e. dormancy during dry periods; Jones 1997, Frouz et al. 2003). The relative abundance of taxa is also a function of pond permanence, with chironomids seen in high abundances when ponds have been recently established (Brooks 2000). As the mayflies Baetidae and Caenidae belong to the sensitive order Ephemeroptera, their presence in the Late Wet season of 2021 may suggest that the environmental quality of Central Creek Pool was apparently better during this period (Menetrey et al. 2007).



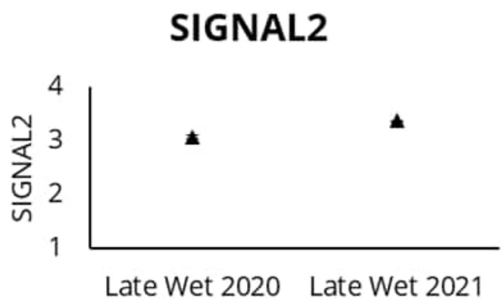
a) Total abundance at Central Creek Pool



b) Taxonomic richness at Central Creek Pool



c) EPT richness at Central Creek Pool



d) SIGNAL2 scores at Central Creek Pool

Figure 3-53 Macroinvertebrate indices for Central Creek Pool – Late Wet 2020 and Late Wet 2021.

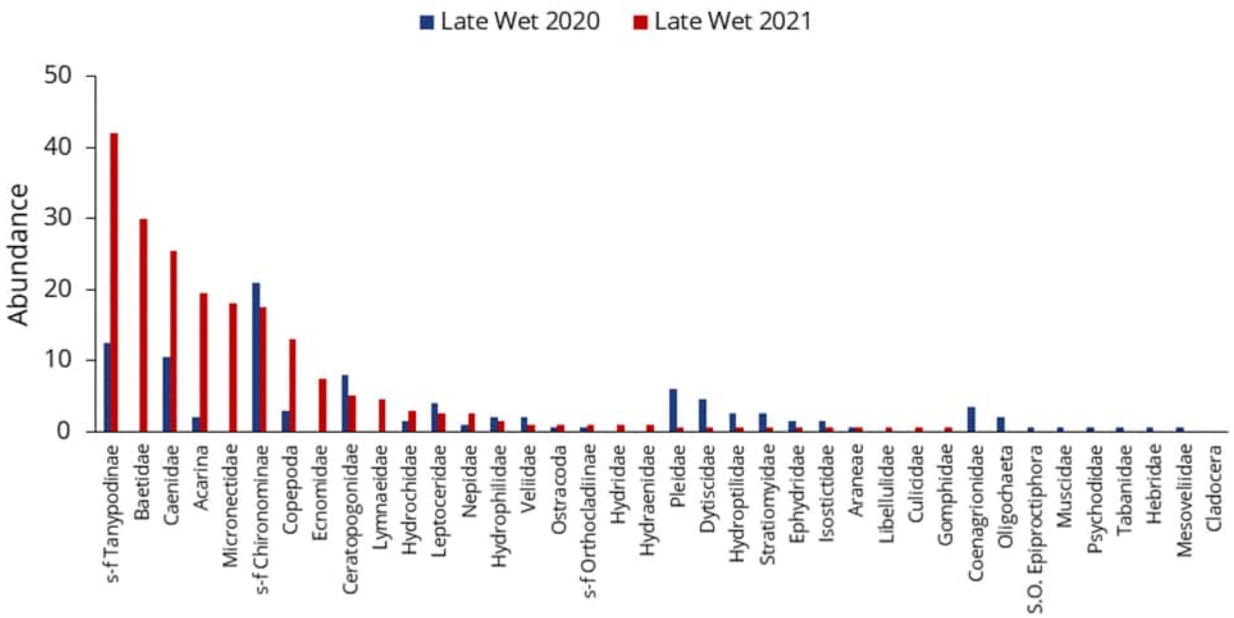


Figure 3-54 Average abundances of all macroinvertebrate taxa at Central Creek Pool in the Late Wet season of 2021 and the Late Wet and Late Dry season of 2020, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.4.5 PHYTOPLANKTON & DIATOMS

3.4.5.1 DIATOMS

Table 3-15 presents the Late Wet 2020 and Late Wet 2021 diatom species present, abundance, and biotic indices at Central Creek Pool. Figure 3-55 shows the average count by diatom species present. No diatom data was collected in the Late Dry 2020 due to the pool being dry.

High taxonomic diversity of diatoms was observed for both seasons at Central Creek. A total of 41 species were observed at Central Creek ranging across a large number of families, with the Late Wet 2021 season recording slightly higher taxonomic diversity with 33 species compared with Late Wet 2020 which recorded 27 diatom species. The majority of diatoms species observed in Central Creek were recorded in both seasons with only 14 species (~34% of total species) only observed in one season.

High average abundance was observed both seasons, with Late Wet 2021 recording a higher average abundance of 433. *Achnanthidium exiguum* (average count = 258) was the most abundant species in Late Wet 2020. The second most abundant diatom species in 2020, *Nitzschia palea*, occurred at a substantially lower abundance (average count = 28). The Late Wet 2021 season was dominated by *Pleurosigma elongatum* (average count = 116), followed by *Navicula menisculus* (average count = 85).

The tolerance to environmental stress is reflected in the low DSIAR scores for both 2020 and 2021 (42.0 and 36.5, respectively), which indicates the pool is dominated by species tolerant to degraded water quality. While the DSIAR score is low, no teratological forms were detected and the diversity of species is relatively high for North Star pools. The low presence or abundance of species associated with higher water quality likely reflects the environmental stress resulting from nutrient pollution from cattle visitation and declining water quality due to high evapo-concentration.

Table 3-15 Summary of Diatom species abundance (total count per species), average abundance and DSIAR score for Central Creek in the Late Wet 2020 and 2021.

Taxon name	Late Wet 2020			Late Wet 2021		
	Replicate 1	Replicate 2	Average	Replicate 1	Replicate 2	Average
Achnanthidium exiguum	246	270	258	88	0	44
Pleurosigma elongatum	28	0	14	118	114	116
Navicula menisculus	0	4	2	74	96	85
Nitzschia palea	40	16	28	44	38	41
Diploneis parma	6	2	4	46	16	31
Achnanthidium minutissimum	22	12	17	0	46	23
Nitzschia frustulum	10	8	9	14	12	13
Achnanthes subexigua	0	0	0	6	14	10
Epithemia gibba	0	0	0	0	18	9
Navicula veneta	12	6	9	0	0	0
Nitzschia paleaceae	0	0	0	10	8	9

Taxon name	Late Wet 2020			Late Wet 2021		
Nitzschia lacuum	8	4	6	8	4	6
Nitzschia linearis	0	0	0	4	4	4
Nitzschia inconspicua	0	6	3	0	0	0
Brachysira vitrea	0	0	0	0	4	2
Eunotia bilunaris	4	0	2	0	0	0
Eunotia minor	0	0	0	0	4	2
Gomphonema minutum	0	0	0	0	4	2
Hantzschia amphioxys	0	4	2	2	0	1
Nitzschia filiformis	0	0	0	4	0	2
Nitzschia fonticola	0	0	0	0	4	2
Nitzschia graciliformis	4	0	2	2	0	1
Nitzschia microcephala	0	4	2	0	0	0
Pinnularia spp.	0	4	2	0	0	0
Ulnaria ulna	4	0	2	0	0	0
Amphora libyca	0	0	0	0	2	1
Brachysira brebissonii	0	2	1	0	0	0
Cymbella affinis	0	0	0	0	2	1
Cymbella spp	0	2	1	0	0	0
Diploneis smithii	0	0	0	0	2	1
Eolimna minima	2	0	1	0	0	0
Eunotia exigua	0	0	0	0	2	1
Fragilaria spp.	2	0	1	0	0	0
Haslea duerrenbergiana	0	0	0	2	0	1
Mastogloia smithii	0	2	1	2	0	1
Navicula lanceolata	2	0	1	0	0	0
Navicula phyllepta	0	2	1	0	0	0

Taxon name	**Late Wet 2020**			**Late Wet 2021**		
Navicula radiosa	2	0	1	0	0	0
Nitzschia gracilis	2	0	1	0	0	0
Nitzschia suchlandii	0	2	1	0	0	0
Pinnularia legumen	0	2	1	0	0	0
Total Abundance	394	352	373	424	442	433
DSIAR Score	41.3	42.6	42	34	39	36.5

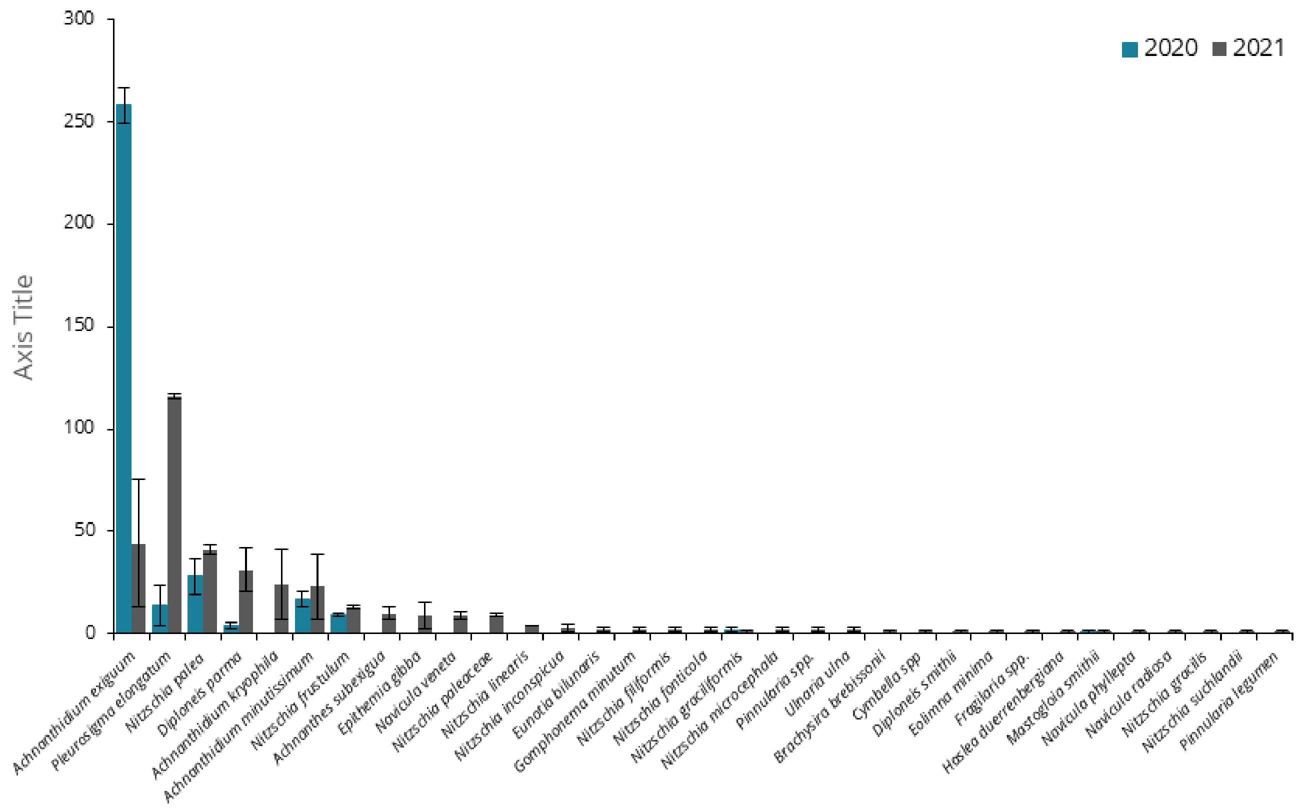


Figure 3-55 Average species abundance (diatom count per replicate) for diatoms sampled at Cental Creek in the Late Wet 2020 and 2021, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis. Standard error (SE±0.5) denoted by error bars.

3.4.5.2 PHYTOPLANKTON

In the Late Wet 2021, a full phytoplankton profile for Central Creek was analysed. Overall, there were relatively low numbers of phytoplankton recorded for Central Creek, indicating relatively low phytoplankton diversity. Two phytoplankton classes were identified; Diatoms (Bacillariophyceae) and Cryptophyceae. Diatoms were observed in considerably higher abundance than Cryptophyceae, and the recorded species in Late Wet 2021 are similar to those observed in Late Wet 2020. Therefore, while the relative phytoplankton biodiversity is low, the diversity within the Diatoms remains high across both wet seasons (Table 3-16).

Table 3-16 Summary of phytoplankton analytical results for Central Creek Pool sampled in late wet season (2021), abundance (cells L^{-1}) and percentage contribution (%), limit of reporting 10 cell L^{-1}. Central Creek Pool did not have phytoplankton samples taken in the late dry season (2020).

Taxon	Late Wet (2021)	
	Abundance	**%**
Bacillariophyceae	**460**	**93.88**
Entomoneis sp.	10	2.04
Fragilaria sp. (O)	10	2.04
Microtabella spp.	10	2.04
Navicula spp.	10	2.04
Navicula spp.	50	10.2
Nitzschia spp.	130	26.53
Pleurosignma sp. (O)	220	44.9
Synedra spp. (O)	10	2.04
Cryptophyceae	**30**	**6.12**
Cryptomonas spp. (O)	30	6.12

3.4.6 MACROPHYTES

There were very few and sparse macrophytes present at Central Creek Pool. These were represented by a small clump of emergent Clubrush reeds (*Schoenoplectus sp*) and a few individual sedge (Cyperacea) plants on the southern side of the pool behind a protective in-stream boulder. Less than 1% of the pool area represented macrophyte habitat.


a)
b)
c)
d)
SWEEP CENTRAL
Date: 25-6-20
Site:
Collector:
Picker:
Replicate: 1
e)
f)

Figure 3-56 Central Creek Pool ecology. a) and b) the shallow pool over alluvial deposits lies on a wide creek bed; c) adult *L. unicolor* as well as juveniles were abundant; d) macroinvertebrates collected that utilise the sediment habitat; e) sparse macrophytes remain and will likely be absent by the late dry season; f) turbid waters may reduce visibility and provide a refuge from large fish predation and terrestrial predation.

3.5 COW SPRING POOL (IB_SW_POOL_Cow Spring)

Cow Spring Pool is a small pool (~8 m by 4 m, average of 1 m depth) confined by bedrock habitat dominated by macrophytes and benthic algal cover. The pool is likely to be sustained by groundwater and has established macrophyte habitat and an abundance of *M. australis,* despite relatively acidic water quality.

Figure 3-57 Cow Spring Pool

3.5.1 WATER QUALITY AND HYDROLOGY

Cow Spring has a small surface water catchment area of 0.15 km^2 (Figure 3-58), draining a single ridgeline to the west. The pool is shaded by the adjacent rockface and forms a micro-climate area with dense melaleuca woodland covering the pool and the downstream drainage line for approximately 50m. Figure 3-59 displays a high-resolution water level, salinity (conductivity) and temperature logger record from Mundagoora Pool for the late dry season 2020 to late wet season 2021.

Cow Spring Pool is very clear (<1 NTU turbidity), low pH (5.72), fresh (456 µS/cm conductivity) and slightly acidic (10 mg/L as $CaCO_3$). It has a mixed balance major ion distribution that is not dominated by any particular ions (Figure 3-60). No metals or metalloids exceeded the ANZG (2018) default water quality guidelines.

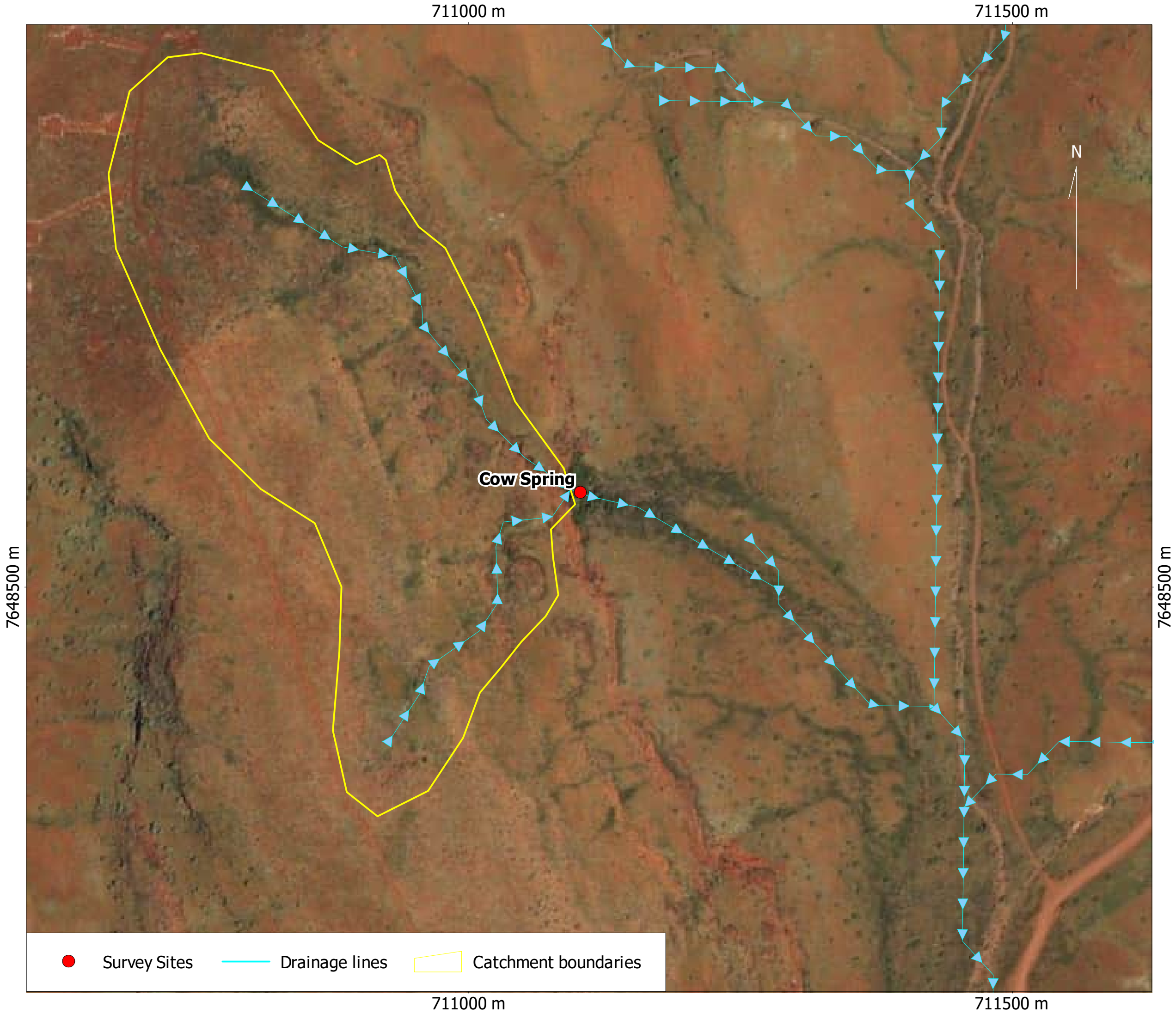


Figure 3-58 Cow Spring catchment area (0.15 km^2)

The water level of Cow Spring Pool is relatively constant over the wet-dry season, with very short peaks of 10 to 20 cm above the mean level during high rainfall events (Figure 3-59). Due to the shaded positioning of the pool, the water temperature tends to be more stable than other pools in the region, ranging between 20-30°C over the annual cycle. Similarly, the water quality in the pool is relatively constant over the seasonal cycles with a mixed cation and SO4- anion dominance (Figure 3-48). The pool is typically slightly acidic though it approached neutral pH in the Late Wet 2021 sampling.

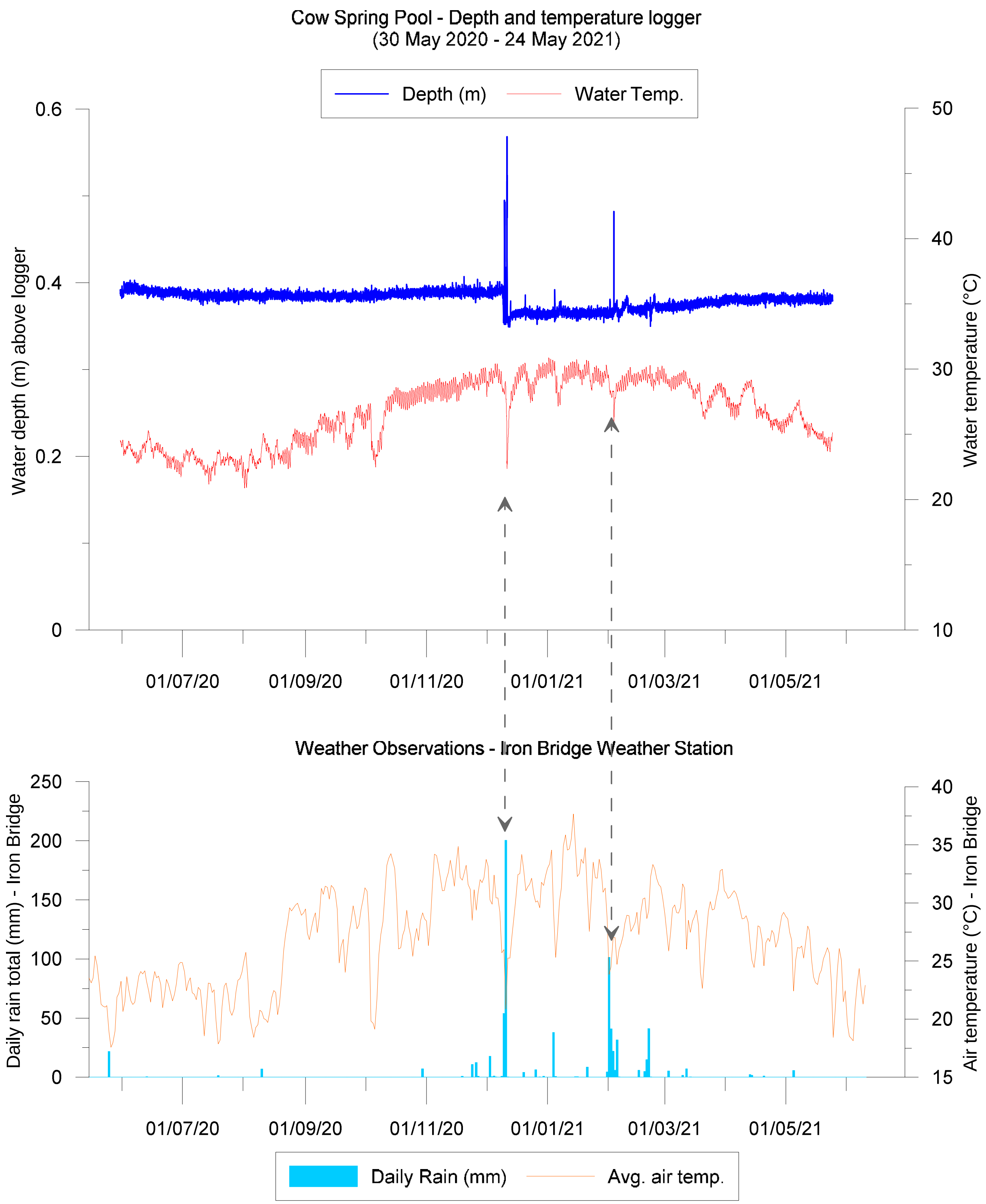


Figure 3-59 Cow Spring Pool depth and temperature logger data (above) relationship to daily rainfall (below) – Wet-Dry season 2021.

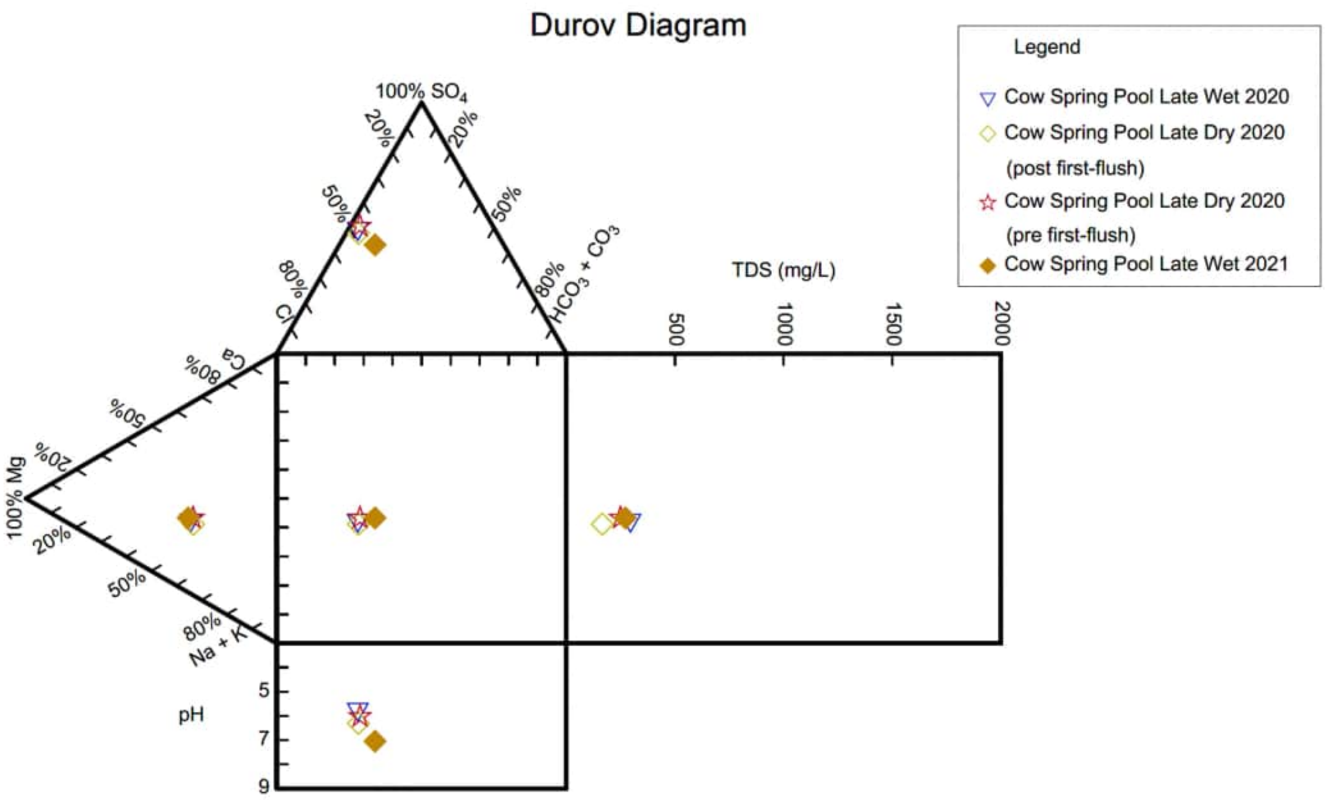


Figure 3-60 Durov diagram showing the Cow Spring Pool major ion distribution.

3.5.2 SEDIMENT QUALITY

Table 3-17 provides the surface sediment quality at Cow Spring Pool during the late wet season (sample collection 30th May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (165 mg/kg) exceeded the DGV but not the GV-high. Chromium naturally occurs in high concentrations across the Project area.

Table 3-17. Summary of the sediment analysis for Cow Spring Pool in late wet season 2020. Bold values denote results recorded above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	Concentration
Total Soluble Salts	mg/kg	**114**
Moisture Content (Dried @ 105-110°C)	%	**23.9**
Total Alkalinity as CaCO3	mg/kg	**4**
Bicarbonate Alkalinity as CaCO3	mg/kg	**4**
Carbonate Alkalinity as CaCO3	mg/kg	<1
Acidity	mg/kg	<1
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**40**
Chloride (by Discrete Analyser)	mg/kg	**20**
Calcium	mg/kg	<10

Analyte grouping/Analyte	Unit	Concentration
Magnesium	mg/kg	<10
Sodium	mg/kg	**20**
Potassium	mg/kg	<10
Mercury (FIMS)	mg/kg	**4.4**
Nitrite + Nitrate as N (Sol.)	mg/kg	**0.1**
Total Kjeldahl Nitrogen as N	mg/kg	**750**
Total Nitrogen as N	mg/kg	**750**
Total Phosphorus as P	mg/kg	**320**
Reactive Phosphorus as P	mg/kg	<0.1
Total Organic Carbon	%	**0.22**
Total Metals by ICP-AES		
Arsenic	mg/kg	**9**
Barium	mg/kg	<10
Beryllium	mg/kg	<1
Boron	mg/kg	<50
Cadmium	mg/kg	<1
Chromium	mg/kg	**165**
Cobalt	mg/kg	**4**
Copper	mg/kg	**7**
Iron	mg/kg	**124,000**
Lead	mg/kg	**9**
Manganese	mg/kg	**151**
Nickel	mg/kg	**18**
Selenium	mg/kg	**6**
Vanadium	mg/kg	**62**
Zinc	mg/kg	**16**

3.5.3 FISH

Only one species of fish, *M. australis* was observed at Cow Spring Pool throughout the three seasons. Table 3-18 presents the abundance, size distribution and CPUE for *M. australis* for all seasons surveyed. *Leiopotherapon unicolor* was not detected at the pool through any methods, which may be due to various factors such as survival, aestivation, or reproduction may be limited by the naturally high acidity. Similarly, no decapod crustaceans were collected or observed.

Most *M. australis* sampled from Cow Spring Pool in the Late Wet 2020 were in the size class 30 – 60 mm, followed by the length classes <30 mm and 60 – 90mm at similar frequencies. Two individuals were recorded with a SL in >90 mm length class. The Late Dry 2020 was dominated by fish in the 60 – 90 mm length class, with notably less in the smaller length classes (Figure 3-62). The Late Dry 2020 also had low frequency of larger fish (<90 mm). *M. australis* sampled in the Late Wet 2021 were dominated by fish in the 30 – 60 mm length class (74.1%). A similar frequency of very small fish (<30 mm) were present between seasons, indicating there is consistent juvenile recruitment occurring (Figure 3-61). As *M. australis* is considered to reach sexual maturity at 50 mm SL (Evans et al. 2010), Cow Spring Pool appears to be dominated with juvenile *M. australis;* only 6 individuals were larger than 50 mm. Individuals in the 30 – 60 mm length class likely hatched at the start of the wet season 2020/2021, with the <30 mm juveniles likely to have hatched post large wet season rains and indicate reproduction occurring within the pool, rather than migrating during periods of connecting flow (Pusey, B., Kennard, M., & Arthington, 2004).

Uperoleia sp. tadpoles were also observed at Cow Spring Pool. Their presence or catchability in Cow Spring Pool may be in part due to the absence of the predators *L. unicolor.*

Table 3-18. Summary of fish count for the standard length class (mm) and the CPUE for *M. australis* in the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys.

Season	Size class (mm)	Catch	CPUE[1]
Late Wet (2020)		**67**	**3.8**
	0 – 30	13	
	30 – 60	37	
	60 – 90	15	
	> 90	2	
Late Dry (2020)		**102**	**5.8**
	0 – 30	12	
	30 – 60	20	
	60 – 90	67	
	> 90	3	
Late Wet (2021)		**31**	**1.77**
	0 – 30	5	
	30 – 60	23	
	60 – 90	3	
	>90	-	

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 17.75 hours.

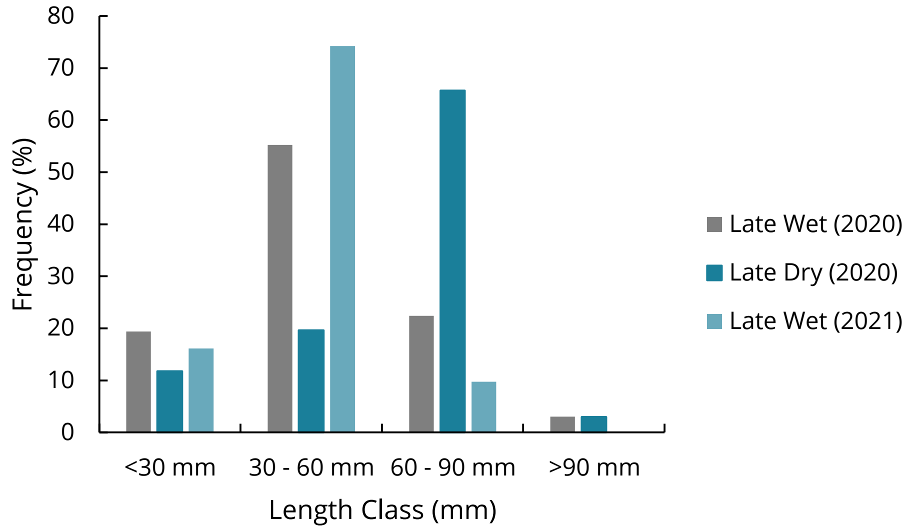


Figure 3-61. Frequency (%) of occurrence for each length class (SL, mm) for *Melanotaenia australis* sampled from Cow Spring Pool in late wet (June) and late dry (December) 2020.

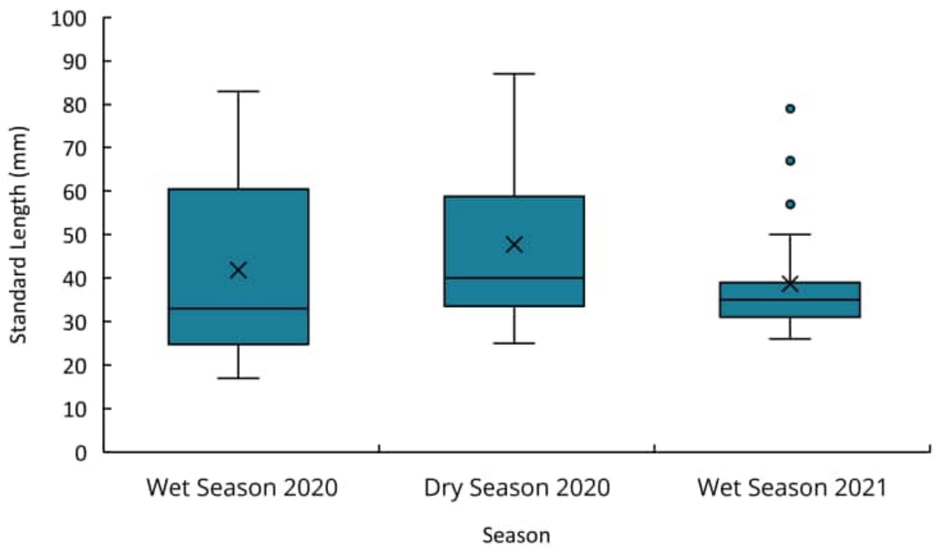
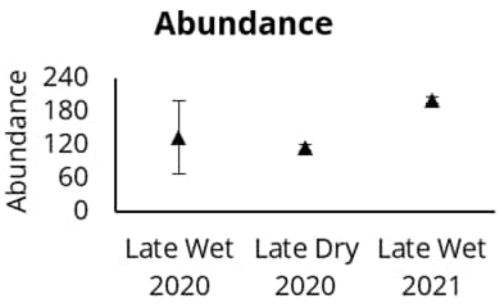


Figure 3-62. Size distribution of the standard length (SL, mm) for *Melanotaemia australis* sampled from Cow Spring Pool.

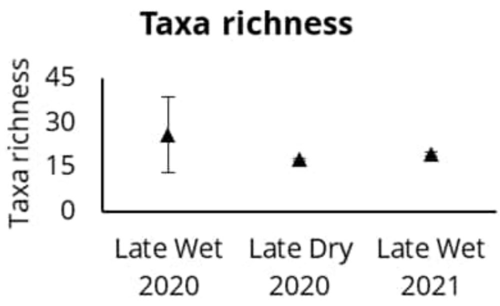
3.5.4 AQUATIC MACROINVERTEBRATES

Figure 3-63 presents the summary of the four macroinvertebrate indices for Cow Spring Pool in the late wet season of 2020 and 2021, and the late dry season of 2021. The key findings were as follows:

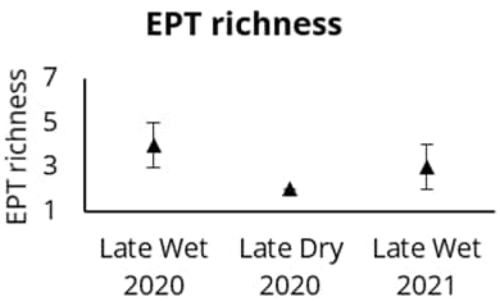
- Abundances of macroinvertebrates varied widely from 67 to 200 in Late Wet 2020, with consistent average abundances of 116 and 202 in the Late Dry 2020 and Late Wet 2021 seasons, respectively (Figure 3-63 a).
- Similarly, taxa richness ranged from 13 to 39 in Late Wet 2020 and from 17 to 20 in both other seasons, indicating more stable communities in Late Dry 2020 and the Late Dry 2021 seasons (Figure 3-63 b).
- EPT richness declined from the Late Wet to Dry season in 2020, before inclining slightly in the Late Wet season of 2021 (Figure 3-63 c). Five families belonging to the Ephemptera and Trichoptera orders have been recorded. Seasonal declines in EPT richness are likely due to the less favourable natural conditions experienced in the dry season.
- SIGNAL2 scores are relatively stable between seasons (Figure 3-63 d), with the range of scores (3.1-3.6) indicating the macroinvertebrate community is moderately tolerant.



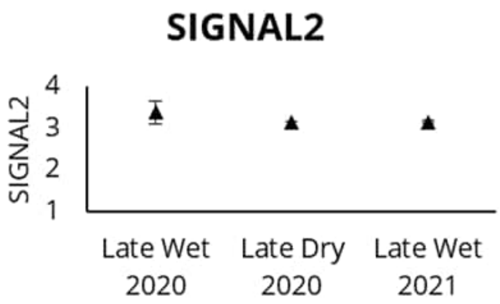
a) Total abundance at Cow Spring Pool



b) Taxonomic richness at Cow Spring Pool



c) EPT richness at Cow Spring Pool



d) SIGNAL2 scores at Cow Spring Pool

Figure 3-63 Macroinvertebrate indices for Cow Spring Pool – Late Wet 2020, Late Dry 2020 and Late Wet 2021.

The abundance of taxa for the three seasonal surveys is provided in Figure 3-64 and shows taxa ranging from the the most abundant (left) to the least abundant (right) along the x-axis. The non-biting midge of the Tanypodinae and Chironominae were more abundant in the most recent Late Wet survery of 2021, with their increase potentially due to the greater rainfall levels in Late Wet 2021as freshwater flow events such as flooding in wetlands can increase their abundances (McInerney et al. 2017). Similar abundances of the Acarina mites and ticks, Libellulidae dragonfly and biting midge of the Ceratopognonidae were found throughout all seasons. For damselflies of the Coenagrionidae, abundances increased during 2020 and then reduced substantially in the latest season of Late Wet 2021.

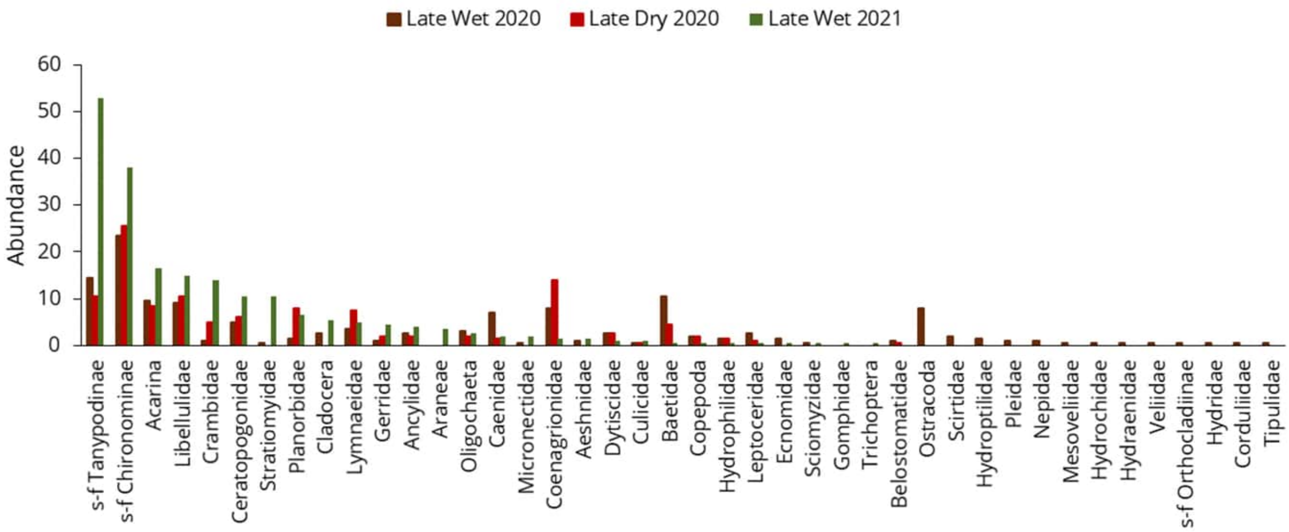


Figure 3-64 Average abundances of all macroinvertebrate taxa at Cow Spring Pool in the Late Wet season of 2021 and the Late Wet and Late Dry season of 2020, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.5.5 DIATOMS AND PHYTOPLANKTON

3.5.5.1 DIATOMS

Error! Reference source not found. summarises the species present, the overall abundance, and biotic indices of diatoms surveyed in the Late Wet 2020. Only one replicate of diatoms collected in Late Wet 2021 was analysed, therefore only total count has been recorded for this season. No diatom data was available for the Late Dry 2020 due to flood flows during the deployment period. **Error! Reference source not found.** presents the average abundance of diatom species recorded at Cow Spring Pool for Late Wet 2020. The key findings are as follows:

Overall, 21 species were recorded at Cow Spring Pool across both seasons, with Late Wet 2021 recording a higher number of species (19) than 2020 (7). Of the 21 species only 5 were present in both seasons. Total abundance of diatoms was higher in Late Wet 2021 but the notable difference in diatom count can be attributed to one species *Brachysira styriaca* with a total abundance of 218 recorded in 2021. The most abundant species for Cow Spring Pool recorded in Late Wet 2020 was *Achnanthidium minutissimum* and *Eunotia bilunaris*, species were also present at all other pools except Fig Pool (Figure 3-65).

Late Wet 2020 showed low diatom diversity for this site. The first replicate for this site detected no diatoms and the other samples noted very sparse abundance. The high acidity and low light conditions at Cow Spring Pool may have contributed to the relatively low diatom growth compared to other North Star pools. The low abundance of diatoms indicates they are able to survive, though the capacity for growth is limited under the conditions that were present during the sampling period. The DSIAR score (64.2) reflects the species sensitivity to environmental stress, where a higher score indicates 'better' water quality as species sensitive to environmental stress are present. This indicates the species richness is more likely limited by factors needed to grow (i.e. sunlight) rather than stressors known to cause mortality of sensitive species (e.g. high salinity). While samples collected in 2021 recorded a higher number of species than 2020, Cow Spring Pool still shows lower taxonomix diversity than other North Star Pools. A higher taxonomic diversity in 2021 of diatoms has been observed for all North Star Pools, with exception of Fig Pool which recorded no diatoms either season.

Table 3-19. Diatom abundance (total count per species), average abundance and DSIAR score Cow Spring Pool surveyed in Late Wet 2020, only total abundance was recorded for Late Wet 2021

Taxon	Late Wet 2020			Late Wet 2021
	Replicate 1	Replicate 2	Average	Total Count
Achnanthidium minutissimum	0	8	4	14
Brachysira styriaca	0	0	0	12
Brachysira vitrea	0	0	0	218
Cymbella affinis	0	2	1	8
Cymbella spp	0	4	2	4
Eunotia bilunaris	0	8	4	62
Eunotia exigua	0	0	0	4
Eunotia faba	0	2	1	0
Eunotia incisa	0	0	0	6
Eunotia paludosa	0	0	0	4
Eunotia spp.	0	0	0	6
Fragilaria acus	0	0	0	16
Fragilariforma virescens	0	0	0	2
Frustulia rhomboides	0	0	0	2
Gomphonema affine	0	0	0	6
Gomphonema minutum	0	0	0	4
Hantzschia amphioxys	0	2	1	0
Luticola mutica	0	2	1	4
Mastogloia smithii	0	0	0	2
Pinnularia spp.	0	0	0	4
Ulnaria ulna	0	0	0	22
Total Abundance	0	28	14	400
DSIAR Score		64.2	64.2	68

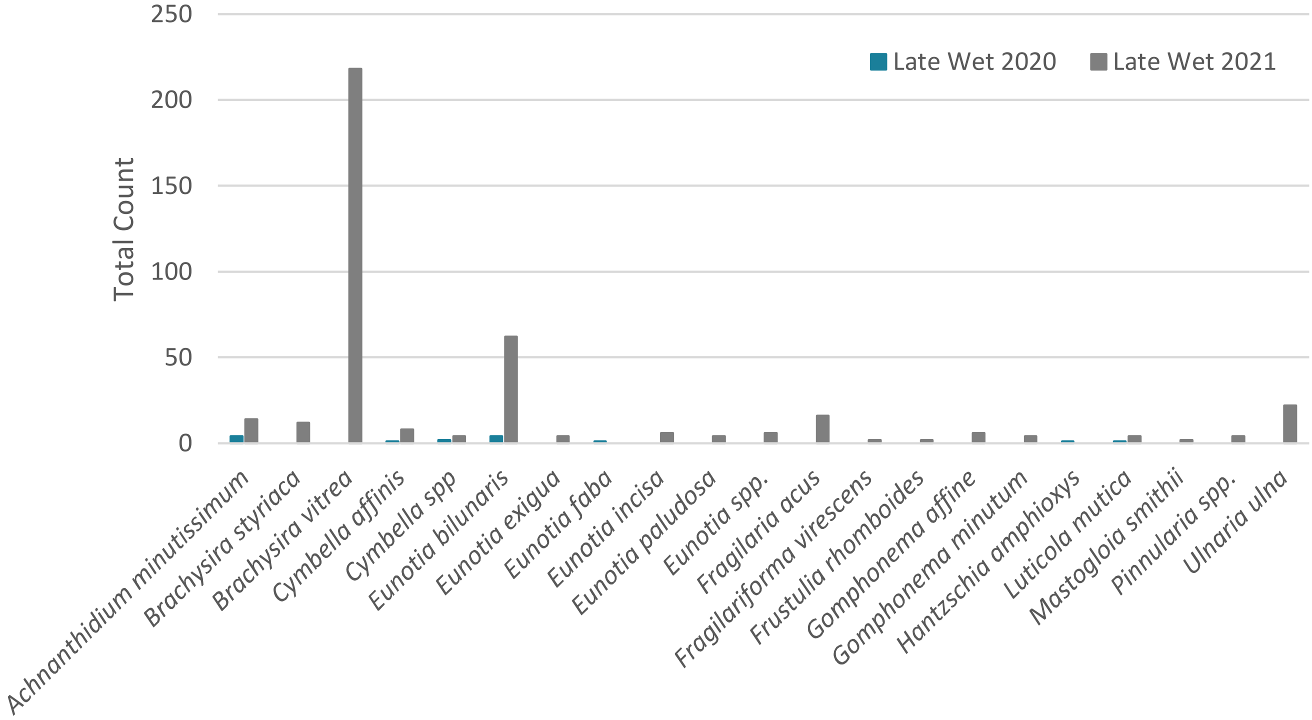


Figure 3-65. Mean abundance for diatom species recorded in late wet season 2020, with error bars denoting ±0.5σ.

3.5.5.2 PHYTOPLANKTON

In the Late Dry 2020 and Late Wet 2021, water samples were taken from Cow Spring Pool to analyse a complete planktonic phytoplankton profile for the site. In the Late Dry 2020, five phytoplankton classes with 15 species were identified, indicating Cow Spring Pool has a relative moderate phytoplankton diversity. Cryptophyceae occurred at the highest abundance, followed by Dinophyceae (Dinoflagellates). Diatoms (Bacillariophyceae) were the third most abundant, and samples collected in the late dry season identified similar diatom species as the previous season.

In the late wet season 2021, there were considerably fewer phytoplankton cells recorded. Overall, the only class that yielded a result above the LOR was the diatoms (Bacillariophyceae) at a very low abundance. The low abundance of phytoplankton is not unusual for Cow Spring Pool based on diatom results in the previous wet season and could also be attributed to heavy rain during the wet season (Table 3-20).

Table 3-20 Summary of phytoplankton analytical results for Cow Spring Pool sampled in late wet season (2021), abundance (cells L^{-1}) and percentage contribution (%), limit of reporting 10 cell L^{-1}.

Taxon	Late Dry (2020)		Late Wet (2021)	
	Abundance	**%**	**Abundance**	**%**
Bacillariophyceae	**7000**	**19.02**	**20**	**100**
Achnanthidium minutissima	1400	3.8	0	0
Amphora spp.	200	0.54	0	0
Cymbella spp.	400	1.09	0	0
Navicula spp.	2800	7.61	10	50

Taxon	Late Dry (2020)		Late Wet (2021)	
Nitzschia spp.	400	1.09	0	0
Synedra spp. (O)	1800	4.89	10	50
Chlorophyceae	**1400**	**3.8**	**0**	**0**
Cosmarium spp. (O)	1200	3.26	0	0
Staurastrumn spp. (O)	200	0.54	0	0
Cryptophyceae	**15000**	**40.76**	**0**	**0**
Chroomonas spp.	3000	8.15	0	0
Cryptomonas spp. (O)	11800	32.07	0	0
Plagioselmis spp.	200	0.54	0	0
Dinophyceae	**13200**	**35.87**	**0**	**0**
Gonyaulax spp.	12200	33.15	0	0
Gymnodinium spp.	600	1.63	0	0
Peridinium spp. (O)	400	1.09	0	0
Euglenophyceae	**200**	**0.54**	**0**	**0**
Trachelomonas spp.	200	0.54	0	0

3.5.6 MACROPHYTES

Table 3-21 presents the macrophyte species and qualitative abundance during the Late Wet 2020, Late Dry 2020 and Late Wet 2021 surveys. A diverse range of macrophyte flora was observed within Cow Spring Pool. These comprised aquatic species and groundwater-dependent species. A total of seven macrophyte species were recorded in each season. These included reeds (Clubrush, *Typha* spp.), sedges (Cyperaceae) as well as submerged macrophytes (ribbon weed, charophytes, Hydrocharitaceae) (Figure 3-66, Figure 3-67 and Figure 3-18). The abundance and diversity of species of macrophytes present in this system indicate relatively high water quality and ecological health conditions. The macrophytes, both emergent and submerged, are providing important habitat structure, refuge and food sources to organisms such as the *M. australis* (western rainbowfish). There was a decrease in the abundance of emergent macrophytes in the Late Wet 2021 compared to the Late Wet 2020. However, no changes were substantial enough to alter the categorical abundance classification.

Table 3-21. Description of macrophytes species and abundance observed at Cow Spring Pool in the late wet season (2020)

Common name	Species name	Late Wet 2020 Abundance[1]	Late Dry 2020 Abundance[1]	Late Wet 2021 Abundance[1]
Ribbon weed	*Vallisneria sp.*	Abundant	Abundant	Abundant
Charophytes	*Nitella sp., Chara sp.*	Abundant	Abundant	Abundant
Clubrush	*Schoenoplectus sp.*	Abundant	Abundant	Abundant
Sedges	Cyperaceae	Isolated	Isolated	Isolated
Bulrush	*Typha sp.*	Isolated	Isolated	Isolated
Unidentified 1	Hydrocharitaceae	Isolated	Isolated	Isolated
Unidentified 2	Hydrocharitaceae	Isolated	Isolated	Isolated

[1] Abundance based on *Western Australia AUSRIVAS field sampling sheet* (DoW, 2009).

Figure 3-66 Two macrophytes pending taxonomic identification in Cow Spring Pool

Figure 3-67 Cow Spring Pool aquatic ecology. a) to d) show a diversity of emergent and submerged macrophytes; e) a slide with minimal diatom colonisation; f) and g) *M. australis* present over a wide range of ages; h) Aeshnidae; an example of macroinvertebrates inhabiting macrophytes; i) tadpoles of *Uperoleia* spp.

3.6 GV POOL (GV_SW_POOL_SW)

The South-West Glacier Valley Pool (GV SW Pool) is a series of small pools located in a cut across an adjacent ridgeline. The pool supports fish during the wet season (spangled perch - *Leiopotherapon unicolor*), likely to have migrated from downstream permanent pools as wet season flows provided habitat connectivity. The macrophyte (submerged vegetation community) was limited at GV Pool but some individual plants were observed within the various semi-connected pools along the drainage reach. Overall, the ecology observed at GV Pool was similar to other regional pools studied for the Iron Bridge aquatic ecology monitoring program.

Figure 3-68 GV Pool; The South-West Glacier Valley Pool during the Late Wet Season 2021.

3.6.1 WATER QUALITY AND HYDROLOGY

The GV Pool monitoring site is a string of shallow ephemeral pools perched on bedrock, fed by a 3.3 km^2 catchment (Figure 3-69) draining the western face of the Glacier Valley ridgeline. This catchment is similar in nature to the Mundagoora Pool catchment directly to the north, draining the same ridge system. GV Pool differs in hydrology to the Mundagoora Pool, however, with surface water flows appearing to dominate inputs. The pool system was dry during observations in December 2020 and displayed remnant perched and semi-connected shallow (<0.5m depth) pools during the wet season (May 2021).

The water quality of GV Pool was similar to other ephemeral pools in the region during the Late Wet 2021 sampling with a slightly alkaline pH of 7.88 and moderately brackish salinity (EC = 1444 µS/cm). The pool was well oxygenated (Dissolved Oxygen = 7.99 mg/L) and clear (Turbidity = <1). The major ion distribution is presented as a Durov Plot in Figure 3-71, showing sodium bicarbonate (Na-HCO_3) dominated water type that is saturated with respect to calcite precipitation.

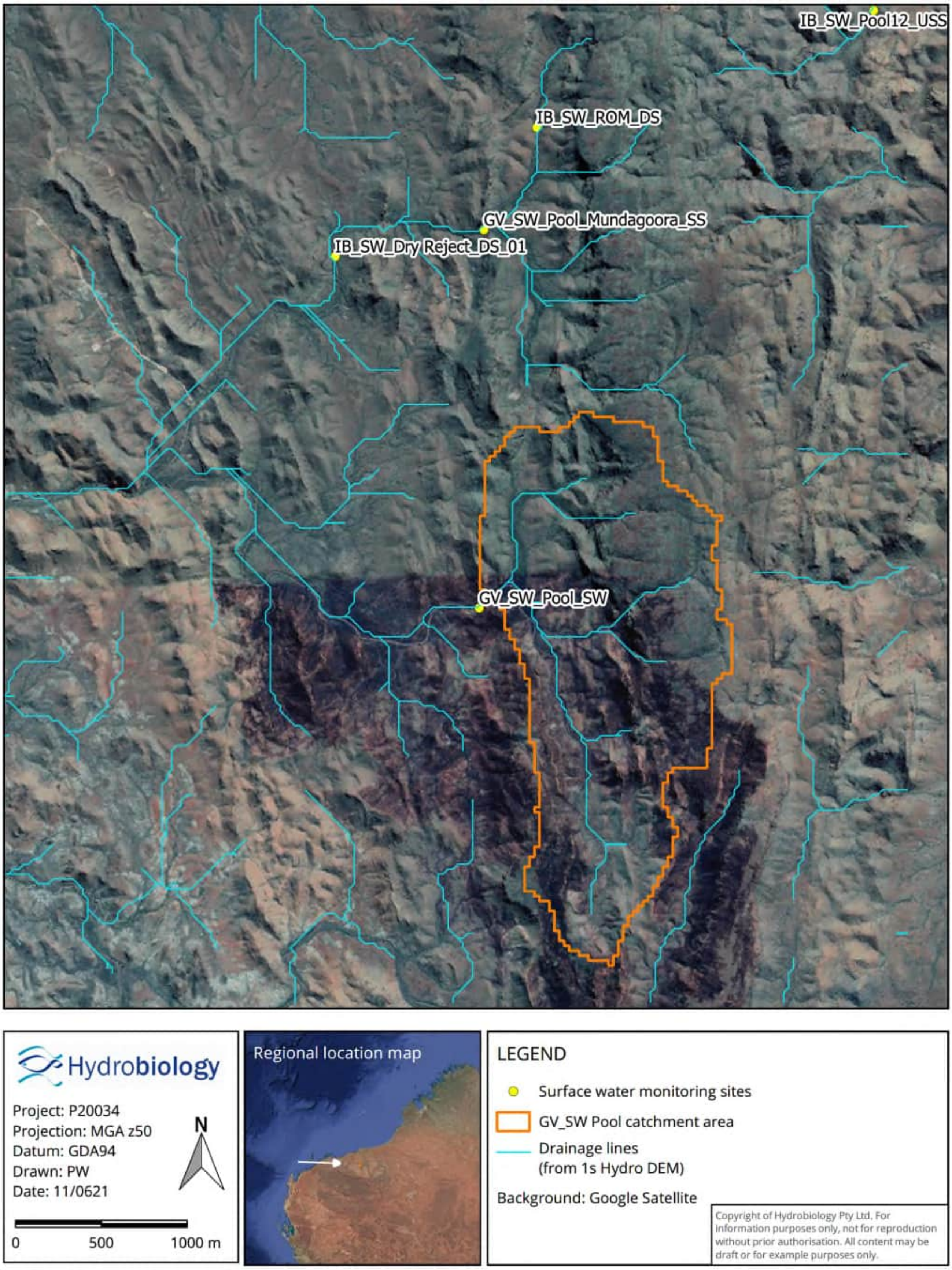


Figure 3-69 GV SW Pool catchment area (3.3 km^2)

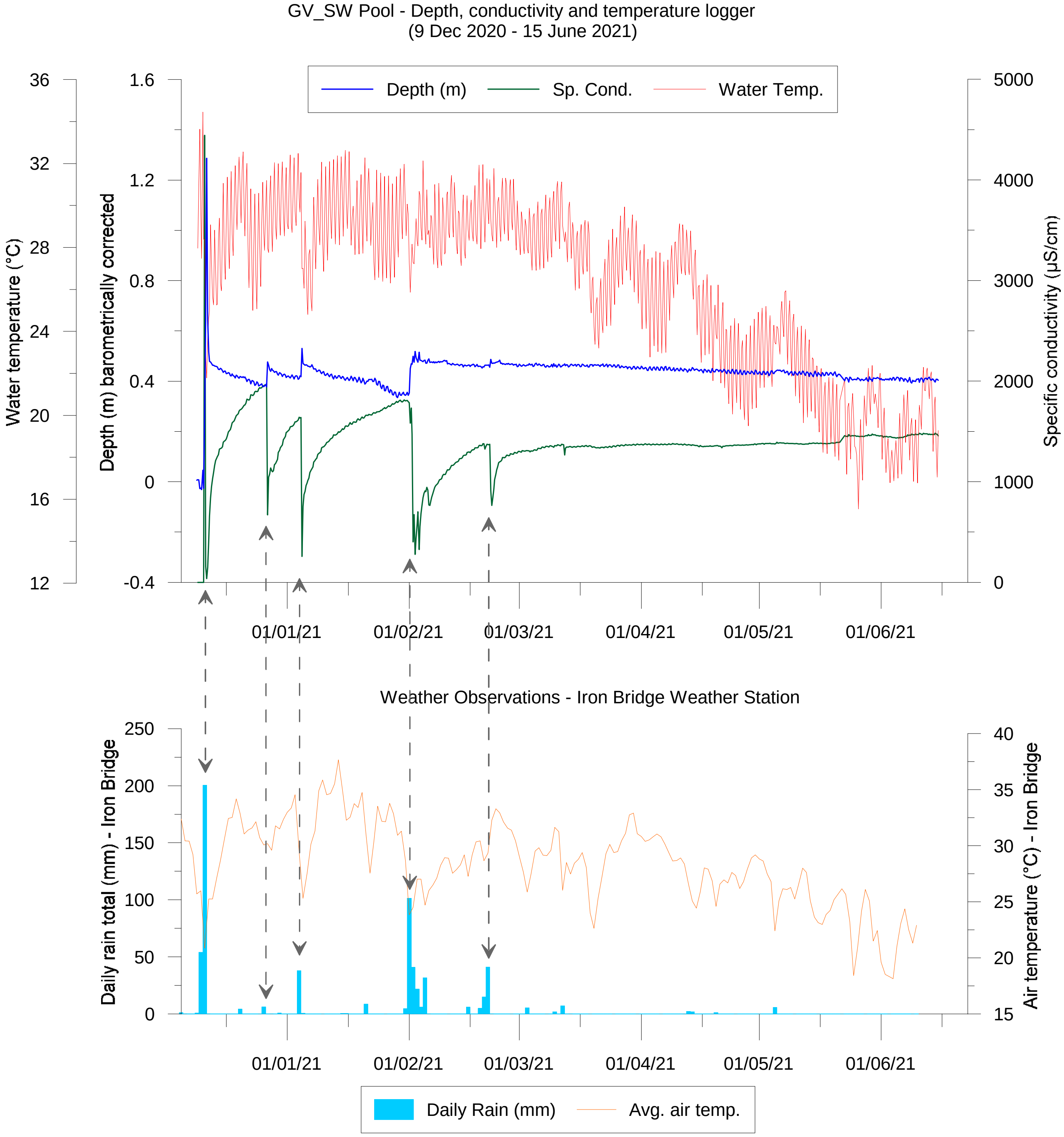


Figure 3-70 GV SW Pool depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Wet-Dry season 2021.

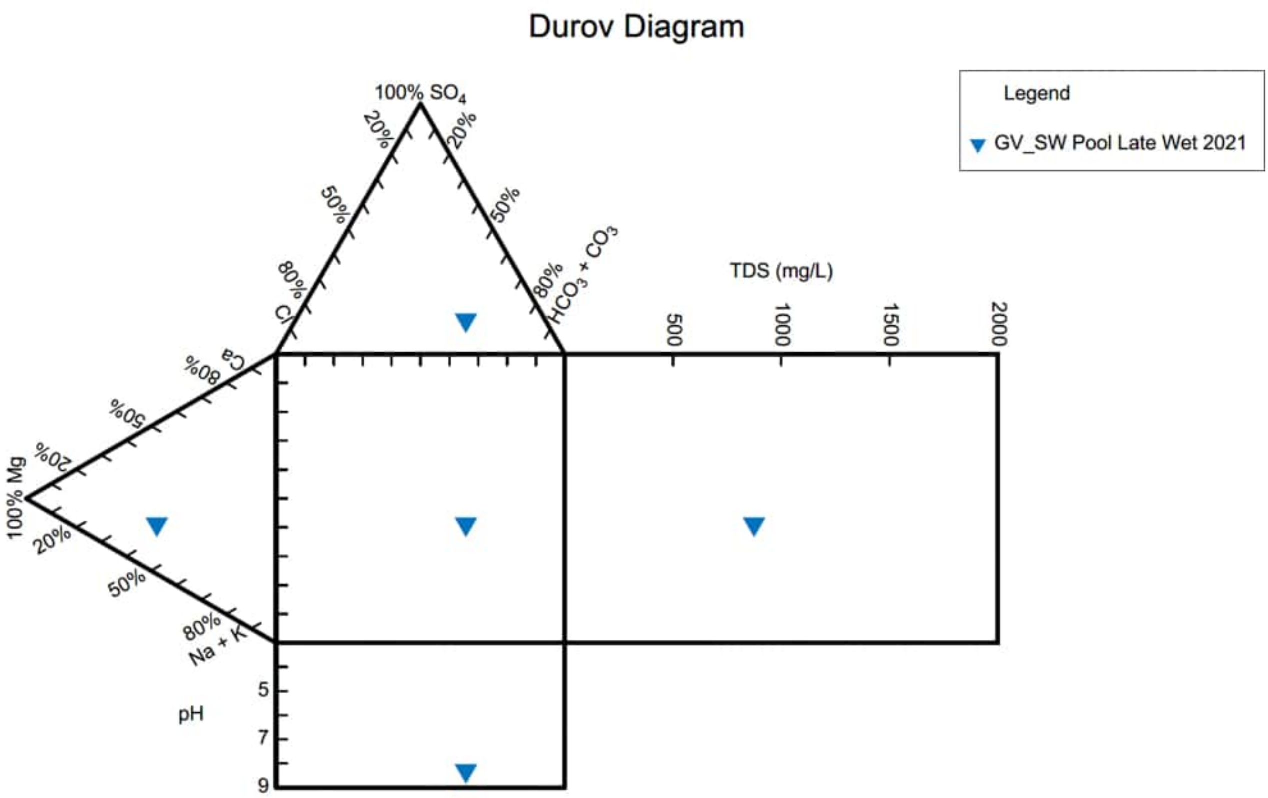


Figure 3-71 Durov diagram showing the South-West Glacier Valley Pool (GV SW Pool) major ion distribution.

3.6.2 SEDIMENT QUALITY

The sediment quality for the Late Wet 2021 sampling at GV Pool is provided in Table 3-22. As with the other sites surveyed, the Chromium concentrations exceeded the DGV of 80 mg/kg and were just below the GV-High of 370 mg/kg (ANZG 2018). Similarly, the Nickel concentrations were above both the DGV (21 mg/kg) and the GV-High (52 mg/kg). This pattern was consistent with other pools in the region.

Table 3-22 Summary of sediment quality analysis for GV Pool in the late wet season 2021. Bolded values denote results recorded above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	Late Wet 2021
Total Soluble Salts	mg/kg	**200**
Moisture Content (Dried @ 105-110°C)	%	**24.8**
Total Alkalinity as CaCO3	mg/kg	<5
Bicarbonate Alkalinity as CaCO3	mg/kg	**239**
Carbonate Alkalinity as CaCO3	mg/kg	**239**
Acidity	mg/kg	**62**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	**<10**
Chloride (by Discrete Analyser)	mg/kg	**20**

Analyte grouping/Analyte	Unit	Late Wet 2021
Calcium	mg/kg	**30**
Magnesium	mg/kg	**20**
Sodium	mg/kg	**30**
Potassium	mg/kg	<10
Mercury (FIMS)	mg/kg	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	**430**
Total Nitrogen as N	mg/kg	**430**
Total Phosphorus as P	mg/kg	**190**
Reactive Phosphorus as P	mg/kg	<0.1
Total Organic Carbon	%	**0.13**
Total Metals by ICP-AES		
Arsenic	mg/kg	**9**
Barium	mg/kg	**60**
Beryllium	mg/kg	<1
Boron	mg/kg	**50**
Cadmium	mg/kg	<1
Chromium	mg/kg	**368**
Cobalt	mg/kg	**33**
Copper	mg/kg	**67**
Iron	mg/kg	**114000**
Lead	mg/kg	**6**
Manganese	mg/kg	**674**
Nickel	mg/kg	**134**
Selenium	mg/kg	**<5**
Vanadium	mg/kg	**161**
Zinc	mg/kg	**30**

3.6.3 FISH

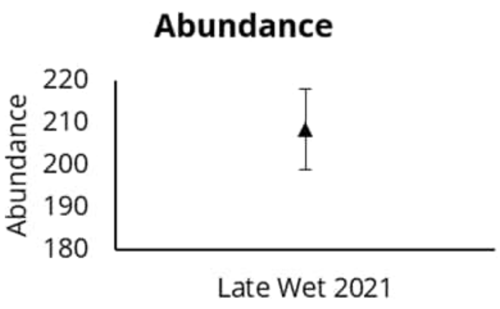
GV Pool was first surveyed in the Late Wet Season 2021. As GV Pool was shallow, a fyke net was not able to be used to survey the fish abundance at this site; therefore, species composition and fish counts were conducted using BRUVs.

L. unicolor (spangled perch) was the only fish species observed on the BRUV footage for GV Pool (MaxN = 13).

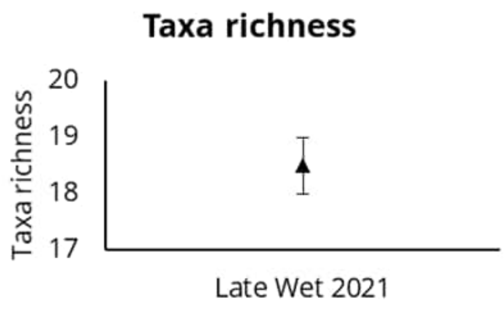
3.6.4 AQUATIC MACROINVERTEBRATES

Figure 3-72 presents the summary of total abundance, taxa richness, EPT richness and SIGNAL2 for the first season sampled (Late Wet 2021) in GV Pool. The key findings were as follows:

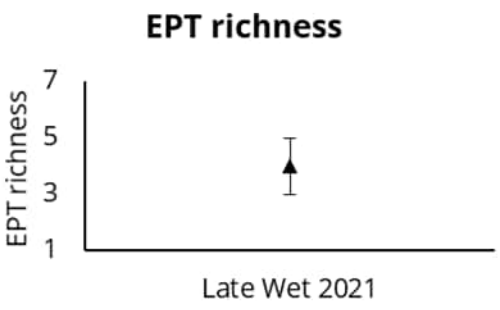
- Total abundance and taxa richness varied, with 199 to 218 individuals and 18 to 19 taxa recorded, respectively.
- Aveerage EPT richness was 4 at the GV Pool, with a total of five families belonging to the Ephemeroptera and Trichoptera orders recorded.
- The average SIGNAL2 score was 3.4, which indicates that the macroinvertebrate community at GV Pool is moderately tolerant.



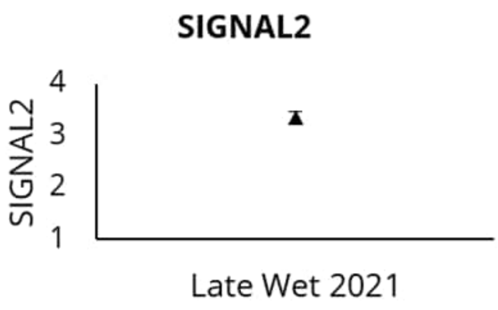
a) Total abundance at GV Pool



b) Taxonomic richness at GV Pool



c) EPT richness at GV Pool



d) SIGNAL2 scores at GV Pool

Figure 3-72 Macroinvertebrate indices for GV Pool in the Late Wet 2021 season.

Figure 3-73 shows the abundance of each macroinvertebrate taxa in GV Pool in the Late Wet season of 2021 and shows taxa ranging from the the most abundant (left) to the least abundant (right) along the x-axis. Cnidarians were highly abundant macroinvertebrates at GV Pool, with members of Hydrozoa, Oceaniidae, Hydrodae and Olindiidae were the top four most abundant taxa. Members of the sponge phylum Porifera were the next most abundant, followed by Bryozoa and the turbellarian flatworms of the Platyhelmithes.

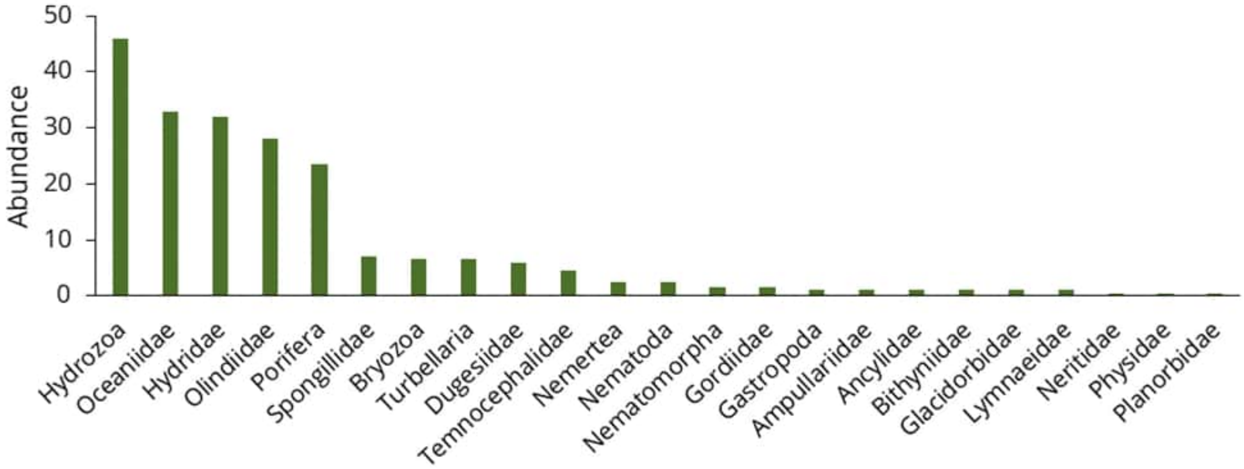


Figure 3-73 Average abundances of all macroinvertebrate taxa at GV Pool in the Late Wet season of 2021, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis.

3.6.5 DIATOMS AND PHYTOPLANKTON

3.6.5.1 DIATOMS

Table 3-23 provides the diatom abundance (total count per species), average abundance and DSIAR score GV Pool surveyed in the Late Wet 2021. Figure 3-74 illustrates the mean abundance (diatom count per replicate) of diatom species recorded at GV Pool. GV Pool was not sampled before the Late Wet 2021 season, the key findings were as follows:

- GV Pool was observed as having a high taxonomic diversity with 34 diatoms species being recorded in Late Wet 2021.
- Overall average abundance was high (average count = 400) with both replicates recording similar total abundances.
- The tolerance to environmental stress for GV Pool is reflected in the moderate sensitivity DSIAR score (49.3 and 51.2 for replicate 1 and 2, respectively). There is likely to be some natural environmental (habitat) stress from the ephemeral nature of the shallow string of pools along the study reach. The catchment during the baseline phase is largely unimpacted by other activities such as grazing.

Table 3-23. Diatom abundance (total count per species), average abundance and DSIAR score GV Pool surveyed in the Late Wet 2021

Taxon name	GV Pool 1	GV Pool 2	Average
Diploneis parma	52	104	78
Nitzschia paleaceae	0	96	48
Nitzschia frustulum	64	30	47
Nitzschia fonticola	22	46	34
Navicula viridula	16	42	29
Gomphonema affine	42	8	25
Nitzschia filiformis	46	4	25
Nitzschia palea	34	14	24
Nitzschia microcephala	14	8	11
Achnanthidium minutissimum	20	0	10
Navicula erifuga	0	16	8
Achnanthidium exiguum	14	0	7
Nitzschia gracilis	14	0	7
Navicula menisculus	4	8	6
Navicula viridula var. linearis	0	8	4
Nitzschia lacuum	8	0	4
Diploneis smithii	0	6	3
Nitzschia inconspicua	0	6	3
Nitzschia linearis	4	2	3
Ulnaria ulna	6	0	3
Achnanthes subexigua	4	0	2
Gomphonema minutum	0	4	2
Karayevia clevei	0	4	2
Navicula cryptocephala	0	4	2
Navicula lanceolata	0	4	2
Navicula tenelloides	4	0	2
Navicula veneta	4	0	2
Fragilaria vaucheriae	0	2	1
Gomphonema gracile	0	2	1
Navicula radiosafallax	0	2	1
Navicula rhynchocephala	2	0	1
Nitzschia clausii	2	0	1
Nitzschia desertorum	0	2	1
Nitzschia palea var debilis	2	0	1
Total Abundance	**378**	**422**	**400**
DSIAR Score	**49.3**	**51.2**	**50.3**

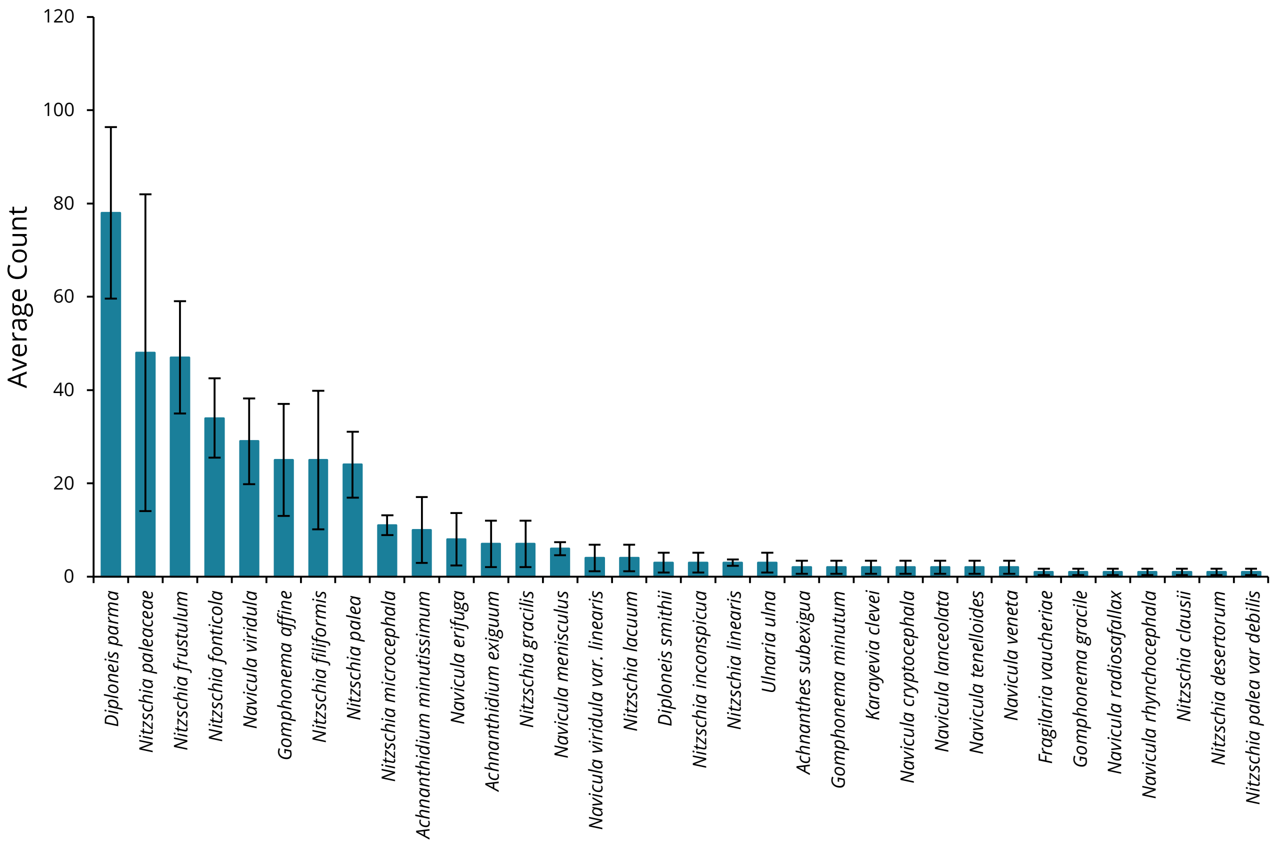


Figure 3-74. Average species abundance (diatom count per replicate) for diatoms sampled at GV Pool in the Late Wet 2021, with taxa arranged from most abundant (left) to least abundant (right) along the x-axis. Standard error (SE±0.5) denoted by error

3.6.5.1 PHYTOPLANKTON

Two classes of phytoplankton were identified in the late wet season (2021). GV Pool was dominated by diatoms (~98.9%, Bacillariophyceae), indicating a low phytoplankton diversity. Approximately six diatom genera were observed in the water sample, indicating a moderate level of diatom diversity.

Table 3-24 Summary of phytoplankton species and abundance for GV Pool sampled in the late wet season 2021.

Taxon	Late Wet (2021)	
	Abundance	**%**
Bacillariophyceae	860	98.85
Amphora spp.	40	4.6
Placoneis sp.	530	60.92
Navicula spp.	100	11.49
Nitzschia spp.	110	12.64
Rhopalodia gibba	60	6.9

Taxon	Late Wet (2021)	
Synedra spp. (O)	20	2.3
Cryptophyceae	10	1.15
Cryptomonas spp. (O)	10	1.15

3.6.6 MACROPHYTES

The macrophyte (submerged vegetation community) observed during the Late Wet 2021 suvery (the initial baseline survey for this site) was limited at GV Pool, though some individual plants (sedges) were observed within the various semi-connected pools along the drainage reach (Figure 3-68). These were undergoing taxonomic identification at the time of reporting.

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APPENDIX A. WATER QUALITY DATA

Table 25 Water quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
		Sample Date	29/05/2020	31/05/2020	01/06/2020	29/05/2020	31/05/2020	01/06/2020	30/05/2020	01/06/2020	01/06/2020	01/06/2020
		ALS Sample Number	EP2005660001	EP2005660002	EP2005660003	EP2005660004	EP2005660005	EP2005660006	EP2005660007	EP2005660008	EP2005660009	EP2005660010
Suspended Solids (SS)	mg/L	5	<5	<5	<5	----	<5	----	<5	----	**9480**	**3220**
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	**478**	**406**	**34**	**204**	**399**	**142**	<1	**422**	**79**	**80**
Total Alkalinity as CaCO3	mg/L	1	**478**	**406**	**34**	**204**	**399**	**142**	<1	**422**	**79**	**80**
Acidity as CaCO3	mg/L	1	<1	**6**	**10**	**12**	**11**	**21**	**16**	**18**	**3**	**3**
Sulfate as SO4 - Turbidimetric	mg/L	1	**22**	**158**	**80**	**9**	**34**	**111**	**34**	**92**	**30**	**32**
Chloride	mg/L	1	**235**	**405**	**56**	**14**	**52**	**104**	**24**	**208**	**39**	**50**
Calcium	mg/L	1	**63**	**28**	**22**	**45**	**63**	**49**	**3**	**48**	**32**	**20**
Magnesium	mg/L	1	**120**	**100**	**18**	**30**	**45**	**41**	**5**	**99**	**15**	**17**
Sodium	mg/L	1	**52**	**317**	**39**	**18**	**64**	**58**	**16**	**142**	**20**	**32**

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Potassium	mg/L	1	<1	**9**	**2**	**2**	<1	**3**	**1**	**3**	**4**	**3**
Arsenic	mg/L	0.001	**0.001**	**0.013**	<0.001	<0.001	<0.001	**0.002**	<0.001	**0.012**	----	----
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	----	----
Barium	mg/L	0.001	**0.026**	**0.057**	**0.003**	**0.135**	**0.016**	**0.040**	**0.023**	**0.024**	----	----
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**0.0001**	----	----
Chromium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**	----	----
Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.004**	**0.002**	**0.001**	----	----
Copper	mg/L	0.001	<0.001	<0.001	<0.001	**0.001**	<0.001	<0.001	<0.001	**0.016**	----	----
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	----	----
Manganese	mg/L	0.001	**0.017**	**0.179**	**0.001**	**0.009**	**0.051**	**0.623**	**0.349**	**0.001**	----	----
Nickel	mg/L	0.001	<0.001	**0.002**	**0.005**	**0.002**	<0.001	**0.026**	**0.010**	**0.004**	----	----
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	----	----
Vanadium	mg/L	0.01	<0.01	**0.02**	<0.01	**0.02**	**0.01**	<0.01	<0.01	**0.04**	----	----
Zinc	mg/L	0.005	<0.005	<0.005	<0.005	**0.017**	<0.005	**0.021**	<0.005	**0.034**	----	----

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Boron	mg/L	0.05	**0.20**	**0.66**	**0.14**	**0.11**	**0.23**	**0.16**	**0.06**	**0.35**	----	----
Iron	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**2.98**	**0.59**	<0.05	----	----
Aluminium	mg/L	0.01	<0.01	**0.05**	<0.01	<0.01	**0.01**	<0.01	**0.16**	**0.01**	**68.7**	**4.13**
Antimony	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.001	<0.001	**0.012**	<0.001	<0.001	<0.001	**0.003**	<0.001	**0.011**	**0.011**	**0.003**
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.004**	<0.001
Barium	mg/L	0.001	**0.026**	**0.056**	**0.003**	**0.096**	**0.018**	**0.019**	**0.022**	**0.024**	**0.523**	**0.065**
Bismuth	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**0.0004**	<0.0001
Cerium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.154**	**0.010**
Caesium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.015**	<0.001
Chromium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**	**0.774**	**0.070**
Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.004**	**0.001**	**0.002**	**0.202**	**0.011**
Copper	mg/L	0.001	<0.001	<0.001	**0.001**	**0.002**	<0.001	<0.001	<0.001	**0.019**	**0.212**	**0.017**

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Dysprosium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.005**	<0.001
Erbium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001
Europium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001
Gadolinium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.008**	<0.001
Gallium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.006**	**0.003**
Hafnium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Holmium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Indium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lanthanum	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.040**	**0.008**
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.056**	**0.003**
Lithium	mg/L	0.001	**0.005**	**0.020**	**0.005**	**0.003**	**0.005**	**0.031**	**0.002**	**0.005**	**0.097**	**0.007**
Lutetium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	**0.014**	**0.198**	<0.001	**0.012**	**0.192**	**0.562**	**0.305**	**0.006**	**4.66**	**0.277**
Molybdenum	mg/L	0.001	<0.001	**0.003**	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**	<0.001	<0.001

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Neodymium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.048**	**0.008**
Nickel	mg/L	0.001	<0.001	**0.001**	**0.005**	**0.002**	<0.001	**0.023**	**0.007**	**0.004**	**1.13**	**0.053**
Praseodymium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.012**	**0.002**
Rubidium	mg/L	0.001	<0.001	**0.006**	**0.002**	<0.001	<0.001	**0.007**	**0.002**	**0.002**	**0.071**	**0.006**
Samarium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.009**	<0.001
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	mg/L	0.001	**0.191**	**0.271**	**0.087**	**0.081**	**0.182**	**0.099**	**0.038**	**0.232**	**0.245**	**0.109**
Tellurium	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Terbium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	mg/L	0.001	**0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.023**	<0.001
Thulium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin	mg/L	0.001	**0.001**	**0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Titanium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.23**	**0.06**
Uranium	mg/L	0.001	<0.001	**0.008**	<0.001	<0.001	<0.001	<0.001	<0.001	**0.003**	**0.004**	<0.001
Vanadium	mg/L	0.01	<0.01	**0.02**	<0.01	**0.03**	**0.02**	<0.01	<0.01	**0.04**	**0.09**	**0.02**
Ytterbium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001
Yttrium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.023**	**0.004**
Zinc	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	**0.012**	<0.005	**0.036**	**0.511**	**0.037**
Zirconium	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	mg/L	0.05	**0.17**	**0.69**	**0.11**	**0.11**	**0.22**	**0.17**	**0.06**	**0.34**	**0.15**	**0.08**
Iron	mg/L	0.05	<0.05	**0.11**	<0.05	<0.05	**0.19**	**2.85**	**0.49**	<0.05	**112**	**11.5**
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**0.0002**	----	----
Nitrite + Nitrate as N	mg/L	0.01	**0.05**	**0.04**	**1.32**	**5.45**	**0.26**	<0.01	**0.02**	**0.70**	**7.48**	**0.24**
Total Kjeldahl Nitrogen as N	mg/L	0.1	<0.1	**0.2**	**0.1**	**1.0**	**0.2**	**0.1**	<0.1	**0.2**	**7.6**	**2.8**
Total Nitrogen as N	mg/L	0.1	<0.1	**0.2**	**1.4**	**6.4**	**0.5**	**0.1**	<0.1	**0.9**	**15.1**	**3.0**
Total Phosphorus as P	mg/L	0.01	**0.01**	**0.02**	<0.01	**0.05**	**0.01**	**0.06**	**0.01**	**0.02**	**1.43**	**0.46**

Analyte grouping/Analyte	Unit	LOR	Site 12 Pool	Central Ck Pool	Cow Spring Pool	Site 12 Pool GW	South Star Pool	Fig Pool GW	Fig Pool	Central Creek GW	TSF-1	TSF-2
Reactive Phosphorus as P	mg/L	0.01	<0.01	**0.01**	<0.01	**0.01**	<0.01	<0.01	<0.01	<0.01	**0.06**	<0.01
Total Anions	meq/L	0.01	**16.6**	**22.8**	**3.92**	**5.05**	**10.1**	**8.08**	**1.38**	**16.2**	**3.30**	**3.68**
Total Cations	meq/L	0.01	**15.3**	**23.6**	**4.33**	**5.55**	**9.63**	**8.42**	**1.28**	**16.8**	**3.80**	**3.86**
Ionic Balance	%	0.01	**4.25**	**1.76**	**4.87**	**4.69**	**2.61**	**2.04**	**3.83**	**1.76**	**7.04**	**2.53**
Dissolved Organic Carbon	mg/L	1	----	**4**	<1	----	**4**	----	<1	----	----	----
Total Organic Carbon	mg/L	1	----	**4**	**1**	----	**2**	----	<1	----	----	----

Table. Water quality data – late wet season 2021, Bold font denotes values above the limit of reporting (LOR)

Analyte grouping/Analyte	Unit	LOR	OPF 2	DRY RWW	MAR UPST	FIG	OPF 1	S12 GW	COW 2	CC	S12 POOL	COW	SS POOL
		Sample Date:	13/12/2020	13/12/2020	13/12/2020	10/12/2020	13/12/2020	09/12/2020	11/12/2020	13/12/2020	09/12/2020	10/12/2020	08/12/2020
		ALS Sample Number:	EP2013964001	EP2013964002	EP2013964003	EP2013964004	EP2013964005	EP2013964006	EP2013964007	EP2013964008	EP2013964009	EP2013964010	EP2013964011
Suspended Solids (SS)	mg/L	5	**32**	**1000**	**305**	<5	**50**	----	**18**	<5	<5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	**101**	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	**84**	**25**	**16**	<1	**75**	**389**	**16**	**112**	**489**	**37**	**366**

Analyte grouping/Analyte	Unit	LOR	OPF 2	DRY RWW	MAR UPST	FIG	OPF 1	S12 GW	COW 2	CC	S12 POOL	COW	SS POOL
Total Alkalinity as CaCO3	mg/L	1	**84**	**25**	**16**	<1	**75**	**389**	**16**	**112**	**590**	**37**	**366**
Sulfate as SO4 - Turbidimetric	mg/L	1	**41**	**2**	**3**	**33**	**41**	**39**	**41**	**61**	**20**	**84**	**32**
Chloride	mg/L	1	**51**	**3**	**3**	**24**	**48**	**77**	**30**	**112**	**101**	**56**	**59**
Dissolved Major Cations													
Calcium	mg/L	1	**28**	**5**	**5**	**4**	**30**	**54**	**11**	**23**	**37**	**24**	**72**
Magnesium	mg/L	1	**23**	**2**	**2**	**5**	**18**	**72**	**9**	**28**	**126**	**18**	**50**
Sodium	mg/L	1	**35**	**3**	**2**	**15**	**33**	**74**	**20**	**82**	**68**	**40**	**69**
Potassium	mg/L	1	**3**	**1**	**1**	**1**	**3**	**1**	**3**	**5**	<1	**2**	**1**
EG020F: Dissolved Metals by ICP-MS													
Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	----	**0.004**	**0.001**	<0.001	<0.001
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	----	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	**0.061**	**0.125**	**0.060**	**0.052**	**0.074**	**0.119**	----	**0.051**	**0.053**	**0.058**	**0.042**
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	----	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	**0.002**	<0.001	<0.001	<0.001	**0.002**	<0.001	----	**0.002**	<0.001	<0.001	<0.001
Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	**0.002**	<0.001	<0.001	----	<0.001	<0.001	<0.001	<0.001

Analyte grouping/Analyte	Unit	LOR	OPF 2	DRY RWW	MAR UPST	FIG	OPF 1	S12 GW	COW 2	CC	S12 POOL	COW	SS POOL
Copper	mg/L	0.001	**0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	----	**0.001**	<0.001	<0.001	<0.001
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	----	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	**0.001**	**0.002**	**0.008**	**0.341**	**0.003**	**0.017**	----	**0.016**	**0.010**	**0.002**	**0.088**
Nickel	mg/L	0.001	<0.001	<0.001	**0.001**	**0.009**	<0.001	**0.002**	----	**0.001**	<0.001	**0.005**	<0.001
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	----	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.01	**0.01**	<0.01	<0.01	<0.01	<0.01	**0.04**	----	**0.01**	<0.01	<0.01	**0.01**
Zinc	mg/L	0.005	**0.008**	**0.020**	**0.023**	**0.016**	**0.014**	**0.008**	----	**0.009**	**0.007**	**0.038**	**0.006**
Boron	mg/L	0.05	**0.10**	<0.05	<0.05	**0.09**	**0.09**	**0.74**	----	**0.20**	**0.32**	**0.17**	**0.28**
Total Metals by ICP-MS													
Arsenic	mg/L	0.001	<0.001	**0.004**	**0.001**	<0.001	<0.001	<0.001	<0.001	**0.004**	**0.002**	<0.001	<0.001
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	**0.015**	**0.121**	**0.040**	**0.023**	**0.021**	**0.104**	**0.005**	**0.023**	**0.014**	**0.004**	**0.016**
Cadmium	mg/L	0.0001	<0.0001	**0.0001**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	**0.020**	**0.300**	**0.283**	<0.001	**0.018**	**0.001**	**0.001**	**0.003**	<0.001	**0.001**	<0.001
Cobalt	mg/L	0.001	**0.002**	**0.045**	**0.022**	**0.001**	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Analyte grouping/Analyte	Unit	LOR	OPF 2	DRY RWW	MAR UPST	FIG	OPF 1	S12 GW	COW 2	CC	S12 POOL	COW	SS POOL
Copper	mg/L	0.001	**0.003**	**0.069**	**0.031**	<0.001	**0.004**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	0.001	<0.001	**0.007**	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	**0.037**	**1.14**	**0.607**	**0.319**	**0.033**	**0.023**	**0.024**	**0.011**	**0.021**	**0.002**	**0.097**
Nickel	mg/L	0.001	**0.009**	**0.186**	**0.142**	**0.008**	**0.008**	**0.002**	**0.005**	**0.002**	<0.001	**0.005**	<0.001
Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.01	**0.02**	**0.06**	**0.04**	<0.01	**0.01**	**0.04**	<0.01	**0.01**	<0.01	<0.01	<0.01
Zinc	mg/L	0.005	<0.005	**0.141**	**0.173**	<0.005	**0.009**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	mg/L	0.05	**0.09**	<0.05	<0.05	**0.07**	**0.08**	**0.68**	**0.10**	**0.18**	**0.30**	**0.14**	**0.26**
Dissolved Mercury by FIMS													
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**----**	<0.0001	<0.0001	<0.0001	<0.0001
Total Recoverable Mercury by FIMS													
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**0.0002**	<0.0001	<0.0001	**0.0004**	<0.0001
Nitrite plus Nitrate as N (NOx) by Discrete Analyser													
Nitrite + Nitrate as N	mg/L	0.01	**7.01**	**0.08**	**0.12**	<0.01	**6.88**	**0.42**	**----**	**3.08**	<0.01	**1.11**	<0.01
Total Kjeldahl Nitrogen By Discrete Analyser													
Total Kjeldahl Nitrogen as N	mg/L	0.1	**1.8**	**2.6**	**1.6**	<0.1	**1.6**	<0.1	**----**	**0.6**	**0.2**	**0.1**	<0.1

Analyte grouping/Analyte	Unit	LOR	OPF 2	DRY RWW	MAR UPST	FIG	OPF 1	S12 GW	COW 2	CC	S12 POOL	COW	SS POOL
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser													
Total Nitrogen as N	mg/L	0.1	**8.8**	**2.7**	**1.7**	<0.1	**8.5**	**0.4**	----	**3.7**	**0.2**	**1.2**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser													
Total Phosphorus as P	mg/L	0.01	<0.02	**0.41**	**0.17**	<0.01	<0.02	<0.01	----	**0.01**	<0.01	<0.01	<0.01
Reactive Phosphorus as P by discrete analyser													
Reactive Phosphorus as P	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	----	<0.01	<0.01	<0.01	<0.01
onic Balance													
Total Anions	meq/L	0.01	**4.47**	**0.62**	**0.48**	**1.36**	**4.20**	**10.8**	**2.02**	**6.67**	**15.0**	**4.07**	**9.64**
Total Cations	meq/L	0.01	**4.89**	**0.57**	**0.53**	**1.29**	**4.49**	**11.9**	**2.24**	**7.15**	**15.2**	**4.47**	**10.7**
Ionic Balance	%	0.01	**4.45**	**4.65**	**5.09**	**2.82**	**3.35**	**4.90**	**5.09**	**3.47**	**0.40**	**4.71**	**5.36**
Dissolved Organic Carbon (DOC)													
Dissolved Organic Carbon	mg/L	1	----	----	----	**4**	----	----	----	----	**10**	**2**	**11**
EP005: Total Organic Carbon (TOC)													
Total Organic Carbon	mg/L	1	----	----	----	**2**	----	----	----	----	**16**	**1**	----

Table. Water quality data – late wet season 2021, Bold font denotes values above the limit of reporting (LOR)

Analyte grouping/analyte	Unit	Sample date: / LOR	GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	23/05/2021
EA005P: pH by PC Titrator								
pH Value	pH Unit	0.01	**7.98**	**8.31**	**8.38**	**7.05**	**4.19**	**8.42**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	µS/cm	1	**738**	**1350**	**2710**	**421**	**189**	**1120**
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	mg/L	1	**480**	**878**	**1760**	**274**	**123**	**728**
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	mg/L	5	<5	<5	**5**	<5	<5	<5
EA045: Turbidity								
Turbidity	NTU	0.1	**0.3**	**0.2**	**0.4**	**0.1**	**3.6**	**0.2**
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	mg/L	1	**327**	**508**	**735**	**128**	**28**	**623**

Analyte grouping/analyte	Unit	Sample date: / LOR	GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	23/05/2021
		LOR						
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	<1	**6**	**19**	<1	<1	**31**
Bicarbonate Alkalinity as CaCO3	mg/L	1	**344**	**512**	**558**	**35**	<1	**561**
Total Alkalinity as CaCO3	mg/L	1	**344**	**518**	**576**	**35**	<1	**592**
ED038A: Acidity								
Acidity as CaCO3	mg/L	1	**6**	<1	<1	**6**	**10**	<1
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	mg/L	1	**29**	**94**	**209**	**81**	**34**	**14**
ED045G: Chloride by Discrete Analyser								
Chloride	mg/L	1	**43**	**138**	**522**	**61**	**23**	**63**
ED093F-DW: Dissolved Major Cations - Drinking Water								
Calcium	mg/L	0.1	**58.6**	**54.1**	**37.0**	**21.6**	**2.8**	**54.8**

Analyte grouping/analyte	Unit	Sample date: / LOR	GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	23/05/2021
Magnesium	mg/L	0.1	**43.8**	**90.7**	**156**	**18.0**	**5.2**	**118**
Potassium	mg/L	0.1	**0.7**	**1.3**	**12.9**	**2.3**	**1.4**	**0.7**
Sodium	mg/L	0.1	**60.0**	**126**	**348**	**36.6**	**14.4**	**52.1**
EG035F: Dissolved Mercury by FIMS								
Mercury	mg/L	0.00004	**0.00007**	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG035T: Total Mercury by FIMS								
Mercury	mg/L	0.00004	<0.00004	<0.00004	<0.00004	**0.00023**	<0.00004	<0.00004
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								
Aluminium	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	**0.198**	<0.005
Iron	mg/L	0.002	**0.007**	<0.002	**0.005**	**0.005**	**0.414**	**0.014**
Selenium	mg/L	0.0002	<0.0002	<0.0002	**0.0002**	**0.0002**	<0.0002	<0.0002
Arsenic	mg/L	0.0002	**0.0004**	**0.0015**	**0.0139**	<0.0002	<0.0002	**0.0010**
Barium	mg/L	0.0005	**0.0164**	**0.0330**	**0.0555**	**0.0530**	**0.0222**	**0.0243**
Beryllium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	mg/L	0.005	**0.160**	**0.283**	**0.680**	**0.125**	**0.058**	**0.159**
Cadmium	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Analyte grouping/analyte	Unit		GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	
		LOR						23/05/2021
Chromium	mg/L	0.0002	<0.0002	<0.0002	<0.0002	**0.0006**	<0.0002	<0.0002
Cobalt	mg/L	0.0001	<0.0001	<0.0001	**0.0002**	<0.0001	**0.0016**	<0.0001
Copper	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lead	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	mg/L	0.0005	**0.0566**	**0.0055**	**0.0138**	**0.0010**	**0.359**	**0.0128**
Nickel	mg/L	0.0005	**0.0009**	**0.0005**	**0.0013**	**0.0055**	**0.0098**	<0.0005
Vanadium	mg/L	0.0002	**0.0136**	**0.0074**	**0.0312**	<0.0002	<0.0002	**0.0008**
Zinc	mg/L	0.001	<0.001	**0.004**	<0.001	**0.034**	**0.002**	<0.001
EG094T: Total metals in Fresh water by ORC-ICPMS								
Aluminium	mg/L	0.005	**0.008**	**0.011**	**0.017**	<0.005	**0.227**	**0.007**
Iron	mg/L	0.002	**0.125**	**0.016**	**0.067**	**0.017**	**1.46**	**0.027**
Selenium	mg/L	0.0002	<0.0002	<0.0002	**0.0002**	<0.0002	<0.0002	<0.0002
Arsenic	mg/L	0.0002	**0.0004**	**0.0012**	**0.0122**	<0.0002	**0.0004**	**0.0008**
Barium	mg/L	0.0005	**0.0147**	**0.0218**	**0.0521**	**0.0033**	**0.0214**	**0.0228**
Beryllium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	mg/L	0.005	**0.141**	**0.251**	**0.600**	**0.119**	**0.053**	**0.138**
Cadmium	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Chromium	mg/L	0.0002	<0.0002	**0.0003**	**0.0004**	**0.0006**	<0.0002	**0.0003**
Cobalt	mg/L	0.0001	<0.0001	<0.0001	**0.0002**	<0.0001	**0.0016**	<0.0001

Analyte grouping/analyte	Unit		GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	
		LOR						23/05/2021
Copper	mg/L	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lead	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	mg/L	0.0005	**0.0793**	**0.0229**	**0.0372**	**0.0008**	**0.331**	**0.0129**
Nickel	mg/L	0.0005	**0.0006**	**0.0006**	**0.0012**	**0.0049**	**0.0095**	<0.0005
Vanadium	mg/L	0.0002	**0.0132**	**0.0068**	**0.0284**	<0.0002	<0.0002	**0.0008**
Zinc	mg/L	0.001	<0.001	<0.001	<0.001	**0.002**	**0.002**	<0.001
EK055G-NH4: Ammonium as N by DA								
Ammonium as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	mg/L	0.01	**0.09**	<0.01	<0.01	**1.26**	<0.01	<0.01

Analyte grouping/analyte	Unit	Sample date: / LOR	GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	
		LOR						23/05/2021
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	mg/L	0.01	**0.09**	<0.01	<0.01	**1.26**	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	mg/L	0.1	**0.3**	**0.2**	**0.1**	**0.2**	**0.1**	**0.1**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
Total Nitrogen as N	mg/L	0.1	**0.4**	**0.2**	**0.1**	**1.5**	**0.1**	**0.1**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	mg/L	0.01	**0.01**	<0.01	**0.03**	<0.01	**0.02**	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Reactive Phosphate	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Analyte grouping/analyte	Unit		GV_SW_Pool_Mundagoora_SS	GV_SW_Pool_SW	IB_SW_Pool_Central Ck	IB_SW_Pool_Cow Spring	IB_SW_Pool_Fig	IB_SW_Pool12_01
		Sample date:	21/05/2021	21/05/2021	22/05/2021	25/05/2021	24/05/2021	
		LOR						23/05/2021
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	mg/L	1	**2**	**3**	**2**	<1	<1	**2**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	mg/L	1	**6**	**4**	**3**	<1	<1	**2**
EP025: Oxygen - Dissolved (DO)								
Dissolved Oxygen	mg/L	0.1	**9.1**	**10.0**	**10.3**	**9.9**	**9.2**	**10.3**
ED009: Anions								
Fluoride	mg/L	0.010	**0.180**	**0.392**	**0.345**	**0.069**	**0.019**	**0.166**

APPENDIX B. SEDIMENT QUALITY DATA

Table 26 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	South Star Pool	Cow Spring Pool	Fig Pool	Site 12 Pool	Central Ck Pool
		Sample Date	30/05/2020	30/05/2020	30/05/2020	29/05/2020	31/05/2020
		ALS Sample Number	EP2005660011	EP2005660012	EP2005660013	EP2005660014	EP2005660015
Total Soluble Salts	mg/kg	5	**693**	**114**	**248**	**408**	**1180**
Moisture Content (Dried @ 105-110°C)	%	1.0	**59.7**	**23.9**	**----**	**28.6**	**29.8**
Total Alkalinity as CaCO3	mg/kg	1	**77**	**4**	**2**	**71**	**120**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**77**	**4**	**2**	**67**	**120**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1	<1	<1	**4**	<1
Acidity	mg/kg	1	**12**	<1	**14**	**4**	**4**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**80**	**40**	**120**	**20**	**200**
Chloride (by Discrete Analyser)	mg/kg	10	**100**	**20**	<10	**30**	**170**
Calcium	mg/kg	10	**220**	<10	**30**	**50**	**40**
Magnesium	mg/kg	10	**110**	<10	<10	**60**	**70**
Sodium	mg/kg	10	**170**	**20**	**10**	**40**	**220**
Potassium	mg/kg	10	**20**	<10	**10**	<10	**20**
Mercury (FIMS)	mg/kg	0.1	**0.6**	**4.4**	<0.1	<0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1	**0.1**	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**3950**	**750**	**1110**	**520**	**1090**
Total Nitrogen as N	mg/kg	20	**3950**	**750**	**1110**	**520**	**1090**
Total Phosphorus as P	mg/kg	2	**242**	**320**	**60**	**73**	**100**

Analyte grouping/Analyte	Unit	LOR	South Star Pool	Cow Spring Pool	Fig Pool	Site 12 Pool	Central Ck Pool
Reactive Phosphorus as P	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Organic Carbon	%	0.02	**3.15**	**0.22**	**0.30**	**0.18**	**1.80**
Total Metals by ICP-AES							
Arsenic	mg/kg	5	**9**	**9**	<5	<5	**9**
Barium	mg/kg	10	**40**	<10	**10**	**50**	**40**
Beryllium	mg/kg	1	**1**	<1	<1	<1	<1
Boron	mg/kg	50	<50	<50	<50	<50	<50
Cadmium	mg/kg	1	<1	<1	<1	<1	<1
Chromium	mg/kg	2	**169**	**165**	**143**	**384**	**219**
Cobalt	mg/kg	2	**22**	**4**	<2	**23**	**16**
Copper	mg/kg	5	**52**	**7**	**8**	**23**	**22**
Iron	mg/kg	50	**76600**	**124000**	**58500**	**32800**	**26600**
Lead	mg/kg	5	<5	**9**	<5	<5	<5
Manganese	mg/kg	5	**481**	**151**	**94**	**561**	**476**
Nickel	mg/kg	2	**79**	**18**	**6**	**179**	**112**
Selenium	mg/kg	5	**5**	**6**	<5	<5	<5
Vanadium	mg/kg	5	**166**	**62**	**27**	**48**	**39**
Zinc	mg/kg	5	**39**	**16**	**5**	**26**	**35**

Analyte grouping/Analyte	Unit	LOR	Mundagoora Pool	Fig Pool	Site 12 Pool
		Sample Date	08/12/2020	10/12/2020	09/12/2020
		ALS Sample Number	EP2013964-012	EP2013964-013	EP2013964-014
Total Soluble Salts	mg/kg	5	**-**		
Moisture Content (Dried @ 105-110°C)	%	1.0	**49.3**	**38.3**	**20.9**
Total Alkalinity as CaCO3	mg/kg	1	**104**	**<5**	**329**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**104**	**<5**	**265**
Carbonate Alkalinity as CaCO3	mg/kg	1	<5	<5	**65**
Acidity	mg/kg	1	**53**	**166**	**<5**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**70**	**160**	**<10**
Chloride (by Discrete Analyser)	mg/kg	10	**40**	**40**	**30**
Calcium	mg/kg	10	**30**	**<10**	**40**
Magnesium	mg/kg	10	**20**	10	**90**
Sodium	mg/kg	10	**100**	**40**	**40**
Potassium	mg/kg	10	<10	**30**	<10
Mercury (FIMS)	mg/kg	0.1	-		
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**1970**	**1670**	**200**
Total Nitrogen as N	mg/kg	20	**1970**	**1670**	**200**
Total Phosphorus as P	mg/kg	2	**179**	**223**	**61**
Reactive Phosphorus as P	mg/kg	0.1	<0.1	<0.1	<0.1

Total Organic Carbon	%	0.02	**4.88**	**3.60**	**0.29**
Total Metals by ICP-AES					
Arsenic	mg/kg	5	-		
Barium	mg/kg	10	-		
Beryllium	mg/kg	1	-		
Boron	mg/kg	50	-		
Cadmium	mg/kg	1	-		
Chromium	mg/kg	2	-		
Cobalt	mg/kg	2	-		
Copper	mg/kg	5	-		
Iron	mg/kg	50	**57000**	**90200**	**41200**
Lead	mg/kg	5	-		
Manganese	mg/kg	5	-		
Nickel	mg/kg	2	-		
Selenium	mg/kg	5	-		
Vanadium	mg/kg	5	-		
Zinc	mg/kg	5	-		

Table. Sediment quality data – late dry season (2020). Bold font denotes values above the limit of reporting (LOR)

Table. Sediment quality data – late wet season (2021). Bold font denotes values above the limit of reporting (LOR)

Analyte grouping/Analyte	Unit	LOR	Mundagoora Pool	Fig Pool	Site 12 Pool	Central Ck Pool
		Sample Date	21/05/2021	30/05/2020	23/05/2021	28/05/2021
		ALS Sample Number	EP2106077-001	EP2106077-005	EP2106077-006	EP2106077-003
Total Soluble Salts	mg/kg	5	**200**	**384**	**402**	**559**
Moisture Content (Dried @ 105-110°C)	%	1.0	**24.8**	**37**	**25**	**19.1**
Total Alkalinity as CaCO3	mg/kg	1	<5	**<5**	**26**	<5
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**239**	**<5**	**26**	**198**
Carbonate Alkalinity as CaCO3	mg/kg	1	**239**	<5	**253**	**198**
Acidity	mg/kg	1	**62**	**1000**	**<5**	<5
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	<10	**150**	**<10**	**40**
Chloride (by Discrete Analyser)	mg/kg	10	**20**	**60**	**20**	**90**
Calcium	mg/kg	10	30	**<10**	**30**	<10
Magnesium	mg/kg	10	**20**	10	**60**	**40**
Sodium	mg/kg	10	**30**	**12**	**6**	**10**
Potassium	mg/kg	10	<10	**10**	<10	<10
Mercury (FIMS)	mg/kg	0.1	<0.1	**0.2**	<0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1	**0.2**	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**430**	**3030**	**80**	**80**
Total Nitrogen as N	mg/kg	20	**430**	**3030**	**80**	**80**
Total Phosphorus as P	mg/kg	2	**190**	**310**	**56**	**43**

Analyte grouping/Analyte	Unit	LOR	Mundagoora Pool	Fig Pool	Site 12 Pool	Central Ck Pool
Reactive Phosphorus as P	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Total Organic Carbon	%	0.02		**3.08**	**0.2**	**0.18**
Total Metals by ICP-AES						
Arsenic	mg/kg	5	**9**	**12**	**6**	**10**
Barium	mg/kg	10	**60**	**40**	**70**	**30**
Beryllium	mg/kg	1	<1	<1	<1	<1
Boron	mg/kg	50	**50**	<50	<50	<50
Cadmium	mg/kg	1	<1	<1	<1	<1
Chromium	mg/kg	2	**68**	**127**	**492**	**247**
Cobalt	mg/kg	2	**33**	**2**	**36**	**18**
Copper	mg/kg	5	**67**	**24**	**37**	**17**
Iron	mg/kg	50	**114000**	**64600**	**49400**	**30600**
Lead	mg/kg	5	6	<5	<5	<5
Manganese	mg/kg	5	**674**	**39**	**894**	**492**
Nickel	mg/kg	2	**134**	**12**	**246**	**113**
Selenium	mg/kg	5	<5	<5	<5	<5
Vanadium	mg/kg	5	**161**	**53**	**65**	**36**
Zinc	mg/kg	5	**30**	**8**	**44**	**20**

APPENDIX C. FISH DATA

Table 27 Fish catch summary table – Late Wet 2020

Species	Central Creek Pool	Cow Spring Pool	Site 12 Pool	South Star Pool	Fig Pool
Neosilurus hyrtlii	0	0	37	0	0
50 - 90 mm	0	0	18	0	0
90 - 130 mm	0	0	16	0	0
130 - 170 mm	0	0	3	0	0
Melanotaenia australis	171	67	196	212	0
< 30 mm	1	13	0	63	0
30 - 60 mm	113	37	84	95	0
60 - 90 mm	57	15	112	54	0
> 90 mm	0	2	0	0	0
Leiopotherapon unicolor	207	0	24	1	0
30 - 60 mm	109	0	7	0	0
60 - 90 mm	53	0	10	0	0
> 90 mm	45	0	7	1	0
Total catch	378	67	257	213	0
Soak duration	19	17.7	15.5	16.5	16
CPUE	19.9	3.8	16.6	12.9	0

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is net and trap soak duration hours.

Fish standard length and total length - Late Wet 2020

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	32	37
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	36	45
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	38	47
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	37	49
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	41	49
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Leiopotherapon unicolor*	42	50
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	46	56
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	46	58
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	49	58
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	55	67
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	60	74
Central Ck Pool	Box	1	26/06/2020	16:00	10:30	Muddy	*Leiopotherapon unicolor*	66	81
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	69	85
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	75	94
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	80	97
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	81	100
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	87	109
Central Ck Pool	Box	1	26/06/2020	16:00	10:30	Muddy	*Leiopotherapon unicolor*	94	115
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	100	125
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	107	130
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	115	139
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	119	141
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	119	142
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	120	144

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	120	145
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	127	154
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	134	160
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	134	161
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	147	173
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	174	205
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	29	38
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	33	41
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	33	42
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	33	42
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	39	43
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	37	46
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	46
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	47
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	48
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	48
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	49
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	39	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	41	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	40	51
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	41	51
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	40	52
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	47	60
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	47	61

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	49	61
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	49	62
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	50	64
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	52	65
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	53	65
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	53	66
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	59	75
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	65	80
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	67	84
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Melanotaenia australis*	67	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	17	22
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	18	23
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	20	25
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	23	27
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	23	30
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	24	30
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	24	31
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	25	32
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	29	37
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	39
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	32	40
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	31	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	33	42
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	33	43

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	35	43
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	38	46
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	40	50
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	49	62
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	53	67
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	57	72
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	60	74
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	62	80
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	67	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	68	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	70	86
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	71	87
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	80	100
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	83	104
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Uperoleia sp.*	NA	24
Cow Spring Pool	Bait	1	29/06/2020	16:00	9:30	Marco/Edge	*Uperoleia sp.*	NA	29
Cow Spring Pool	Bait	2	29/06/2020	16:00	9:30	Reeds	*Uperoleia sp.*	NA	35
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Uperoleia sp.*	NA	36
Cow Spring Pool	Bait	1	29/06/2020	16:00	9:30	Marco/Edge	*Uperoleia sp.*	NA	40
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	32	41
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	38	50
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	43	54
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	44	55
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	45	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	46	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	47	59

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	49	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	52	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	54	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	55	71
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	58	73
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	59	74
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	64	79
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	70	87
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	78	92
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	79	95
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	104	122
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	111	134
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	148	162
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	155	182
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	166	199
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	45	56
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	58
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	58
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	59
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	59
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	60
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	60
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	60

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	50	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	51	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	51	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	52	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	52	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	69
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	59	75
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	68	76
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	58	77
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	55	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	54	69
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	67	75
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	70	76
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	65	77

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	70	80
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	72	80
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	72	81
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	73	82
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	74	84
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	75	84
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	76	85
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	75	86
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	76	86
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	79	87
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	79	88
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	90
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	91
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	82	91
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	92
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	84	94
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	92	104
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	95	105
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	95	106
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	97	110
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	101	111
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	102	113
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	105	117
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	105	120
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	120
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	107	122

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	123
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	125
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	115	126
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	125	144
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	129	144
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	150	162
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Leiopotherapon unicolor*	104	126
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	21	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	21	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	27
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	30
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	24	31
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	25	31
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	32
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	33
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	33
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	41	53
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	43	53
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	55
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	45	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	58
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	48	61
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	50	62

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	50	63
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	54	66
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	53	67
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	55	69
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	55	70
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	57	70
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	59	74
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	63	80
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	64	80
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	63	81
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	65	82

Table. Fish standard length (SL) and total length (TL) for Iron Bridge pools in the late dry season 2020

Site Name	Gear Type	Replicate	Date	Time Out	Habitat Type	Species	SL	TL	Size
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	25	33	X Small (<30mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	28	37	X Small (<30mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	30	39	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	30	38	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	30	39	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	31	40	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	32	41	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	34	42	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	36	46	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	37	47	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	38	50	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	39	51	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	39	50	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	40	51	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	40	51	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	40	50	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	42	53	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	43	56	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	45	57	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	47	61	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	48	60	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	50	63	Small (30-60mm)

Site Name	Gear Type	Replicate	Date	Time Out	Habitat Type	Species	SL	TL	Size
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	55	72	Small (30-60mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	70	85	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	72	92	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	75	94	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	81	112	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	83	112	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	86	110	Large (60-90mm)
Cow Spring Pool	Fyke	1	11/12/2020	9:37	Pool	Melanotaenia australis	87	111	Large (60-90mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	20	25	X Small (<30mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	25	32	X Small (<30mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	26	33	X Small (<30mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	28	32	X Small (<30mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	32	40	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	33	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	33	41	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	34	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	35	45	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	35	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	35	42	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	36	44	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	36	47	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	37	74	Small (30-60mm)

Site Name	Gear Type	Replicate	Date	Time Out	Habitat Type	Species	SL	TL	Size
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	37	46	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	38	50	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	39	51	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	40	51	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	43	55	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	50	61	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	57	70	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	58	71	Small (30-60mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	60	74	Large (60-90mm)
Mundagoora Pool	Fyke	1	9/12/2020	9:24	Pool	Melanotaenia australis	62	76	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	34	41	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	48	60	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	49	63	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	49	61	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	50	62	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	50	61	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	50	63	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	53	66	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	53	67	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	53	65	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	55	70	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	55	69	Small (30-60mm)

Site Name	Gear Type	Replicate	Date	Time Out	Habitat Type	Species	SL	TL	Size
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	55	69	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	55	70	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	58	71	Small (30-60mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Melanotaenia australis	62	76	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	62	75	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	67	81	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	71	84	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	72	85	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	75	90	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	75	92	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	80	98	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Neosilurus hyrtlii	80	89	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Leiopotherapon unicolor	81	96	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Neosilurus hyrtlii	81	90	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Neosilurus hyrtlii	83	93	Large (60-90mm)
Site 12 Pool	Fyke	1	10/12/2020	10:00	Pool	Neosilurus hyrtlii	87	96	Large (60-90mm)

Table. Fish standard length (SL) and total length (TL) for Iron Bridge pools in the late wet season 2021

Site Name	Gear Type	Replicate	Date	Habitat Type	Species	SL	TL	Size
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	30	39	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	38	50	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	49	62	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	49	65	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	50	62	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	79	96	Large (60-90mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Rainbow	80	100	Large (60-90mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	39	47	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	42	54	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	42	53	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	43	53	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	47	57	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	47	58	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	47	57	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	49	60	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	50	62	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	50	62	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	55	104	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	55	66	Small (30-60mm)
Cent Creek	Fyke	1	23/05/2021	Pool	Spangled	80	97	Large (60-90mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	23	31	X Small (<30mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	30	36	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	31	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	32	41	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	32	40	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	32	41	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	32	40	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	32	39	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbow	33	43	Small (30-60mm)

Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 3	41	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 3	42	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	45	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	40	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	42	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	42	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 4	43	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 5	46	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 6	46	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 7	47	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 8	47	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 8	50	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	3 8	47	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	5 3	67	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	5 7	73	Small (30-60mm)
Mundagoora Pool	Fyke	1	22/05/2021	Pool	Rainbo w	7 0	90	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	2 4	31	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	2 5	33	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 6	34	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 7	35	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 8	36	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 8	34	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 9	38	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	2 9	38	X Small (<30mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	3 0	38	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	3 0	39	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	3 0	40	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangle d	3 3	42	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	3 4	44	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	3 4	44	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	3 4	43	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbo w	3 4	42	Small (30-60mm)

Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	34	43	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	34	44	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	34	45	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	34	43	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	35	46	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	36	47	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	40	53	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	40	50	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	40	53	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	42	55	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	42	53	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	43	55	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	45	58	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	57	72	Small (30-60mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	60	75	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Rainbow	62	77	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	70	85	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Catfish	70	80	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	75	92	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	81	100	Large (60-90mm)
Site 12 Pool	Fyke	1	24/05/2021	Pool	Spangled	87	106	Large (60-90mm)

APPENDIX D. MACROINVERTEBRATE DATA

			Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
			Habitat	Edge	Edge	Pool	Edge	Macrophyte	Macrophyte	Macrophyte	Edge	Macrophyte	Edge
			Replicate	1	2	1	2	1	2	1	2	1	2
			Date Sampled	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	28/06/2020	28/06/2020	29/06/2020	29/06/2020
			Sampled By	SK	SK	SK	SK	SK	SK	SK	SK	SK	SK
			Pick and ID By	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ
			ID Date	27/07/2020	28/07/2020	28/07/2020	28/07/2020	29/07/2020	30/07/2020	30/07/2020	30/07/2020	30/07/2020	31/07/2020
SIGNAL2 Score	**AusRivAS taxa code**	**Order**	**Family**										
1		**Hydrozoa**	**Hydrozoa**										
3	IB029999	Hydrozoa	Oceaniidae										
2	IB019999	Hydrozoa	Hydridae									1	
		Hydrozoa	Olindiidae										
1	**KG999999**	**Gastropoda**	**Gastropoda**										
	-	Gastropoda	Ampullariidae										
4	KG069999	Gastropoda	Ancylidae					10				5	
3	KG039999	Gastropoda	Bithyniidae										
5	KG099999	Gastropoda	Glacidorbidae										
1	KG059999	Gastropoda	Lymnaeidae					12	4		1	7	
	KG109999	Gastropoda	Neritidae										
1	KG089999	Gastropoda	Physidae										
2	KG079999	Gastropoda	Planorbidae					3	8	3		3	
4	KG029999	Gastropoda	Tateidae										
4	KG049999	Gastropoda	Thiaridae										
4	KG019999	Gastropoda	Viviparidae										
2	**QO219999**	**Oligochaeta**	**Oligochaeta**				**4**	**1**	**1**	**4**	**1**	**6**	
	LP999999	**Polychaeta**	**Polychaeta**										
	-	**Araneae**	**Araneae**				**1**	**1**	**1**	**2**	**1**		
6	**MM999999**	**Acarina**	**Acarina**	**10**	**3**	**2**	**2**	**5**	**21**	**14**	**14**	**11**	**8**
		GROUP	**Microcrustacea**										
	OG999999	Cladocera	Cladocera					2	11			4	1
1	OF999999	Conchostraca	Conchostraca										

	OJ999999	Copepoda	Copepoda			1	5	6		3	4	2	2
	OH999999	Ostracoda	Ostracoda				1	15				16	
5	**QCZZ9999**	**Coleoptera**	**Coleoptera**										
3	QCAM9999	Coleoptera	Brentidae										
3	QC059999	Coleoptera	Carabidae										
2	QCAH9999	Coleoptera	Chrysomelidae										
2	QCAN9999	Coleoptera	Curculionidae										
2	QC099999	Coleoptera	Dytiscidae	9	6	2	7			2	2	3	2
7	QC349999	Coleoptera	Elmidae										
2	QC119999	Coleoptera	Georissidae										
4	QC109999	Coleoptera	Gyrinidae										
2	QC069999	Coleoptera	Haliplidae										
1	QC369999	Coleoptera	Heteroceridae										
3	QC139999	Coleoptera	Hydraenidae									1	
4	QCAO9999	Coleoptera	Hydrochidae			1	2	2				1	
2	QC119999	Coleoptera	Hydrophilidae	10	2	2	2				1	3	
1	QC079999	Coleoptera	Hygrobiidae										
4	QC359999	Coleoptera	Limnichidae								1		
4	QC089999	Coleoptera	Noteridae										
6	QC379999	Coleoptera	Psephenidae										
10	QC399999	Coleoptera	Ptilodactylidae										
6	QC209999	Coleoptera	Scirtidae									4	
2	QC119999	Coleoptera	Spercheidae										
7	QC039999	Coleoptera	Sphaeriusidae										
3	QC189999	Coleoptera	Staphylinidae										
3	**QDZZ9999**	**Diptera**	**Diptera**										
8	QD229999	Diptera	Athericidae										
10	QD049999	Diptera	Blephariceridae										
4	QD099999	Diptera	Ceratopogonidae			7	9	3	2	4	2	10	
2	QD059999	Diptera	Chaoboridae										
3	QDAZ9999	Diptera	Chironomidae										
8	QDAA9999	Diptera	s-f Aphroteniinae										
3	QDAJ9999	Diptera	s-f Chironominae	23	25	16	26	9	20	21	3	25	22
6	QDAB9999	Diptera	s-f Diamesinae										
4	QDAF9999	Diptera	s-f Orthocladiinae			1						1	

6	QDAD9999	Diptera	s-f Podonominae										
4	QDAE9999	Diptera	s-f Tanypodinae			14	11	15	9	19	15	25	4
	-	Diptera	Corethrellidae										
1	QD079999	Diptera	Culicidae	1	4				1			1	
7	QD069999	Diptera	Dixidae										
3	QD369999	Diptera	Dolichopodidae										
5	QD359999	Diptera	Empididae										
2	QD789999	Diptera	Ephydridae			1	2						
1	QD899999	Diptera	Muscidae				1						
3	QD129999	Diptera	Psychodidae				1						
6	-	Diptera	Sciaridae										
2	QD459999	Diptera	Sciomyzidae									1	
5	QD109999	Diptera	Simuliidae										
2	QD249999	Diptera	Stratiomyidae			4	1			2	3	1	
2	QD439999	Diptera	Syrphidae										
3	QD239999	Diptera	Tabanidae				1						
6	QD039999	Diptera	Tanyderidae										
7	QD119999	Diptera	Thaumaleidae										
5	QD019999	Diptera	Tipulidae									1	
9	**QE999999**	**Ephemeroptera**	**Ephemeroptera**										
7	QE049999	Ephemeroptera	Ameletopsidae										
5	QE029999	Ephemeroptera	Baetidae					9	13	2	2	9	12
4	QE089999	Ephemeroptera	Caenidae			7	14	10	1	1		12	2
8	QE059999	Ephemeroptera	Coloburiscidae										
8	QE069999	Ephemeroptera	Leptophlebiidae										
10	-	Ephemeroptera	Nesameletidae										
8	QE039999	Ephemeroptera	Oniscigastridae										
4	QE099999	Ephemeroptera	Prosopistomatidae										
9	QE079999	Ephemeroptera	Teloganodidae										
2	**QHZZ9999**	**Hemiptera**	**Hemiptera**										
	-	Hemiptera	Aphelocheiridae										
1	QH629999	Hemiptera	Belostomatidae									2	
2	QH659999	Hemiptera	Corixidae										
	-	Hemiptera	Dipsocoridae										
5	QH649999	Hemiptera	Gelastocoridae										

4	QH579999	Hemiptera	Gerridae							2	2	2	
3	QH539999	Hemiptera	Hebridae			1					3		
3	QH549999	Hemiptera	Hydrometridae										
	QH589999	Hemiptera	Leptopodidae										
2	QH529999	Hemiptera	Mesoveliidae			1						1	
2	QH659999	Hemiptera	Micronectidae					1			1	1	
2	QH669999	Hemiptera	Naucoridae										
3	QH619999	Hemiptera	Nepidae			1	1					2	
1	QH679999	Hemiptera	Notonectidae	2	3								
2	QH639999	Hemiptera	Ochteridae										
2	QH689999	Hemiptera	Pleidae			8	4	3		1	2	1	1
1	QH609999	Hemiptera	Saldidae										
3	QH569999	Hemiptera	Veliidae	1		4				1		1	
3	**QO999999**	**Odonata**	**Odonata**										
3	**QO999997**	**Odonata**	**S.O. Zygoptera**										
5	QO079999	Odonata	Argiolestidae										
	QO109999	Odonata	Calopterygidae										
	QO189999	Odonata	Chorismagrionidae										
2	QO029999	Odonata	Coenagrionidae		1	7		9	10	7	2	14	2
6	QO099999	Odonata	Diphlebiidae										
	QO019999	Odonata	Hemiphlebiidae										
9	QO069999	Odonata	Hypolestidae										
3	QO039999	Odonata	Isostictidae			3							
1	QO069999	Odonata	Lestidae										
4	QO049999	Odonata	Platycnemididae										
7	QO089999	Odonata	Synlestidae										
3	**QO999998**	**Odonata**	**S.O. Epiproctiphora**				**1**	**1**					
4	QO129999	Odonata	Aeshnidae		1				5			1	1
	QO199999	Odonata	Archipetaliidae										
10	QO279999	Odonata	Austrocorduliidae										
	QO209999	Odonata	Austropetaliidae										
9	QO219999	Odonata	Brachytronidae										
	QO289999	Odonata	Cordulephyidae										
5	QO169999	Odonata	Corduliidae					1				1	
5	QO139999	Odonata	Gomphidae										

	QO249999	Odonata	Gomphomacromiidae										
5	QO309999	Odonata	Hemicorduliidae										
4	QO179999	Odonata	Libellulidae	15	15			1	7	2		9	9
3	QO229999	Odonata	Lindeniidae										
8	QO269999	Odonata	Macromiidae										
	QO299999	Odonata	Oxygastridae										
	QO159999	Odonata	Petaluridae										
	QO259999	Odonata	Pseudocorduliidae										
2	QO239999	Odonata	Synthemistidae										
9	QO219999	Odonata	Telephlebiidae										
8	**QT999999**	**Trichoptera**	**Trichoptera**										
8	QT169999	Trichoptera	Antipodoeciidae										
7	QT239999	Trichoptera	Atriplectididae										
7	QT249999	Trichoptera	Calamoceratidae										
9	QT189999	Trichoptera	Calocidae										
7	QT159999	Trichoptera	Conoesucidae										
9	QT269999	Trichoptera	Dipseudopsidae										
4	QT089999	Trichoptera	Ecnomidae					3		7		2	1
9	QT029999	Trichoptera	Glossosomatidae										
10	QT199999	Trichoptera	Helicophidae										
8	QT179999	Trichoptera	Helicopsychidae										
10		Trichoptera	Heloccabucidae										
8	QT019999	Trichoptera	Hydrobiosidae										
6	QT069999	Trichoptera	Hydropsychidae										
4	QT039999	Trichoptera	Hydroptilidae			2	3		4	3	3	3	
3	QT209999	Trichoptera	Kokiriidae										
6	QT259999	Trichoptera	Leptoceridae			2	6	4	2	5		5	
8	QT109999	Trichoptera	Limnephilidae										
7	QT229999	Trichoptera	Odontoceridae										
8	QT129999	Trichoptera	Oeconesidae										
8	QT049999	Trichoptera	Philopotamidae										
8	QT219999	Trichoptera	Philorheithridae										
	QT119999	Trichoptera	Plectrotarsidae										
7	QT079999	Trichoptera	Polycentropodidae										
	QT099999	Trichoptera	Psychomyiidae										

	QT059999	Trichoptera	Stenopsychidae										
8	QT139999	Trichoptera	Tasimiidae										
3	**QL019999**	**Lepidoptera**	**Crambidae**					**1**	**6**			**2**	

Table 28 Macroinvertebrate taxa present at Iron Bridge pools in the late dry season (2020)

	Site		Cow spring		Fig pool		Site 12 Pool		Mundagoora Pool	
	Date sampled		11/12/2020		10/12/2020		9/12/2020		8/12/2020	
	Replicate		1	2	1	2	1	2	1	2
Order	**Family**	**Signal2 score**								
Nematoda	**Nematoda**	*3*						**1**		
Gastropoda	**Gastropoda**	*1*								
	Ancylidae	*4*	2	2					7	3
	Lymnaeidae	*1*	6	9					8	12
	Planorbidae	*2*	7	9				1	10	15
Oligochaeta	**Oligochaeta**	*2*	**2**	**2**				**2**	**4**	**3**
Araneae	**Araneae**									**1**
Acarina	**Acarina**	*6*	**7**	**10**	**3**			**1**	**8**	**6**
Group	**Microcrustacea**									
Cladocera	Cladocera						9		5	1
Copepoda	Copepoda		2	2				4	9	7
Ostracoda	Ostracoda								11	11
Coleoptera	**Coleoptera**	*5*								

	Site		Cow spring		Fig pool		Site 12 Pool		Mundagoora Pool	
	Dytiscidae	*2*	3	2	5	1			3	4
	Hydraenidae	*3*							1	
	Hydrochidae	*4*							18	2
	Hydrophilidae	*2*	2	1		7		1	1	2
	Scirtidae	*6*								5
Diptera	**Diptera**	*3*								
	Ceratopogonidae	*4*	4	8			7	5	4	7
	S-f chironominae	*3*	24	27	28	29	28	16	19	20
	S-f tanypodinae	*4*	10	11		6	12	16	7	23
	Culicidae	*1*		1	1	1				
	Stratiomyidae	*2*						5		
	Tabanidae	*3*						1		
Ephemeroptera	**Ephemeroptera**	*9*								
	Baetidae	*5*	9					3	5	5
	Caenidae	*4*		3				1	6	11
Hemiptera	**Hemiptera**	*2*								
	Belostomatidae	*1*	1							
	Gerridae	*4*		4		3				1
	Mesoveliidae	*2*							1	1
	Micronectidae	*2*								1
	Pleidae	*2*							3	1

	Site		Cow spring		Fig pool		Site 12 Pool		Mundagoora Pool	
	Veliidae	*3*			2	13			1	2
Odonata	**Odonata**	*3*								
	Coenagrionidae	*2*	12	16	13	23			6	15
	Gomphidae	*5*					3			
	Libellulidae	*4*	11	10	12	15		2	2	
Trichoptera	**Trichoptera**	*8*								
	Ecnomidae	*4*							1	
	Hydroptilidae	*4*					1			1
	Leptoceridae	*6*	1	1				2	22	22
Lepidoptera	**Crambidae**	*3*	**7**	**3**						

Table: Macroinvertebrate data for the Late Wet Season 2021

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
	Replicate	1	2	1	2	1	2	1	2	1	2
	Date Sampled	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	28/06/2020	28/06/2020	29/06/2020	29/06/2020
Order	**Family**										
Hydrozoa	Hydridae									1	
Gastropoda	Ancylidae					10				5	

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
Gastropoda	Lymnaeidae					12	4		1	7	
Gastropoda	Planorbidae					3	8	3		3	
Oligochaeta	**Oligochaeta**				**4**	**1**	**1**	**4**	**1**	**6**	
Araneae	**Araneae**				**1**	**1**	**1**	**2**	**1**		
Acarina	**Acarina**	**10**	**3**	**2**	**2**	**5**	**21**	**14**	**14**	**11**	**8**
Cladocera	Cladocera					2	11			4	1
Copepoda	Copepoda			1	5	6		3	4	2	2
Ostracoda	Ostracoda				1	15				16	
Coleoptera	Dytiscidae	9	6	2	7			2	2	3	2
Coleoptera	Hydraenidae									1	
Coleoptera	Hydrochidae			1	2	2				1	
Coleoptera	Hydrophilidae	10	2	2	2				1	3	
Coleoptera	Limnichidae								1		
Coleoptera	Scirtidae									4	
Diptera	Ceratopogonidae			7	9	3	2	4	2	10	
Diptera	s-f Chironominae	23	25	16	26	9	20	21	3	25	22

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
Diptera	s-f Orthocladiinae			1						1	
Diptera	s-f Tanypodinae			14	11	15	9	19	15	25	4
Diptera	Culicidae	1	4				1			1	
Diptera	Ephydridae			1	2						
Diptera	Muscidae				1						
Diptera	Psychodidae				1						
Diptera	Sciomyzidae									1	
Diptera	Stratiomyidae			4	1			2	3	1	
Diptera	Tabanidae				1						
Diptera	Tipulidae									1	
Ephemeroptera	Baetidae					9	13	2	2	9	12
Ephemeroptera	Caenidae			7	14	10	1	1		12	2
Hemiptera	Belostomatidae									2	
Hemiptera	Gerridae							2	2	2	
Hemiptera	Hebridae			1					3		
Hemiptera	Mesoveliidae			1						1	

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
Hemiptera	Micronectidae					1			1	1	
Hemiptera	Nepidae			1	1					2	
Hemiptera	Notonectidae	2	3								
Hemiptera	Pleidae			8	4	3		1	2	1	1
Hemiptera	Veliidae	1		4				1		1	
Odonata	**Odonata**										
Odonata	Coenagrionidae		1	7		9	10	7	2	14	2
Odonata	Isostictidae			3							
Odonata	**S.O. Epiproctiphora**				**1**	**1**					
Odonata	Aeshnidae		1				5			1	1
Odonata	Corduliidae					1				1	
Odonata	Libellulidae	15	15			1	7	2		9	9
Trichoptera	Ecnomidae					3		7		2	1
Trichoptera	Hydroptilidae			2	3		4	3	3	3	
Trichoptera	Leptoceridae			2	6	4	2	5		5	
Lepidoptera	**Crambidae**					**1**	**6**			**2**	

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
	Abundance	71	60	87	105	127	126	105	63	200	67
	Taxonomic Richness	8	9	21	22	24	18	20	19	39	13
	PET Richness	0	0	3	3	4	4	5	2	5	3
	Terrestrial insect	1					7	5	5		1

	Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
	SMI Comments		3 Chironominae and 2 Culicidae are pupa	1 Hydroptilidae is a very early instar.	1 Hydroptilidae is a very early instar. Oligochaeta very small and unidentified Epiproctaphora too small to identify to family level. 1 Chironominae is a pupa.	1 Ceratopogonidae is a pupa. Label disintegrated when the sample was rinsed so I am unsure what habitat type sample was collected from. Unidentified Epiproctaphora too small to identify to family level.	1 Hydroptilidae, 1 Ceratopogonidae and 3 Chironominae are pupa. 1 Leptoceridae and Ecnomidae very small.	Partially live-picked sample. 1 Tanypodinae and 1 Ceratopogonidae are pupa. Many very small Chironomids.	1 Chironominae and 1 Ceratopogonidae are pupa. Limnichidae is an adult, which are generally considered semi-aquatic / terrestrial.	Photo of specimen is an Aeshnidae (can just see bifid apex of epiproct) and this record has been included in this data. 1 Ceratopogonidae is a pupa.	Some very small Acarina.

APPENDIX E. DIATOM DATA

Diatom species and count data for the five surveyed pools – Late Wet 2020.

Taxon name		Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
	Replicate Number	1	2	1	2	1	2	1	2	1	2
	Collection date	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	27/06/2020	27/06/2020	28/06/2020	28/06/2020
	Sample description	no valves	no valves					very sparse	very sparse. teratological forms	no valves	very sparse
Total Count		**0**	**0**	**394**	**352**	**420**	**386**	**60**	**166**	**0**	**28**
DSIAR Score		**NA**	**NA**	**41.3**	**42.6**	**59.1**	**66.3**	**54.7**	**53.95**	**NA**	**64.25**
Achnanthes brevipes		0	0	22	12	302	92	4	24	0	8
Achnanthes impexa		0	0	0	0	48	164	4	8	0	0
Achnanthes subexigua		0	0	4	0	14	70	8	10	0	8
Achnanthidium exiguum		0	0	2	0	12	24	0	0	0	0
Achnanthidium kryophila		0	0	0	0	8	4	0	0	0	0
Achnanthidium lineare		0	0	0	0	6	8	0	0	0	2
Achnanthidium minutissimum		0	0	0	0	6	0	0	0	0	0
Achnanthidium minutissimum var affine		0	0	0	2	4	4	0	0	0	4
Achnanthidium spp.		0	0	2	0	4	4	0	0	0	0
Actinocyclus normanii		0	0	0	0	4	0	0	0	0	0
Adlafia aff bryophila		0	0	0	0	4	0	0	0	0	0
Adlafia minuscula v. muralis		0	0	0	0	4	0	0	0	0	0

Taxon name	Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Amphicampa mirabilis	0	0	6	2	2	0	0	0	0	0
Amphipleura pellucida	0	0	0	0	2	0	0	0	0	0
Amphora delicatissima	0	0	0	4	0	0	0	0	0	2
Amphora libyca	0	0	0	0	0	0	0	0	0	2
Amphora ovalis	0	0	0	0	0	0	0	0	0	2
Amphora pediculus	0	0	0	2	0	0	42	112	0	0
Amphora spp.	0	0	0	0	0	0	0	6	0	0
Aneumastus tuscula	0	0	0	0	0	2	0	4	0	0
Anomoneis spaerophora	0	0	0	0	0	0	0	2	0	0
Asterionella ralfsii var americana	0	0	246	270	0	0	2	0	0	0
Aulacoseira ambigua	0	0	4	0	0	12	0	0	0	0
Aulacoseira crenulata	0	0	0	0	0	2	0	0	0	0
Aulacoseira granulata	0	0	40	16	0	0	0	0	0	0
Bacillaria paxillifer	0	0	10	8	0	0	0	0	0	0
Brachysira brebissonii	0	0	12	6	0	0	0	0	0	0
Brachysira styriaca	0	0	0	6	0	0	0	0	0	0
Brachysira vitrea	0	0	8	4	0	0	0	0	0	0
Caloneis aerophila	0	0	0	4	0	0	0	0	0	0
Caloneis silicula	0	0	0	4	0	0	0	0	0	0
Chamaepinnularia bremensis	0	0	0	4	0	0	0	0	0	0
Chamaepinnularia muscicola	0	0	0	2	0	0	0	0	0	0

Taxon name		Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Cocconeis pediculus		0	0	0	2	0	0	0	0	0	0
Cocconeis placentula		0	0	0	2	0	0	0	0	0	0
Cocconeis placentula var. euglypta		0	0	0	2	0	0	0	0	0	0
Cocconeis placentula var. lineata		0	0	28	0	0	0	0	0	0	0
Cocconeis pseudothumensis		0	0	4	0	0	0	0	0	0	0
Craticula accomoda		0	0	2	0	0	0	0	0	0	0
Craticula cuspidata		0	0	2	0	0	0	0	0	0	0
Craticula halophila		0	0	2	0	0	0	0	0	0	0

Diatom species and count data - late wet 2021

Sample name:	Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Further sample details:	1 of 2	2 of 2	1 of 2	2 of 2	1 of 2	2 of 2	1 of 2	2 of 2	1 of 2	2 of 2
Date	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	27/06/2020	27/06/2020	28/06/2020	28/06/2020
Taxon name/Notes:	no valves	no valves					very sparse	very sparse and teratological forms	no valves	very sparse
Achnanthidium exiguum	0	0	246	270	0	0	2	0	0	0
Achnanthidium minutissimum	0	0	22	12	302	92	4	24	0	8

Sample name:	Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Amphora spp.	0	0	0	0	0	0	0	6	0	0
Brachysira brebissonii	0	0	0	2	0	0	0	0	0	0
Brachysira vitrea	0	0	0	0	48	164	4	8	0	0
Caloneis silicula	0	0	0	0	0	2	0	4	0	0
Craticula halophila	0	0	0	0	2	0	0	0	0	0
Cymbella affinis	0	0	0	0	6	8	0	0	0	2
Cymbella spp	0	0	0	2	4	4	0	0	0	4
Diploneis parma	0	0	6	2	2	0	0	0	0	0
Encyonema minutum	0	0	0	0	4	0	0	0	0	0
Eolimna minima	0	0	2	0	0	0	0	0	0	0
Eunotia bilunaris	0	0	4	0	14	70	8	10	0	8
Eunotia faba	0	0	0	0	0	0	0	0	0	2
Eunotia incisa	0	0	0	0	0	0	0	2	0	0
Fragilaria spp.	0	0	2	0	0	0	0	0	0	0
Hantzschia amphioxys	0	0	0	4	0	0	0	0	0	2
Luticola mutica	0	0	0	0	0	0	0	0	0	2

Sample name:	Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Mastogloia smithii	0	0	0	2	0	0	42	112	0	0
Navicula cryptocephala	0	0	0	0	6	0	0	0	0	0
Navicula cryptotenella	0	0	0	0	0	2	0	0	0	0
Navicula gregaria	0	0	0	0	4	0	0	0	0	0
Navicula lanceolata	0	0	2	0	4	4	0	0	0	0
Navicula menisculoides	0	0	0	0	8	4	0	0	0	0
Navicula menisculus	0	0	0	4	0	0	0	0	0	0
Navicula phyllepta	0	0	0	2	0	0	0	0	0	0
Navicula radiosa	0	0	2	0	12	24	0	0	0	0
Navicula recens	0	0	0	0	4	0	0	0	0	0
Navicula veneta	0	0	12	6	0	0	0	0	0	0
Nitzschia frustulum	0	0	10	8	0	0	0	0	0	0
Nitzschia graciliformis	0	0	4	0	0	0	0	0	0	0
Nitzschia gracilis	0	0	2	0	0	0	0	0	0	0
Nitzschia inconspicua	0	0	0	6	0	0	0	0	0	0
Nitzschia lacuum	0	0	8	4	0	0	0	0	0	0

Sample name:	Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Nitzschia microcephala	0	0	0	4	0	0	0	0	0	0
Nitzschia palea	0	0	40	16	0	0	0	0	0	0
Nitzschia suchlandii	0	0	0	2	0	0	0	0	0	0
Pinnularia legumen	0	0	0	2	0	0	0	0	0	0
Pinnularia spp.	0	0	0	4	0	0	0	0	0	0
Pleurosigma elongatum	0	0	28	0	0	0	0	0	0	0
Ulnaria ulna	0	0	4	0	0	12	0	0	0	0
Total	0	0	394	352	420	386	60	166	0	28

APPENDIX F. PHYTOPLANKTON DATA

Table. Phytoplankton profile for the Iron Bridge Pools sampled in the late dry season (2020)

	F16 HB		SS Pool		S12 Pool		Cow Spring	
	DE01565.1		DE01565.2		DE01565.3		DE01565.4	
	10/12/2020		8/12/2020		09/12/2020		11/12/2020	
Taxon	Abund.	%	Abund.	%	Abund.	%	Abund.	%
Bacillariophyceae	**200**	**8.00**	**80300**	**76.11**	**3200**	**2.27**	**7000**	19.02
Achnanthidium minutissima			35200	33.36			1400	**3.80**
Amphora spp.					400	0.28	200	**0.54**
Cocconeis spp.			700	0.66				
Cymbella spp.			300	0.28			400	**1.09**
Lyrella spp.			100	0.09				
Microtabella spp.	100	4.00						

Taxon	F16 HB		SS Pool		S12 Pool		Cow Spring	
	DE01565.1		DE01565.2		DE01565.3		DE01565.4	
	10/12/2020		8/12/2020		09/12/2020		11/12/2020	
	Abund.	%	Abund.	%	Abund.	%	Abund.	%
Navicula spp.	100	4.00	19600	18.58				
Navicula spp.			19600	18.58	1200	0.85	2800	**7.61**
Nitzschia spp.			100	0.09	1200	0.85	400	**1.09**
Pinnularia spp.			200	0.19				
Synedra spp. (O)			4500	4.27	400	0.28	1800	**4.89**
Chlorophyceae	**2200**	**88.00**	**900**	**0.85**	**3200**	**2.27**	**1400**	3.80
Closterium spp. (O)					1200	0.85		
Cosmarium spp. (O)	2200	88.00	700	0.66	2000	1.42	1200	**3.26**
Oocystis spp.			200	0.19				
Staurastrumn spp. (O)							200	**0.54**
Cryptophyceae			**8800**	**8.34**	**24000**	**17.00**	**15000**	40.76
Chroomonas spp.			800	0.76	2400	1.70	3000	**8.15**
Cryptomonas spp. (O)			8000	7.58	21600	15.30	11800	**32.07**
Plagioselmis spp.							200	**0.54**
Cyanobacteria			**8200**	**7.77**	**8000**	**5.67**		
Chroococcus spp.					1600	1.13		
Planktolyngbya spp.					6400	4.53		
Pseudoanabaena spp. (O) (PT)			8200	7.77				
Dinophyceae			**7200**	**6.82**	**102800**	**72.80**	**13200**	35.87
Gomphonema spp.			500	0.47				

Taxon	F16 HB		SS Pool		S12 Pool		Cow Spring	
	DE01565.1		DE01565.2		DE01565.3		DE01565.4	
	10/12/2020		8/12/2020		09/12/2020		11/12/2020	
	Abund.	%	Abund.	%	Abund.	%	Abund.	%
Gonyaulax spp.			800	0.76	42800	30.31	12200	**33.15**
Gymnodinium spp.			1400	1.33			600	**1.63**
Peridinium spp. (O)			4500	4.27	60000	42.49	400	**1.09**
Euglenophyceae	**100**	**4.00**	**100**	**0.09**			**200**	0.54
Euglena spp. (O)			100	0.09				
Trachelomonas spp.	100	4.00					200	**0.54**
TOTAL (All Taxa)	2500	100	105500	100	141200	100	36800	100

Table. Phytoplankton profile for Iron Bridge pools sampled in the late wet season (2021)

Taxon	Fig Pool		Central Creek		Site 12		Cow Spring		Gv Pool		Mundagoora Pool	
	DE01792.1		DE01792.2		DE01792.4		DE01792.5		DE01792.6		DE01792.3	
	24/05/2021		24/05/2021		24/05/2021		24/05/2021		24/05/2021		24/05/2021	
	Abund.	%	Abund.	%	Abund.	%	Abund.	%	Abund.	%	Abund.	%
Bacillariophyceae			**460**	**93.88**	**20**	**100.00**	**20**	**100.00**	**860**	**98.85**	**70**	63.64
Achnanthidium sp.											10	**9.09**
Amphora sp.									40	4.60	10	**9.09**
Entomoneis			10	2.04								
Fragilaria sp. (O)			10	2.04								
Placoneis sp.									530	60.92		

Taxon	Fig Pool		Central Creek		Site 12		Cow Spring		Gv Pool		Mundagoora Pool	
	DE01792.1		DE01792.2		DE01792.4		DE01792.5		DE01792.6		DE01792.3	
	24/05/2021		24/05/2021		24/05/2021		24/05/2021		24/05/2021		24/05/2021	
	Abund.	%	Abund.	%	Abund.	%	Abund.	%	Abund.	%	Abund.	%
Navicula capitata			10	2.04								
Navicula pupula capitata			10	2.04								
Navicula sp.			50	10.20	20	100.00	10	50.00	100	11.49	40	**36.36**
Nitzschia sp.			130	26.53					110	12.64		
Pleurosigma sp. (O)			220	44.90								
Rhopalodia gibba			10	2.04					60	6.90		
Stauroneis sp.			10	2.04								
Synedra sp. (O)							10	50.00	20	2.30	10	**9.09**
Chlorophyceae											**40**	36.36
Mougeotia sp.											40	**36.36**
Cryptophyceae			**30**	**6.12**					**10**	**1.15**		
Cryptomonas sp. (O)			30	6.12					10	1.15		
TOTAL (All Taxa)			490	100	20	100	20	100	870	100	110	100

APPENDIX G. MACROPHYTE TABLE

Name	Description	Image	Site 12	Cow	South	Central
Ribbon weed (*Vallisneria sp.*)	Bright green soft ribbon fronds which float and spread across the water surface. Fronds about 0.5 cm wide.		Y	Y	Y	

Name	Description	Image	Site 12	Cow	South	Central
Charophytes (*Nitella sp., Chara sp.*)			Y			

Name	Description	Image	Site 12	Cow	South	Central
Clubrush (*Schoenoplectus sp.)*			Y	Y	Y	Y
Sedges (*Cyperus sp.)*			Y	Y	Y	Y

Name	Description	Image	Site 12	Cow	South	Central
Bulrush (*Typha sp.*)	Tall emergent ribbon like fronds with sharp margins.		Y	Y	Y	
Unidentified species 1				Y		

Name	Description	Image	Site 12	Cow	South	Central
Unidentified species 2				Y		

APPENDIX H. ISOTOPE DATA ANALYSIS MEMO

MEMORANDUM

TO:	Sylvie Ogier-Halim (FMG- Strategic Planning - Hydrogeology Projects)
CC:	
SENDER:	Phil Whittle
DATE:	9 Sept 2021
PROJECT:	Iron Bridge – Assessment of pool water sources from isotope analysis

ASSESSMENT OF IRON BRIDGE POOL WATER SOURCES FROM ISOTOPE ANALYSIS

This memorandum provides a summary of the water quality isotopic data captured for Iron Bridge river pools and groundwater from December 2019 to June 2021. The isotope data was collected to assess the sustaining water sources for a range of permanent to semi-permanent river pools across the Iron Bridge project site.

Three groundwater monitoring bores and six permanent or semi-permanent river pools were sampled for the stable isotopes $\delta^{18}O$ and $\delta^{2}H$, as well as a range of field and major ion parameters (Figure 1; Table 1). As common practice in hydrogeology, the isotopic ratios are compared to the Vienna Standard Mean Ocean Water (VSMOW) reference. The VSMOW represents enriched isotopic conditions in aged "seawater". Rainfall is typically depleted in $\delta^{18}O$ and $\delta^{2}H$, therefore the enrichment or depletion of these isotopes in various water sources can provide a signature relative to recent rainfall, evaporative processes (which concentrate or enrich these isotopes) or groundwater sources (which are more stable relative to the age of the water source). Considering the lack of regional isotopic data in the Iron Bridge project area, the dataset of Dogramaci et al (2012) from the Hamersley Range region has been used for context (Figure 2). Overall, the isotope data showed a large range in values across both groundwater and surface waters at Iron Bridge (Figure 2). The relationship between the two isotopes ($\delta^{18}O$ and $\delta^{2}H$) was however relatively consistent across the site and sampling dates, as well as being consistent with regional literature (Dogramaci et al., 2012, Hedley 2009, Hedley et al, 2009, Dogramaci and Skrzypek 2015).There is a general pattern of depletion (increasingly negative) isotopic ratios in the region following large singular rainfall events (such as cyclones or associated large low systems; Dogramaci et al., 2012). There was an evident depletion of both isotopes between the dry to wet season 2019/20 and following the wet season of 2020/21. The tropical low (02U) of 11-12 December 2020 produced a large (200 mm) rainfall event across the Iron Bridge site. This may be a factor in the depleted June 2021 isotope ratios (Figure 3).

SITE 12 POOL

The large range in isotope ratio values for the Site 12 pool groundwater (bore NS-0064; labelled as Site 12 GW in Figure 2) is consistent with the records from water level loggers and other water quality parameters from this bore, showing variability in response to rainfall events (Figure 4). It is notable that the isotope ratios for the surface water within Site 12 Pool and the upstream monitoring bore (NS-0664) were

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consistently different, with the groundwater being substantially more depleted, particularly for the late dry season (Dec 2019) sampling event. However, the water level data indicate that the bore (NS-0664) levels and the pool levels are both similarly responsive to large rainfall events (Figure 4). This suggests that the surface water within Site 12 Pool is maintained by groundwater, though not directly that which is represented by bore NS-0664. It is likely that some degree of evaporation along the groundwater inflow to the pool, and within the pool system itself, is creating an enriched signature relative to the deeper groundwater (NS-0664) which is more representative of large rainfall event recharge.

The December 2019 isotope enrichment in the Site 12 Pool is evidence that at this stage "fresh" or deep groundwater recharge was at a minimum and evaporative isotopic enrichment was a dominant process. This is consistent with the water level data (Figure 4) which shows that as the groundwater levels reach a critical point, evaporative losses from the pool are in excess of groundwater inflows and rapid drying occurs.

The most depleted isotopic ratio of the dataset was observed at the Site 12 groundwater monitoring bore (NS-0664) following the large 2020/21 wet season. This may indicate that the source of the groundwater at the site was relatively recent rainfall during this period. There are preliminary indications that the groundwater at the Site 12 Pool monitoring bore is more similar to a rainwater isotopic composition after the wet season, moving towards the evaporation line in the late dry. Further sampling would be required to confirm this.

MUNDAGOORA POOL

While there are currently no groundwater monitoring bores within the vicinity of Mundagoora Pool, the water quality and water level logger data indicate that this is a groundwater dependent system. It is a permanent water feature and maintains a constant water level through to the end of the dry season. The pattern of isotopic enrichment within the pool is consistent with evaporative processes active over groundwater replenishment. The highest enrichment occurred in the late dry season, with the lowest following the large wet season of 2020/21. The evident isotopic ratios for Mundagoora Pool were along the Local Evaporation Line (LEL) for the region (Dogramaci et al 2012), providing further evidence that evaporative processes are a feature of the water balance for the pool and that groundwater recharge is relatively slow over the dry season, though high enough to replace evaporative losses (as the pool level remains constant). Older groundwater (with more isotopic enrichment) may also contribute a larger fraction of the inflows as the dry season progresses.

The isotope data from Mundagoora Pool indicates that there is little direct rainfall influence on the pool, with the trend-line being closest to the Hamersley groundwater line (Dogramaci et al 2012).

FIG AND COW SPRING POOLS

Fig Pool was the least variable of the sampled sites with only minor variability and evaporative effects evident across the seasonal sampling (Figure 2). The local groundwater monitoring bore (NS-Obs29) was depleted relative to the pool, though to a lesser extent. The lack of direct catchment, and the permanent status of Fig Pool indicate that it is groundwater dependant. The low pH however indicates that there are geochemical processes within the pool that occur at a higher rate than groundwater replenishment (such as root mat iron oxidation (redox) processes. The evidence of evaporative enrichment of isotopes also indicates that groundwater inflow is relatively slow to this site.

Cow Spring Pool does not have an associated monitoring bore, however the late wet season (May 2020) sampling showed similar isotopic depletion at Cow Spring Pool and the Fig Pool monitoring bore (NS-

Obs29; Figure 2). The small catchment and permanent status of Cow Spring Pool indicate that it is likely to be groundwater dependant, which is supported by the limited available isotopic data.

CENTRAL CREEK POOL

The groundwater adjacent to Central Creek Pool (monitoring bore NS-Obs17) was only sampled in May 2020 (late wet season), when it was representative of relatively isotopically enriched waters. This is possibly due to its location low within the catchment providing a more evaporative signature as groundwater moves down through the local elevation. The surface water pool showed a ratio closer to the Hamersley rainfall line (Figure 2) though with some enrichment evident. The late wet 2021 pool isotopic signature was closer to the groundwater signature indicating that under wetter conditions both may be associated with a superficial or alluvial aquifer.

SOUTH-WEST GV POOL

There are no groundwater monitoring bores currently associated with the South-West GV Pool (GV_SW_Pool_SW). Only a single late wet 2021 surface water sample is available for this site, which indicated that it had a similar isotopic signature to other pools in the area including Site 12 Pool, Mundagoora Pool and Central Creek Pool. It is likely that this pool is representative of local relatively recent inflows from superficial groundwater systems in the upper catchment. The ephemeral nature of the pool also suggests that it is not fed by regional groundwater over the dry season. There is anecdotal evidence from discussions with Traditional Owners that a spring is present at this site, though this was not evident (flowing) at the time of a late dry season (2020) site inspection.

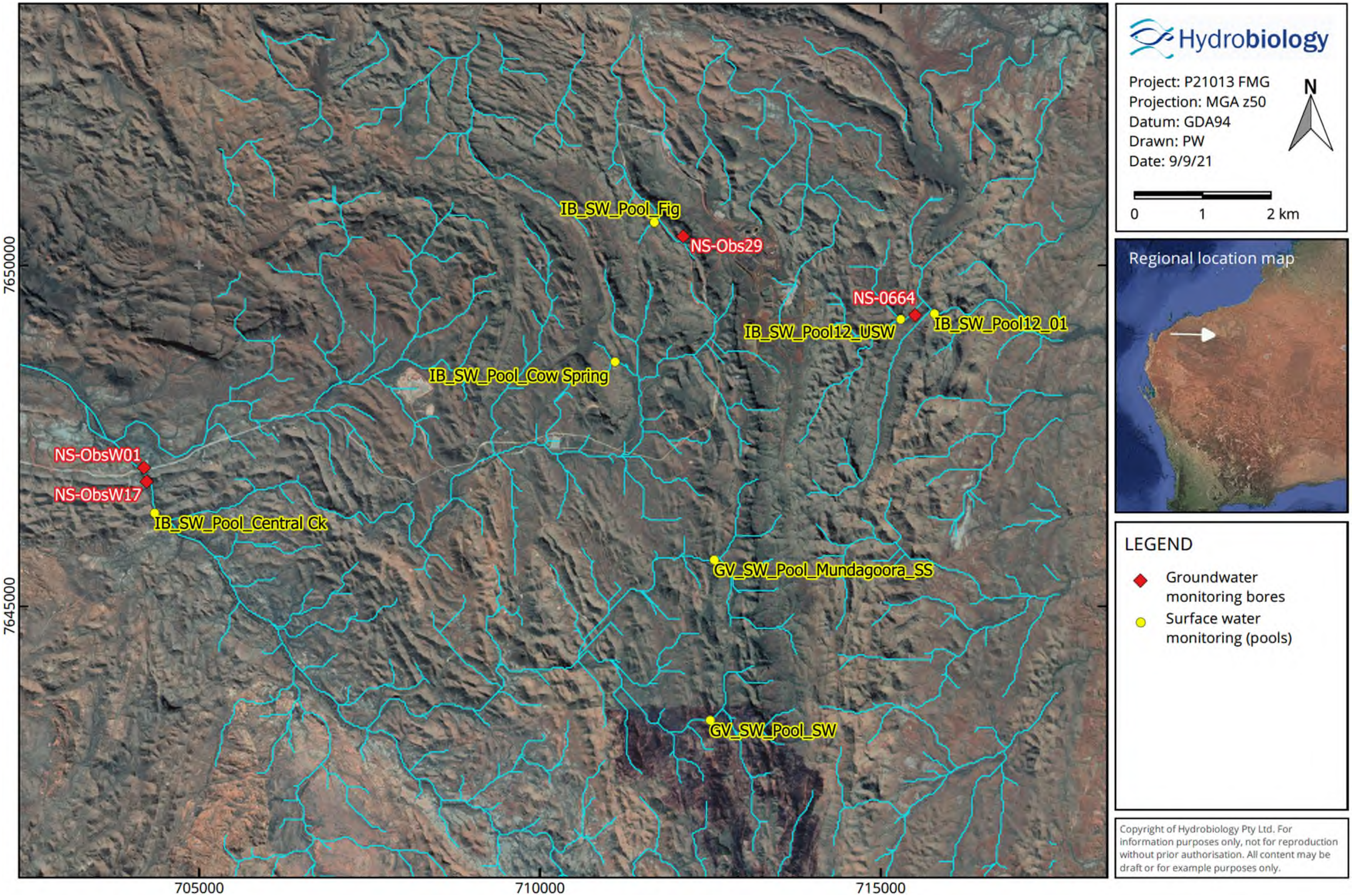

Figure 1 Map of site locations for isotope analysis – Iron Bridge Project Area

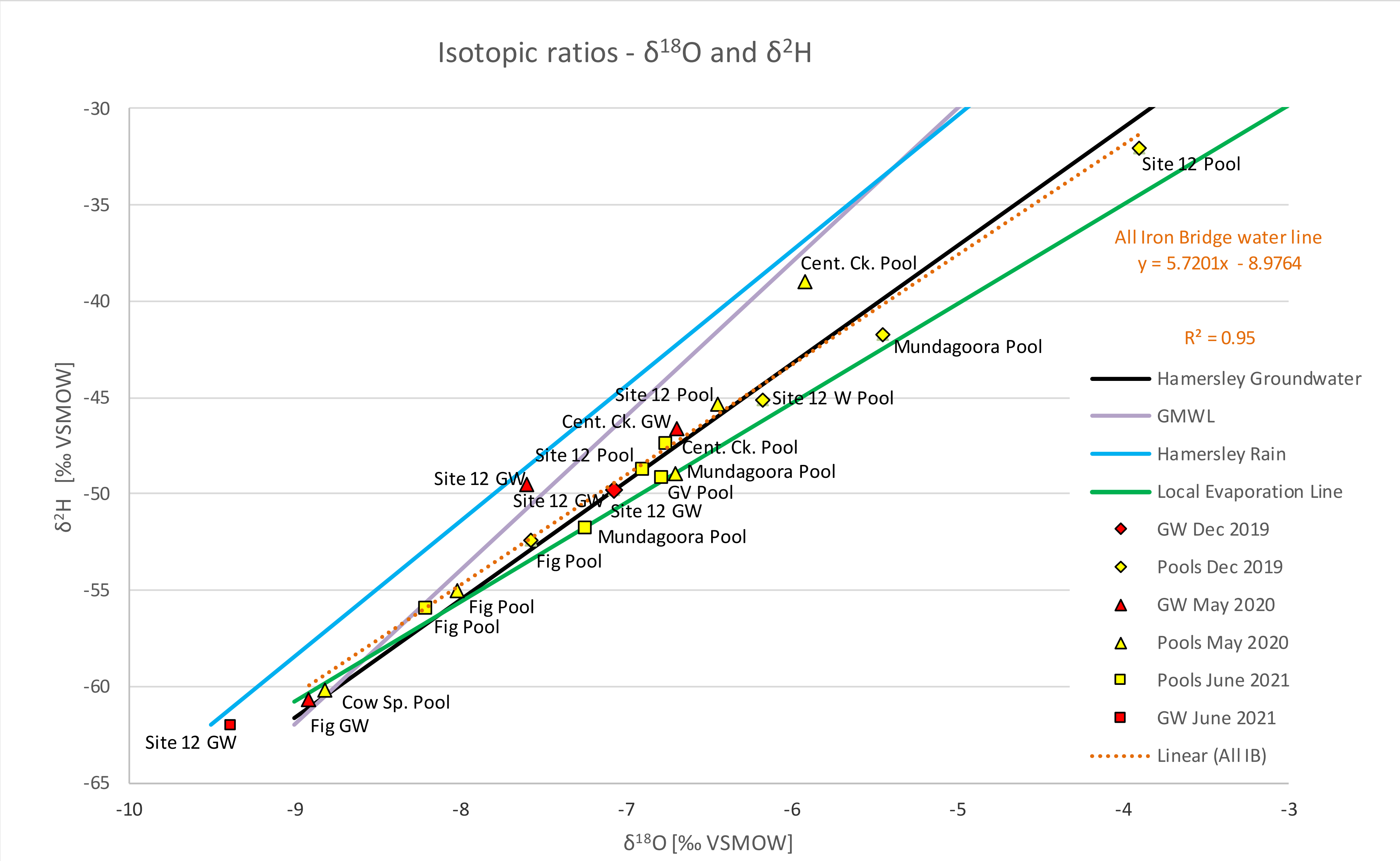

Figure 2 Isotope ratios for surface and groundwater samples collected from December 2019 to June 2021

Table 1 Stable isotope data (December 2019 to June 2021)

Site Name	Site description	Date	Type	d18O [‰ VSMOW]	d2H [‰ VSMOW]
GV_SW_Pool_SW	Small ephemeral river pool in Glacier Valley project area to south of Mundagoora pool catchment	16/06/2021	Pool	-6.78	-49.2
GV_Pool_Mundagoora_SS	Permanent pool in Glacier Valley project area	17/12/2019	Pool	-5.44	-41.8
GV_Pool_Mundagoora_SS		30/05/2020	Pool	-6.7	-49
GV_Pool_Mundagoora_SS		16/06/2021	Pool	-7.24	-51.8
IB_SW_Pool_Central Ck	Small ephemeral pool in Iron Bridge project area.	31/05/2020	Pool	-5.92	-39
IB_SW_Pool_Central Ck		16/06/2021	Pool	-6.75	-47.4
IB_SW_Pool_Cow Spring	Small permanent pool at base of rockface in Iron Bridge project area.	1/06/2020	Pool	-8.81	-60.2
IB_SW_Pool_Fig	Small permanent pool at base of rockface in Iron Bridge project area. Naturally low pH.	18/12/2019	Pool	-7.57	-52.5
IB_SW_Pool_Fig		30/05/2020	Pool	-8.01	-55.1
IB_SW_Pool_Fig		17/06/2021	Pool	-8.2	-56
IB_SW_Pool12_01	Semi-permanent river pool over bedrock in Iron Bridge project area.	17/12/2019	Pool	-3.9	-32.1
IB_SW_Pool12_01		29/05/2020	Pool	-6.44	-45.4
IB_SW_Pool12_01		15/06/2021	Pool	-6.89	-48.8
IB_SW_Pool12_USW	Small pool in crevice at ridgeline crossing of Site 12 creek. Upstream of Site 12 Pool.	19/12/2019	Pool	-6.17	-45.1
NS-0064	Monitoring bore upstream of Site 12 Pool.	17/12/2019	Groundwater	-7.07	-49.8
NS-0064		29/05/2020	Groundwater	-7.59	-49.6
NS-0064		15/06/2021	Groundwater	-9.38	-62.1
NS-Obs17	Monitoring bore downstream of Central Ck pool	1/06/2020	Groundwater	-6.68	-46.6
NS-Obs29	Monitoring Bore near Fig Pool	1/06/2020	Groundwater	-8.91	-60.7

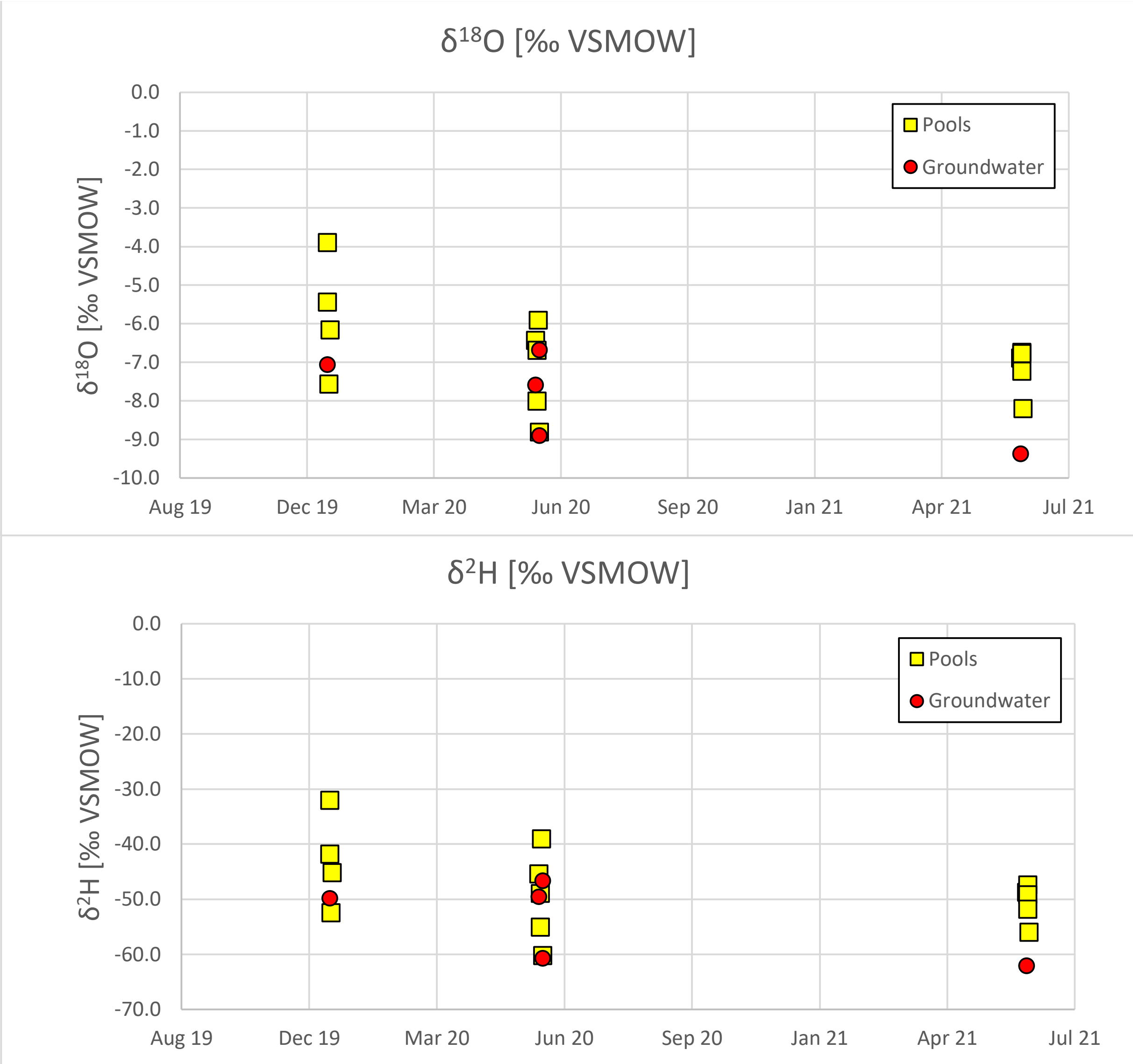

Figure 3 Isotopic ratios by sample date and water type – Dec 2019 to June 2021

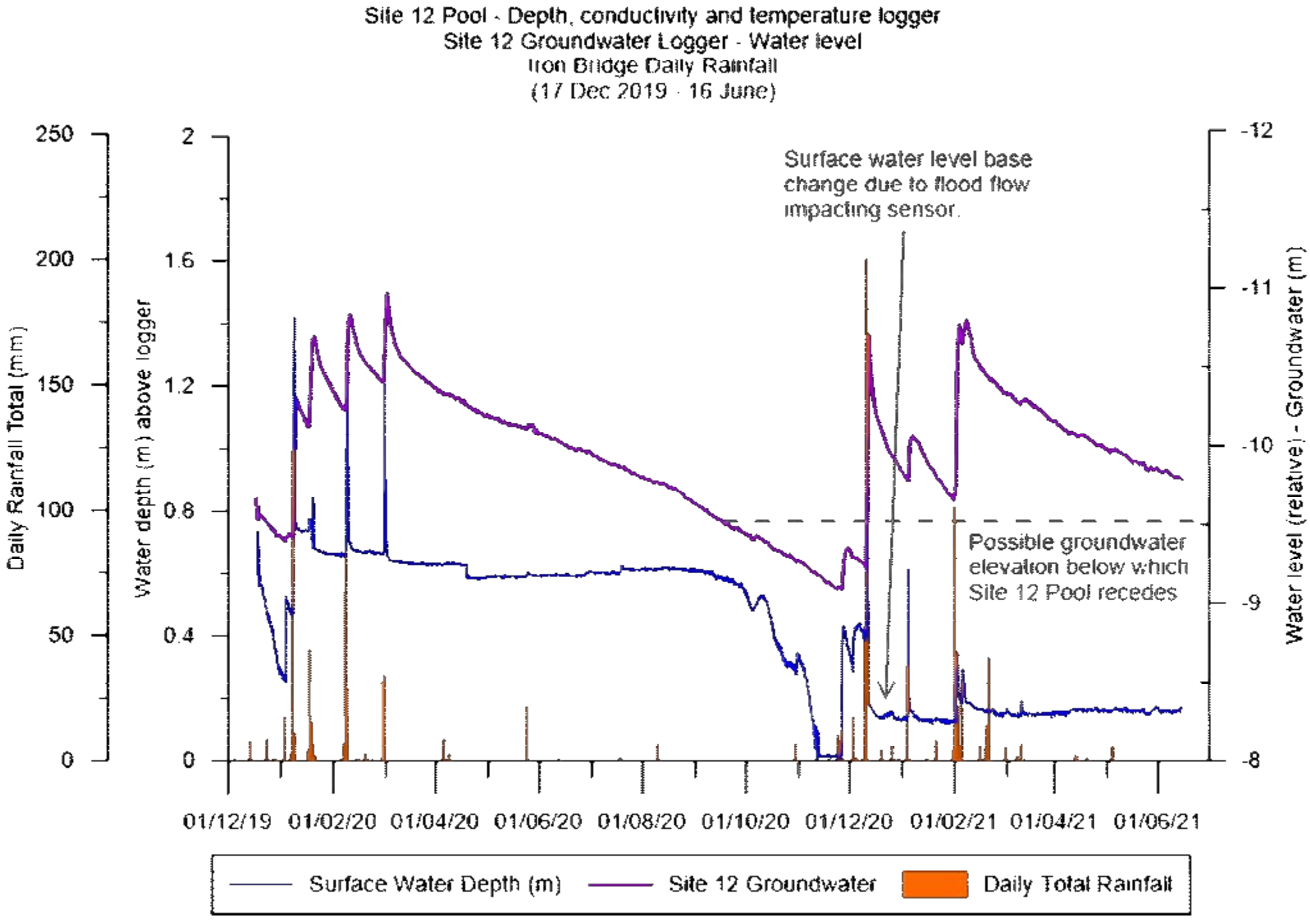

Figure 4 Comparison of surface water levels in Site 12 Pool (IB_SW_Pool12_01) and groundwater levels within the adjacent monitoring bore (NS-0664).

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Attachment 6: Site 12 Pool Water Quality and Hydrological Regime Investigation (Hydrobiology, 2021)

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SITE 12 POOL WATER QUALITY & HYDROLOGICAL REGIME INVESTIGATION

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GLOSSARY OF ACRONYMS

Acronym	Definition
ANZG	Australian and New Zealand Guidelines for fresh and marine water quality
CEO	Chief Executive Officer
DITR	Department of Industry, Tourism and Resources
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DSIAR	Diatom Species Index for Australian Rivers
EC	Electrical Conductivity (conductivity normalised to 25°C)
eDNA	Environmental Deoxyribonucleic Acid
EPBC	Environmental Protection and Biodiversity Conservation
EPT	Ephemeroptera, Plecoptera, Tricoptera
FMGIB	FMG Iron Bridge (Aust) Pty Ltd
MS	Ministerial Statement
N	Nitrogen
NTU	Nephelometric Turbidity Units
P	Phosphorous
QA/QC	Quality Assurance/Quality Control
SO4	Sulphate
TDS	Total Dissolved Solids
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids
WQMMP	Water Quality Monitoring and Management Plan
WRD	Waste Rock Dump

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1. INTRODUCTION

This document provides technical support to inform the Site 12 Pool monitoring and management approach at Iron Bridge mine

1.1 BACKGROUND

Site 12 Pool lies on a small tributary downstream of a proposed Waste Rock Dump (WRD) planned for construction by the proponent, FMG Iron Bridge (Aust) Pty Ltd (FMGIB), as part of the North Star Magnetite Project (the Project) in the Pilbara region of Western Australia (Figure 1-1). The managing entity for the Project is IB Operations Pty Ltd (Iron Bridge), a joint venture company between FMGIB and Formosa Steel IB Pty Ltd.

The Project was approved by Ministerial Statement (MS) 993, where Condition 12 of MS 993 specifies that a Water Quality and Quantity Monitoring Plan (WQQMP) is developed to demonstrate that the implementation of the Project within the Site 12 Pool catchment does not have a detrimental impact on the water quality or hydrological regime of Site 12 Pool. To assist FGMIB to meet MS 993 Condition 12, the current technical report was prepared to support the WQQMP. This report details the monitoring and evaluation process, trigger levels, threshold criteria and contingency actions to demonstrate compliance with the water quality and hydrological regime objectives under Condition 12-2 of MS 993.

The Project is located 145 km by road south of Port Hedland in the Pilbara region and incorporates the North Star Magnetite ore bodies. Site 12 Pool is part of a series of pools that lie to the east of the Project on a small tributary to the upper Six Mile Creek within the Strelley River Water Catchment (Figure 1-2) and is situated within the Chichester IBRA bioregion and the Grassland climate class (Koppen; Figure 2-6). It is connected to both surface water and groundwater sources over the hydrologic cycle. It is an ephemeral system, known to dry out following small wet seasons. The Site 12 Pool area provides a habitat to the EPBC Act (1999) listed Pilbara olive python (*Liasis olivaceus barroni*) (vulnerable). The protection of the Pilbara olive python habitat was a factor for the inclusion of condition 12. The importance of managing the Project within the catchment of Site 12 Pool not to have a detrimental impact on the water quality is encompassed in this report.

This report followed the ANZG (2018a) guidance for developing water quality guidelines, the *Managing Acid and Metalliferous Drainage* (DITR 2007) guidelines, the EPA (2018) factor for *Inland Waters*, and applies the *Temporary Waters Guidance* (ANZG 2018b). The *Temporary Waters Guidance* (ANZG 2018b) considers the formulation of site-specific guideline values using a multiple lines of evidence approach to be most appropriate for the protection of aquatic ecosystems, above applying generic principles and default guidelines (ANZG 2018a; ANZG 2018b). Therefore, we have formed a management and monitoring approach by measuring indicators and developing guideline values from multiple lines of evidence across the Pressure-Stressor-Ecosystem Receptor (PSER) causal pathway. These were selected to be protective of the ecological functioning of the system and protect key temporal stages of the hydrological cycle.

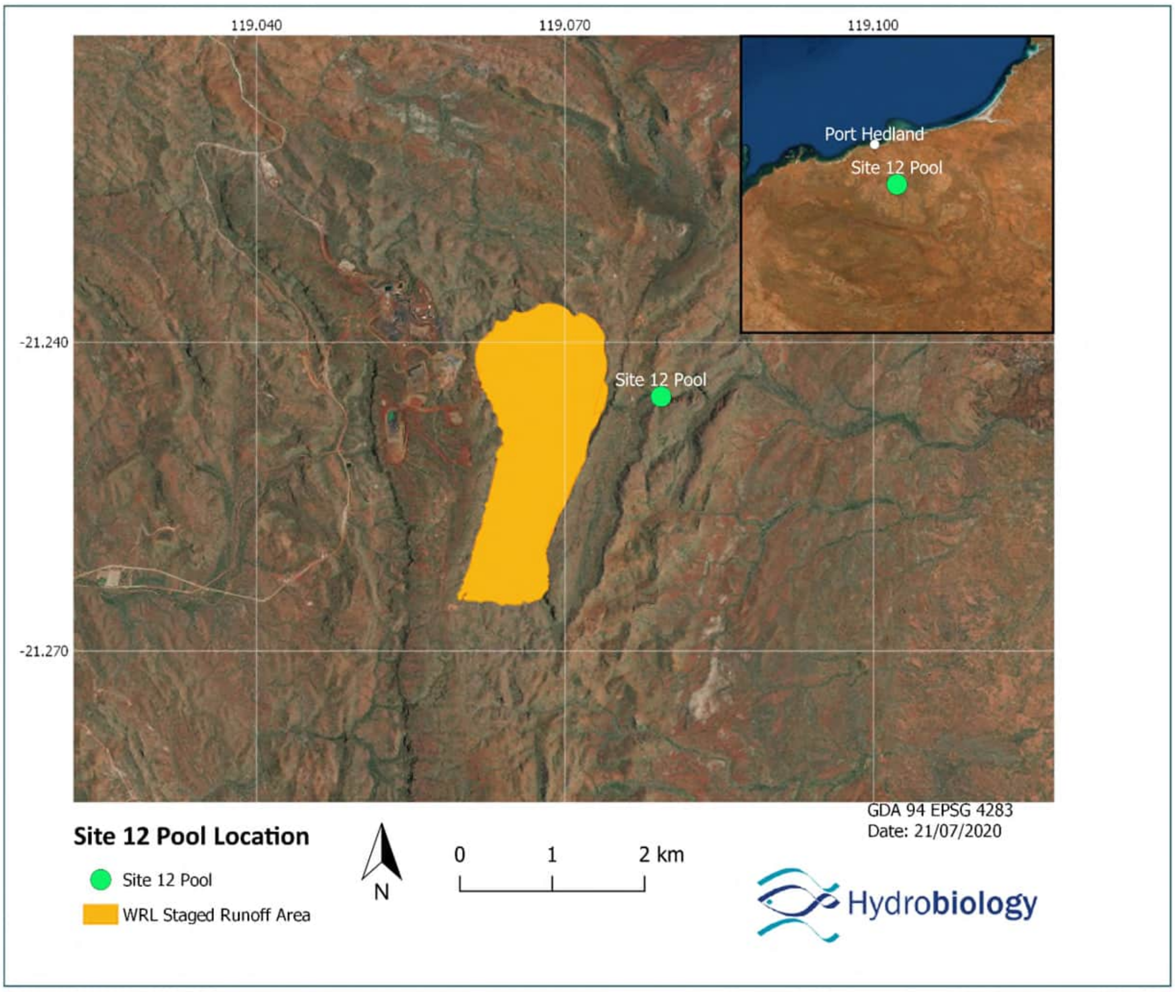


Figure 1-1 Overview map of Site 12 Pool location.

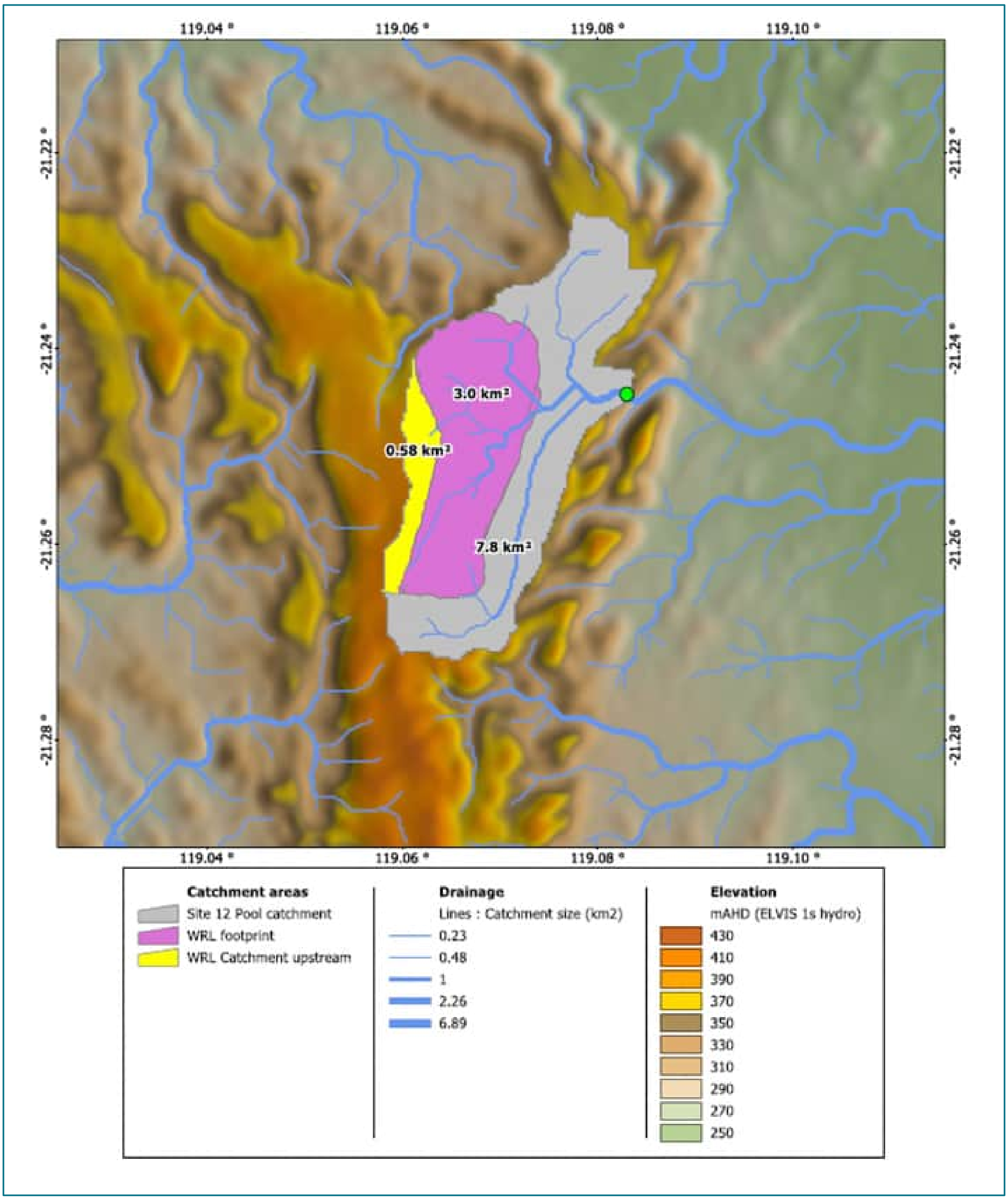


Figure 1-2 Site 12 Pool catchment and the footprint of the WRD within the catchment.

1.2 OBJECTIVES

The objective of this Water Quality and Hydrological Regime Investigation is to provide technical input to the Site 12 Pool WQQMP to inform the Site 12 Pool monitoring and management approach including:

- Monitoring locations, frequency and parameters
- Specified Early Response Trigger Levels and guidance for conducting an Early Response Trigger Investigation to determine the cause of exceedance
- Specified ecological monitoring parameters, levels and corresponding Threshold Criteria
- Framework for the development of contingency actions to be implemented for mitigating changes to water quality and quantity in the event that any Early Response Trigger Levels or Threshold Criteria are exceeded.
- Assessment framework to determine if the implementation of the Project within the catchment of Site 12 Pool has had a detrimental impact on Site 12 Pool.

2. RATIONALE AND APPROACH

This section outlines the monitoring and management approach as guided by ANZG (2018a), ANZG (2018b) and DITR (2007). This methodology section details the following:

- Environmental outcomes and outline of measures to ensure environmental outcomes are achieved.
- Detrimental impact definition and assessment, and environmental value definition.
- Survey and study findings of water quality, hydrological regime and aquatic ecology.
- Identification of conceptual impacts and impact mechanisms.
- Selection of relevant indicators from the PSER causal pathway using a multiple lines of evidence approach and rationale for indicator selection.
- Derivation of seasonally relevant Early Response Trigger Levels for water quality indicators.
- Derivation of Threshold Criteria based on ecological indicators.
- Key assumptions and uncertainties

2.1 ENVIRONMENTAL OUTCOMES

There shall be no detrimental impact on the water quality or hydrological regime of Site 12 Pool from implementation of the Project within the catchment of Site 12 Pool located in the Mine Development Envelope.

The environmental outcome is achieved through:

- Implementation of the Site 12 Pool WQQMP, which is informed by this Site 12 Pool Water Quality and Hydrological Regime Investigation.
- The monitoring approach incorporating the use of Early Response indicators to detect early changes to water quality and quantity parameters, and ecological parameters that link changes in water quality and quantity to changes to flora and fauna.
- The contingency actions were developed to be responsive to detected exceedances and allow for case-specific response to exceedances caused by the Project.
- Implementation of preventative management measures to ensure no detrimental impact to water quality and water quantity of Site 12 Pool, including a large toe bund / plug as part of the WRD development for the WRD sediment control.
- The monitoring of groundwater quality and level, as well as surface water quality and quantity upstream of Site 12 Pool to allow for early detection of changes.

2.2 DETRIMENTAL IMPACT ASSESSMENT

2.2.1 ENVIRONMENTAL VALUE

The Site 12 Pool environmental value is the value as an aquatic ecosystem, encompassing both the surface water and surface water dependant systems.

The management approach and derived guidelines, therefore, aim to monitor and mitigate detrimental impacts to the Site 12 Pool environmental value as an aquatic ecosystem. The ecological parameters selected to be monitored and assessed are those which can be reliably measured, and their presence and health indicate the ability of Site 12 Pool to sustain the aquatic ecosystem flora and fauna. These parameters include algal, macrophyte, fish and macroinvertebrate communities. Indicator selection is outlined in Section 2.6.2. The assessment of these parameters aligns with the EPA (2018) Environmental Factor Guideline for Inland Waters, where the environmental value related to inland waters includes the ability to sustain vegetation, aquatic fauna and birdlife and the ecological processes that support them.

Environmental Value

Environmental value is defined under the *Environmental Protection Act 1986* as a beneficial use or an ecosystem health condition. For example, water resources may be used for humans, food production or aquatic ecosystems. The Water Quality Guidelines (ANZG 2018a) aims to provide guidance to assess whether the water quality of the water resource is sufficient to allow it to be used for its environmental value. Where water quality guidelines are not met, this indicates the waters may not be suitable for the environmental values and management actions are triggered to assess the issue more thoroughly or implement contingency measures to mitigate the issue.

(ANZG 2018a)

2.2.2 DETRIMENTAL IMPACT

To comply with the approval requirements (MS 993 Condition 12) and the EPA (2018) Inland Waters objective, Iron Bridge shall ensure that the Project within the catchment of Site 12 Pool does not have a detrimental impact on Site 12 Pool.

'Detrimental impact' at Site 12 Pool is defined as '**the loss of environmental value**', where the environmental value is the Site 12 Pool aquatic ecosystem (Section 2.2.1). The aquatic ecosystem is measured by a set of four ecological criteria that are assigned either low, moderate or high risk of indicating loss to the environmental value. When the designated number of moderate and/or high-risk criteria are met, the Threshold Criteria is determined to be exceeded. Detrimental impact or 'the loss of environmental value' is determined as where the Threshold Criteria is exceeded (Section 3.4.1).

A detrimental impact resulting from the Project is demonstrated through a multiple lines of evidence approach, where indicators have been selected from the Pressure-Stressor-Ecosystem Receptor (PSER) causal pathway (Figure 2-10). Due to the highly variable hydrological and ecological system at Site 12 Pool, determining a detrimental impact resulting from the Project rather than natural variability involves linking the Pressure to Stressor to Ecosystem Receptor. Therefore, Threshold Criteria is assessed after all the following have occurred:

I. An exceedance of Early Response Trigger Levels (*Stressor identified*);
II. Early Response Trigger Investigation determines the exceedance is due to the Project, not a natural cause (*Pressure identified*); and
III. Ecological parameters meeting Moderate or High-Risk categories for indicating declining environmental value are validated by expert ecological assessment as not occurring due to natural causes (*Ecosystem receptor identified)*
IV. The required number of Moderate-Risk or High-Risk ecological parameters exceeded meets the Threshold Criteria (Table 1 & Table 2).

Table 1 Threshold Criteria

Criteria	Assessment Parameters
Threshold Criteria	≥2 High Risk Criteria
	≥2 Moderate Risk and ≥1 High Risk Criteria
	≥3 Moderate Risk Criteria

Table 2 Threshold Criteria Assessment Table.

Environmental parameters	LOW RISK[1]	MODERATE RISK[1]	HIGH RISK[1]
Macroinvertebrate communities[2]	Presence of EPT taxa > 0.5*B*	EPT index < 0.5*B* OR SIGNAL2 score < the lower of 2 or *B*-1	No EPT taxa present
Fish communities	*Melanotaenia australis* present including small size classes (<60 mm)	*Melanotaenia australis* present and no small size classes present	No fish species present
Diatom communities[3]	DSIAR score > 0.5*B*	0.5*B* > DSIAR score > 0.2*B*	DSIAR score less than 0.2*B*
Macrophyte communities	Emergent (reed-like and tussock/rush-like species) present in ≥ isolated abundance	Emergent macrophytes present, with evidence of deteriorating health > *B* maximum	Emergent and submerged macrophytes absent

[1] *B*=Baseline seasonally relevant mean (i.e. wet or dry season ecological baseline values).

[2] The EPT Richness Index estimates water quality by the relative abundance of three major orders of stream insects that have low tolerance to water pollution: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). SIGNAL (Stream Invertebrate Grade Number – Average Level) is a scoring system for macroinvertebrate samples from Australian rivers that indicates water quality based on tolerance or sensitivity of macroinvertebrate families present to water quality.

[3] DSIAR score (Diatom Species Index for Australian Rivers score) estimates water quality by the relative abundance of diatom species sensitive to water quality stressors.

2.3 SURVEY AND STUDY FINDINGS

The Water Quality Guidelines (ANZG 2018a) recommend the use of conceptual models to help understand the key processes involved and facilitate management decisions for complex natural systems. This section characterises the water quality, hydrological and ecological features of Site 12 Pool. This understanding was used to conceptually identify mechanisms that potentially impact environmental value (Section 2.4). The conceptual model was then used as a basis to select informative lines of evidence and indicators and develop the monitoring approach.

2.3.1 KEY CHARACTERISTICS OF POOLS AT IRON BRIDGE

The key characteristics, water quality and aquatic ecology of surface water pools at Iron Bridge are presented in detail in *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2021). To provide context to the features and values of Site 12 Pool, key features of Iron Bridge pools are summarised as follows:

- Surface water pools surveyed in the Iron Bridge area have high spatial and temporal variability. They are generally fresh-brackish and clear (<10 NTU) with pH ranging from acidic (pH: 3.3) to alkaline (pH: 9.3). Pools typically comprise isolated submerged macrophytes and emergent macrophytes. Benthic cover ranges from algae dominated bedrock, bare sediment to thick cover of macrophytes.
- Pools at Iron Bridge, like those of temporary pools in the Pilbara region, undergo large seasonal variability in water quality and water level (Figure 2-1). In the dry season, rivers and creeks are reduced to a series of these isolated pools which are largely sustained by groundwater levels. Where pools are not maintained by groundwater levels (e.g. Central Creek Pool), evaporation has a greater influence and concentrations of parameters that are normally diluted by flows (e.g. salinity) increase, and pH and dissolved oxygen generally decline.
- In the wet season, large flood events are required to recharge aquifers and fill pools. The first small rainfall events early in the wet season primarily infiltrate the surrounding soil and have little impact on surface water levels and quality. However, the first flush from larger rainfall events is typically high in sediment and dissolved oxygen and can have a substantial impact on the water quality. These flush events can transport relatively higher concentrations of metals and metalloids into the pools, and result in rapid decreases in salinity. In pools with substantial groundwater inputs, the salinity increases over time following the rainfall event as the groundwater replaces the pool volume.
- The wetting-drying cycle influences the ecological processes and the composition and distribution of aquatic biota. The ecology is adapted to highly variable hydrology and water quality of pools at Iron Bridge. Fish species recorded include common and widespread species, *Melanotaenia australis* (western rainbowfish) and *Leiopotherapon unicolor* (spangled perch), which were present in pools ranging from acidic to alkaline pH, though were absent from a small naturally acidic pool (Fig Pool). A wide diversity of macroinvertebrates and macrophyte species were present in all pools surveyed, with the exception of Fig Pool. The natural acidity of Fig Pool is discussed in *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2020).
- The aquatic ecology surveys which have informed the key characteristics of Iron Bridge pools were conducted in the late wet season 2020, late dry season 2020 and late wet season 2021. However, high seasonal variability in biodiversity and abundance within and between pools is expected. Typically, in temporary Pilbara pools, the early stages of inundation in the wet season are characterised by largely adult or resting stages being present and food webs are poorly established. In the recessional period (after the wet season), the aquatic ecosystem is established and includes life-history stages that are more sensitive to exposure to toxicants and declining

water quality. In the late drying phase, the concentration of potential stressors (e.g. salinity) occurs and, again, only adults and/or resting stages may be present. Differences in the age/size classes of fish within these pools from wet to dry season sampling events have been recorded, consistent with this cycle (Hydrobiology 2021).

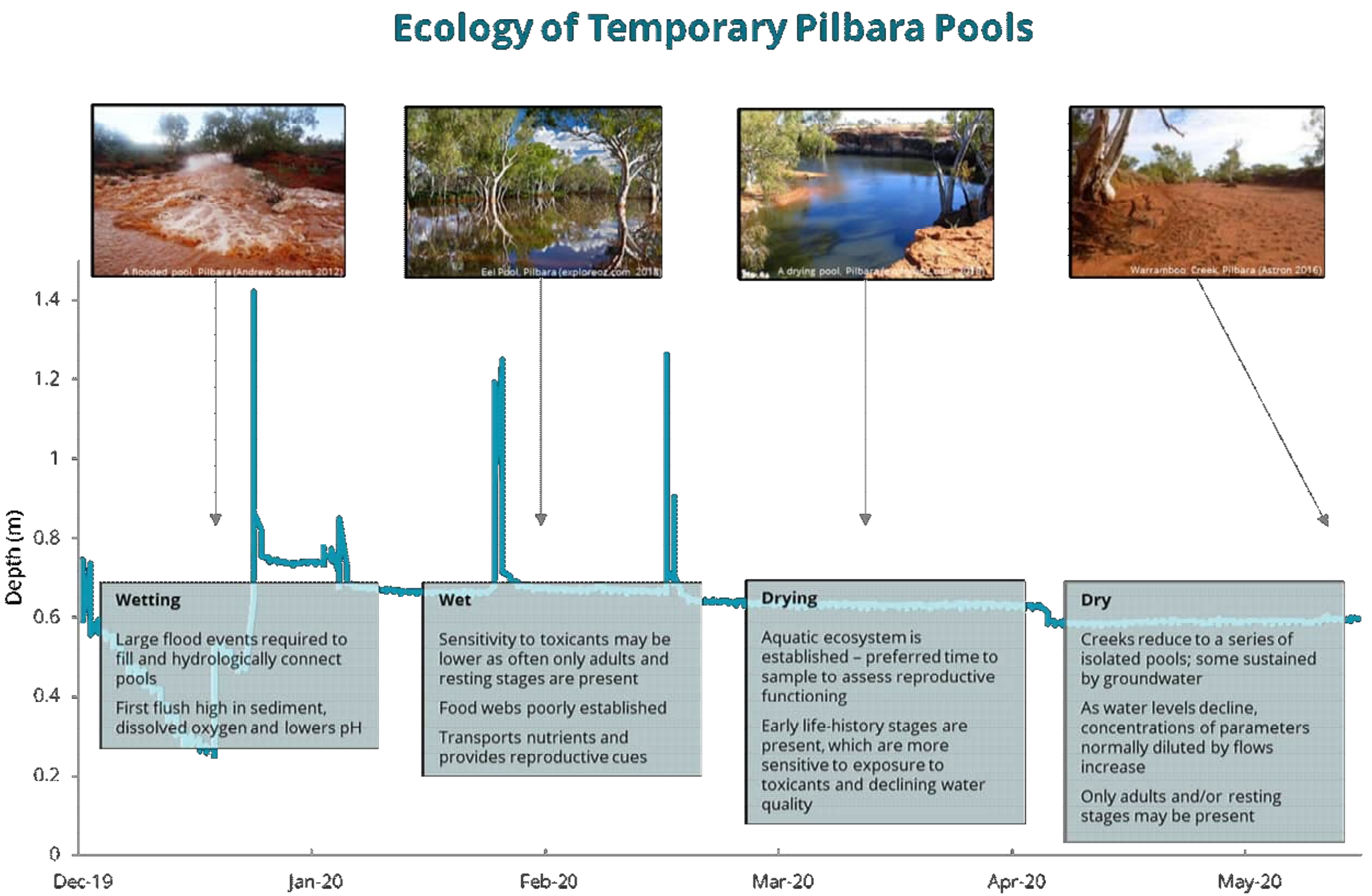


Figure 2-1 Site 12 Pool depth (m) varies over the wetting-drying cycle (Dec 2019 – May 2020). Note the graph is a representation of key stages and does not include the full hydrological cycle, and the above photographs depict a range of sites from the Pilbara, not Site 12 Pool.

2.3.2 KEY CHARACTERISTICS OF SITE 12 POOL

2.3.2.1 WATER QUALITY AND THE HYDROLOGICAL REGIME

The key characteristics of the Site 12 Pool water quality and the hydrological regime are provided in further detail in *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2021). The key features are:

- A bedrock supported natural habitat that lies in a small catchment (Figure 1-2) with typically low rainfall and infrequent high rainfall events largely driven by storm and cyclonic activity.
- The water quality experiences high seasonal variability due to the climatic conditions of the region and the temporary nature of the waterbody. The greatest variability recorded occurs following rainfall events (Figure 2-2 and Figure 2-3).
- Conductivity was typically slightly brackish (1,100-1,300 µS/cm) except during surface water flow events when it would become extremely fresh (<100 µS/cm) (Figure 2-2 and Figure 2-3).
- Groundwater levels in the upgradient monitoring bore (NS-0664) respond similarly to the fluctuations in the Site 12 Pool levels in response to large rainfall/recharge events (Figure 2-4).
- Predominantly clear (mean turbidity = 2.5 NTU), slightly alkaline (mean pH = 8.5) and a magnesium-bicarbonate (Ca/Mg-HCO_3) dominated water type with low sulphates (SO_4) (Figure 2-5).
- Preliminary baseline data indicates that the pool is sustained by groundwater, until the local groundwater level drops below the pool level. The pool is also periodically flushed with fresh surface water flows after rainfall events. The ratio of Site 12 Pool volume against inflow volume is presented in *Site 12 Pool Water Quantity Investigation* (FMG, 2020b). It takes approximately 2-3 weeks for groundwater to replace the pool water once a flushing event has occurred.
- A larger habitat area relative to other Iron Bridge pools, with a series of isolated pools spanning approximately a 650 m reach and 1266 m^2, and likely has greater downstream connectivity relative to other pools in the Iron Bridge area.
- Most pools are shallow, with the deepest being approximately 2.5 m. The total volume of the pools is estimated to be 2,532 m^3 based on an average depth of 2 m. This is a small volume relative to the inflow volume; for example, the 1EY post-development estimated inflow is substantially higher (54,198 m^3) (FMG, 2020b).
- The proposed WRD would reduce the existing Site 12 Pool catchment by 40%, which is predicted to reduce the peak flow into the Site 12 Pool system by approximately 50%. Despite the significant reduction in flow, the impact on the scouring ability and total inflow volume to the pools remain largely unchanged. This is due to the relatively small pool volume compared to the inflow volume of the reduced catchment resulting in even small and frequent rainfall events causing the pool to fill and overflow, maintaining catchment connectivity.
- Recorded water levels were a maximum of ~0.6 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded.
- The pool is frequently temporal, running dry for three to ten months of the year (based on a five-year monitoring period). The most recent observations noted it did not completely dry out in 2019 dry seaon, due to a relatively high rainfall previous wet season. There there was a short dry period in the of several weeks at the end of the 2020 dry season before a rainfall event in November 2020 recharged inflows and groundwater levels (Figure 2-4).

Figure 2-2 displays a high-resolution water level, salinity (conductivity) and temperature logger record from Site 12 Pool for the wet season of 2019/20. The rapid change in conductivity after rainfall events is evident, with one minor inflow at the start of the wet season that partially flushed and filled the pool as well as four major inflows that displayed flooding peaks and complete pool flushing. The falling stage is rapid after large flow events indicating there is little retention capacity in the system beyond the pool spill point.

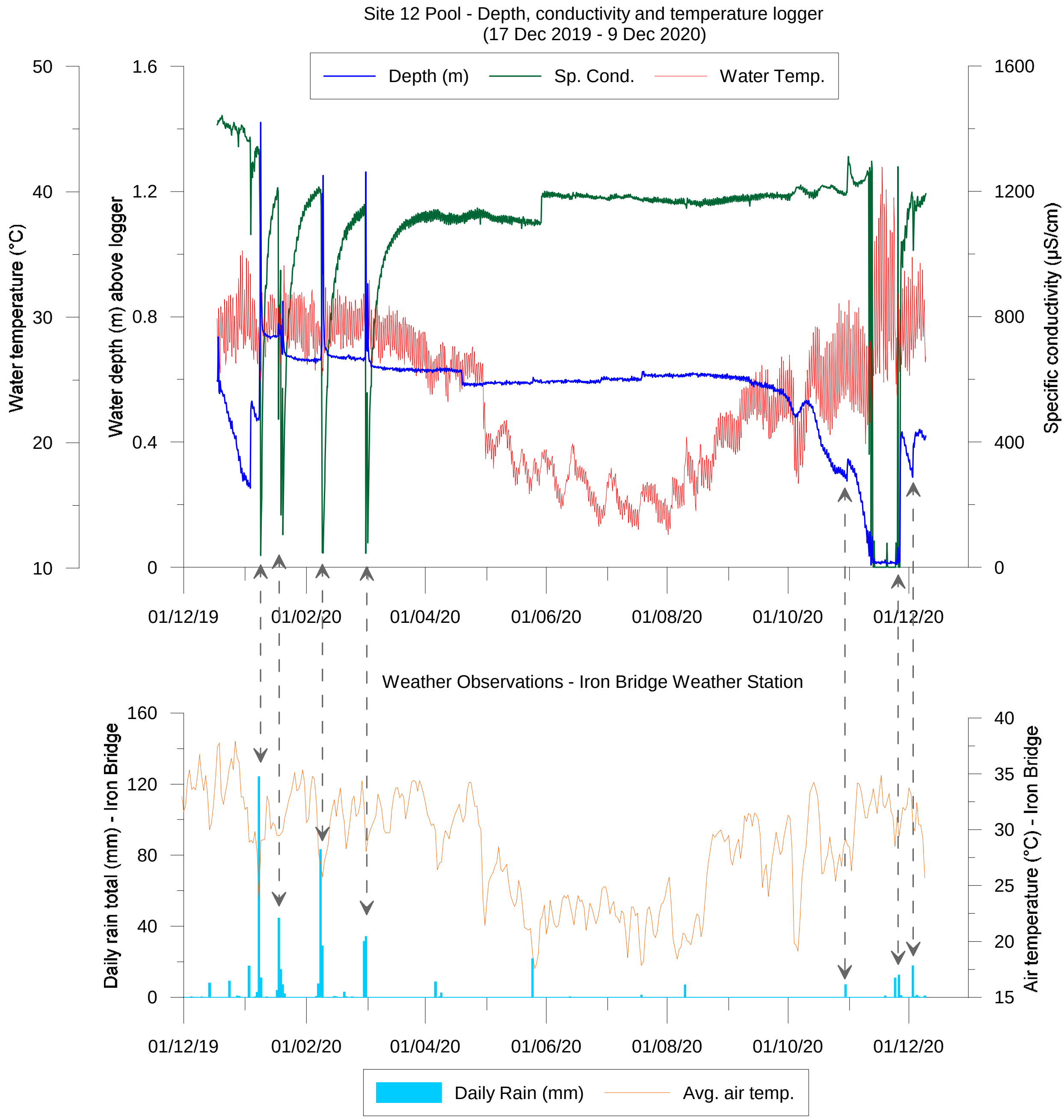


Figure 2-2 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Dec 2019 to Dec 2020.

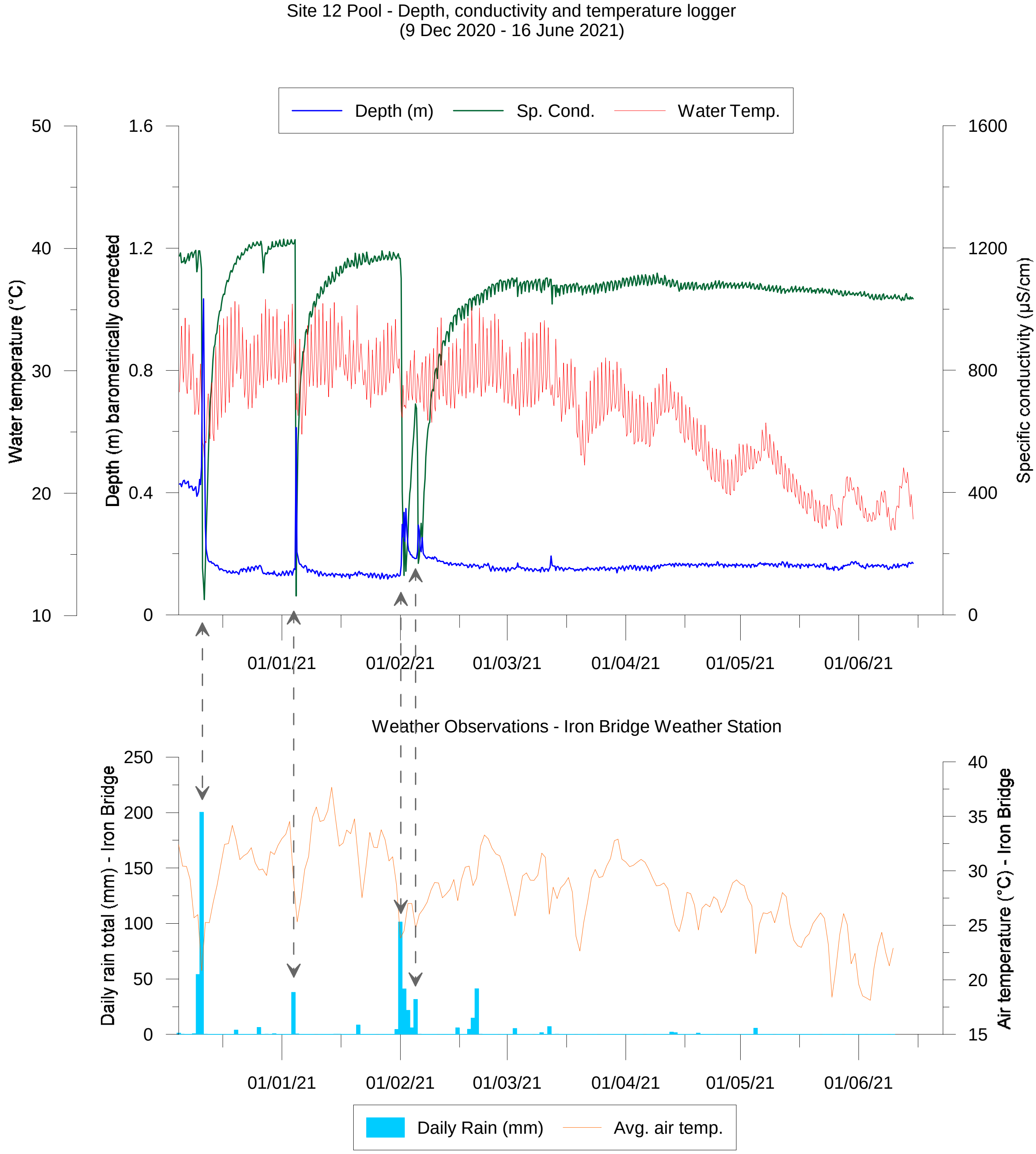


Figure 2-3 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below) – Dec 2020 to June 2021.

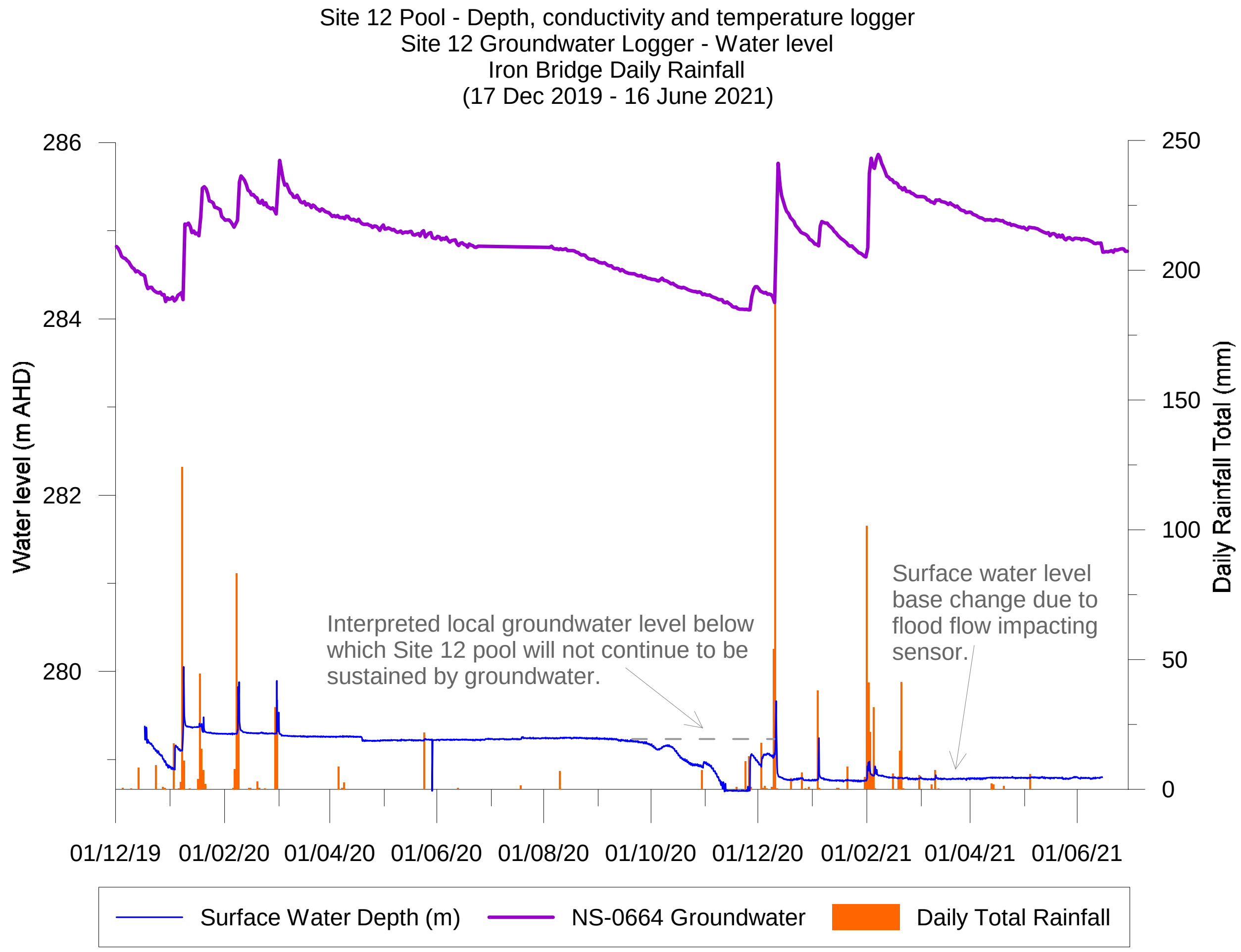


Figure 2-4 Comparison of surface water levels in Site 12 Pool and groundwater levels within the upgradient monitoring bore (NS-0664).

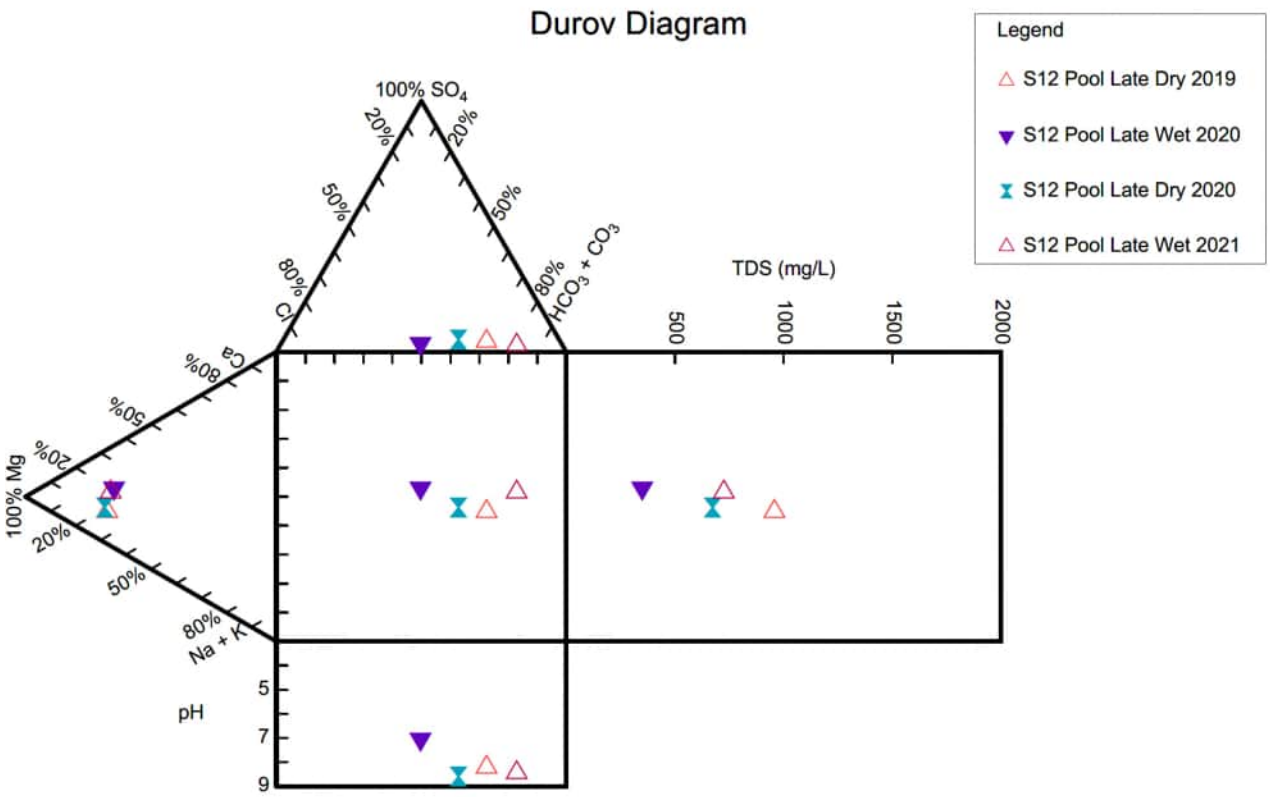


Figure 2-5 Durov diagram illustrates Site 12 Pool is a magnesium-bicarbonate (Ca/Mg-HCO_3) dominated water type. It is fresh-brackish, alkaline (481 mg/kg $CaCO_3$) with low sodium, chloride and sulphate (SO_4).

2.3.2.2 AQUATIC ECOLOGY

Site 12 Pool is situated within the Chichester IBRA bioregion and the Grassland climate class (Koppen; Figure 2-6). The ecology of Site 12 Pool is adapted to wetting and drying cycles over an annual basis, with key reproductive processes occurring during favourable wet season conditions. Although the pool can be sustained by the local groundwater level throughout the dry season, it has been recorded as completely dry in recent years (2015, 2016 and 2020 dry seasons) following low rainfall wet seasons (BOM 2020). The pool naturally drying out or experiencing substantially lower water levels would be expected to impact significantly on the ecological health of Site 12 Pool due to evapo-concentration increasing environmental stressors (e.g. salinity) and lower water levels reducing available habitat. It is notable that during the short period for which the Site 12 Pool was dry in November 2020 (2-3 weeks), the ecological monitoring survey shortly after a small rainfall event which filled the pool (December 2021) showed that fish and other ecological indicators has returned to the site (Hydrobiology 2021). It is likely that the deeper pools below the monitoring site acted as refugia in this case (i.e. they did not dry out) and the fish were able to migrate upstream and rapidly recolonise the pool once connectivity had been returned.

Two wet season and one dry season aquatic ecology survey have been conducted (late wet 2020, late dry 2020 and late wet 2021) and one site visit (2019 late dry season) which inform the reported aquatic ecology characterisation (Hydrobiology 2021).

- The habitat assessment recorded algal (periphyton) dominated bedrock with minimal sediment at the Site 12 Pool water quality sampling site (Figure 2-7; Figure 2-8).

- The aquatic ecology surveys recorded three fish species at Site 12 Pool: *Melanotaenia australis* (western rainbowfish), *Leiopotherapon unicolor* (spangled perch), and *Neosilurus hyrtlii* (Hyrtl's catfish). Site 12 Pool is the only pool of five pools surveyed at Iron Bridge where *N. hyrtlii* has been recorded, which may be due to the connectivity to downstream creeks and rivers. This species exhibits spawning migration into tributaries and the tendency to inhabit riverine habitats more frequently than off-channel lentic habitats (Pusey et al. 2004). Juveniles of each fish species were present, demonstrating evidence of successful wet season or post-wet season reproduction. Fish were variably abundant during all three surveys, although were not observed during the previous years' late dry season site visit (December 2019). The baseline dataset indicates that there is a naturally variable fish presence/population at this site. A planned late dry 2021 survey will provide further evidence of seasonal variability, however the 2020/2021 wet season was established by a large >200 mm rainfall event and the pool is not expected to dry this year.

- Aquatic amphibian larvae (tadpoles) were present during the late dry season though were not observed in the late wet season sampling. eDNA sampling recorded the presence of *Uperoleia* spp. which are burrowing toadlets inhabiting rocky creeks. It is likely tadpoles were observed in the late dry and not the late wet due to the timing of the breeding season.

- Non-native vertebrate species (e.g. cattle, wild boar) were not observed at the pool during the ecology survey and were not detected by eDNA water sampling. However, cattle (*Bos Taurus*), wild boar (*Sus scrofa*) and dingo/dog (*Canis* spp.) were detected at other Iron Bridge pools and may have the potential to access the Site 12 Pool.

- A large number of teratological ('deformed') diatoms (a group of microalgae) were present at Site 12 Pool, which normally occurs as a result of environmental stress. Moisture stress, UV and salinity are possible causes, although heavy metals are most strongly associated with teratological forms (Falasco *et al.*, 2009). Diatoms were present in very sparse abundance and had an average DSIAR score of 54.3.

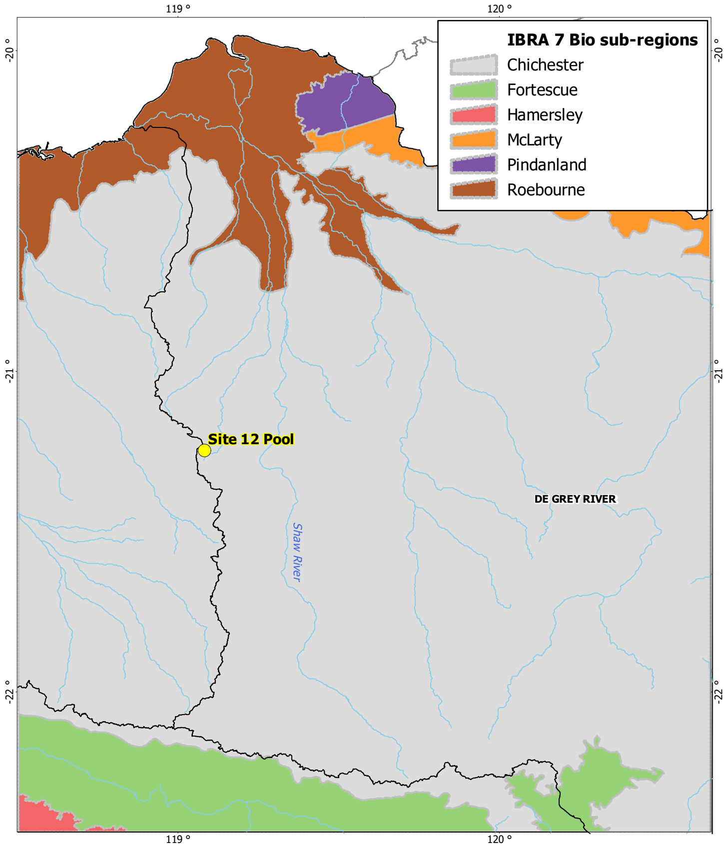
- Macroinvertebrate taxonomic richness (mean=20) and EPT[1] scores (mean=2.6) showed a variety of taxonomic groups inhabit the pools, including species sensitive to water pollution.

- A diverse range of native flora were observed within Site 12 Pool. These comprised aquatic species and groundwater-dependent species. These species are likely not surface water (direct run-off) dependent as the pool refills with groundwater within 2-3 weeks following rainfall events. Aquatic species were present during both late dry and late wet seasons including reeds (*Typha* spp.), sedges (*Juncus* spp.) as well as submerged macrophytes (*Villisneria* spp., *Myriophyllum* spp.). The types and species of macrophytes present in a system are indicators of water quality and ecological health. The abundance and diversity of macrophytes at Site 12 Pool provides habitat structure and refuges to organisms, plays a key role in nutrient dynamics, and indicates that water quality parameters (e.g. turbidity, salinity) have not reached levels that interfere with macrophyte growth and development. Furthermore, the persistence of a diverse range of groundwater-dependent species (including *Melaleuca* spp.) is tightly linked to the surface water quality, recruitment of other flora species, provision of food sources for native wildlife, stability and erosion control of the creek system and the provision of habitat/shelter to wildlife.

1 The EPT Richness Index estimates water quality by the relative abundance of three major orders of stream insects that have low tolerance to water pollution: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies).

- The Pilbara olive python (*Liasis olivaceus barroni*) has been recorded at multiple sites in the vicinity of Site 12 Pool by previous fauna surveys conducted by *ecologia* (2011a, 2011b, 2012) The species has not been sighted by Hydrobiology or recorded within the pool, either through observations or eDNA sampling. However, due to its low DNA shedding, the python and other reptiles are not commonly detected by eDNA water samples. The Pilbara olive python is a semi-aquatic species listed as vulnerable (EPBC Act 1999). Site 12 Pool may attract or provide habitat to the prey of the Pilbara olive python.
- No threatened aquatic species have currently been recorded at Site 12 Pool.

Comprehensive findings of the aquatic ecology survey are addressed in the *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2021).



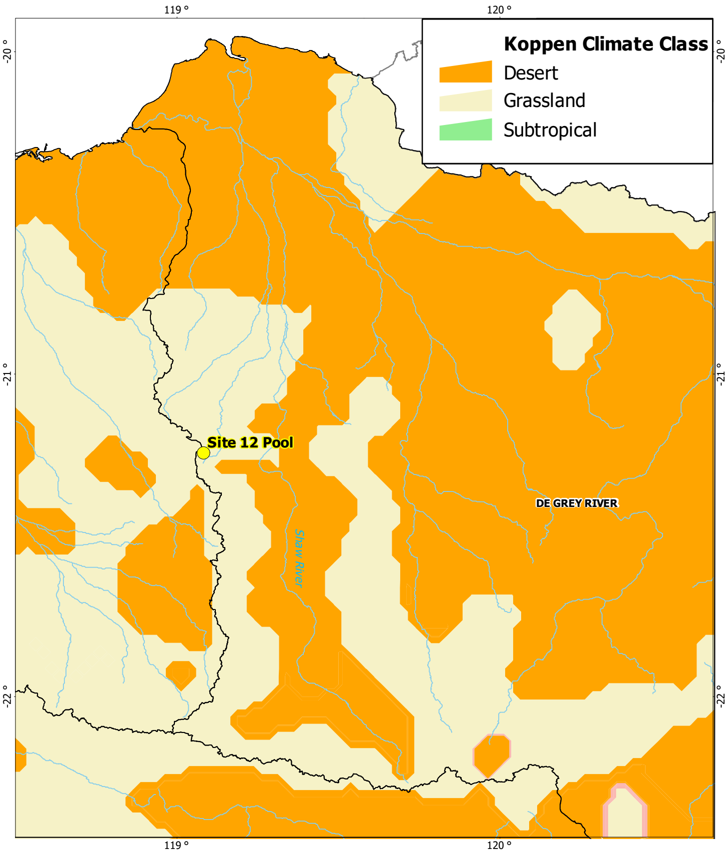


Figure 2-6 Site 12 pool situated within the Chichester IBRA bioregion and the Grassland climate class (Koppen)

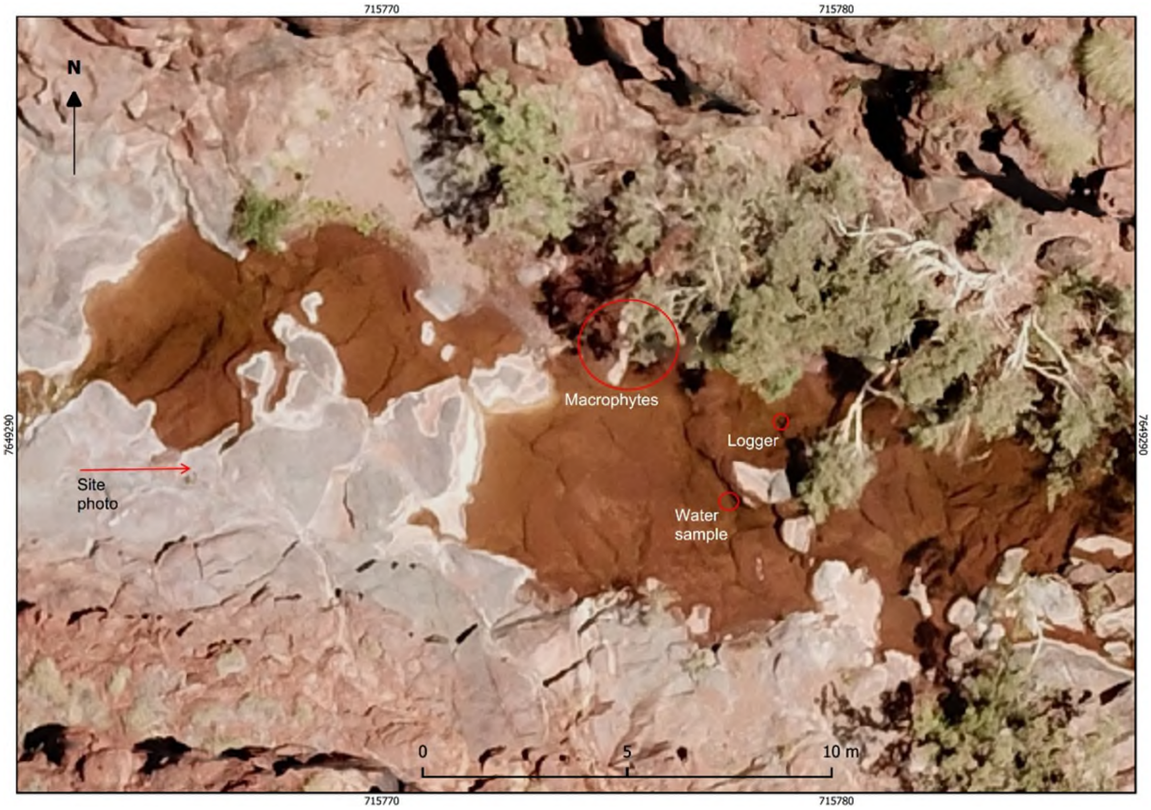


Figure 2-7 Site 12 Pool survey site drone image with sampling features noted.

Figure 2-8 Site 12 Pool – general site photograph looking downstream.

2.4 CONCEPTUAL IMPACT MECHANISMS

As part of the Project, approximately 40% of the Site 12 Pool catchment is expected to comprise a WRD with a footprint of 3 km^2, which has the potential to impact the Site 12 Pool downstream hydrology and water quality. Impacts to water quality and quantity, and consequently the ecology, may occur due to:

- Modification of the upper catchment results in decreased flow rates and deteriorating water quality.
- Storage of waste material resulting in water quality impact at the WRD contacted flow stream.
- Storage of waste material affects the Site 12 Pool catchment's run-off characteristics leading to decreased infiltration rates and volumes of run-off into Site 12 Pool.

These impacts may have direct or indirect effects and interconnect with the natural variability and factors integral to water quality in temporary pools (Figure 2-9). Table 3 outlines the conceptual impact mechanisms to aid in the identification of monitoring indicators and approaches in the development of the Site 12 Pool monitoring approach.

Table 3 Conceptual impact mechanism and associated monitoring parameters.

Conceptual Impact Mechanism	Description	Monitoring Parameters
Ecotoxic response	Ecotoxic response from one or more organisms in the food-web to the potential toxicants (including bioaccumulation) or changes to water quality resulting from WRD leachate or reduced flows causing a concentration of parameters (e.g. salinity) normally diluted by larger flows.	Macroinvertebrates Diatoms Fish Macrophytes Water quality Water quantity
Food availability (indirect ecotoxic effects)	Food availability impact to one or more organisms in the food-web due to an ecotoxic response to the water quality. Subsequent starvation or lowered reproduction of impacted species. For example, a reduced tadpole population directly resulting from toxins or low water quality reduces the food source (adult frogs) for Pilbara olive pythons and northern quolls.	Macroinvertebrates Diatoms Fish Macrophytes Water quality
Vegetation health decline	Decline in vegetation health at surface water pools due to changes in water quality, dust deposition and introduction or spread of invasive weed species.	Habitat Assessment Macrophytes Water quality Water quantity
Habitat alteration	Changes in the available aquatic habitat and/or suitable surrounding habitat due to impacts on vegetation, increased sediment load and turbidity, erosion due to altered hydrological regime or water chemistry.	Macrophytes Habitat Assessment Water quality Water quantity
Hydrological regime alteration	Aquatic ecology of Site 12 Pool is adapted to conditions of the pool including the variability of the hydrological regime and the corresponding water quality. For example, reproductive cues to may be linked to the water quality that corresponds to the natural patterns of the wetting-drying cycle.	Macroinvertebrates Diatoms Fish Macrophytes Water quality Water quantity

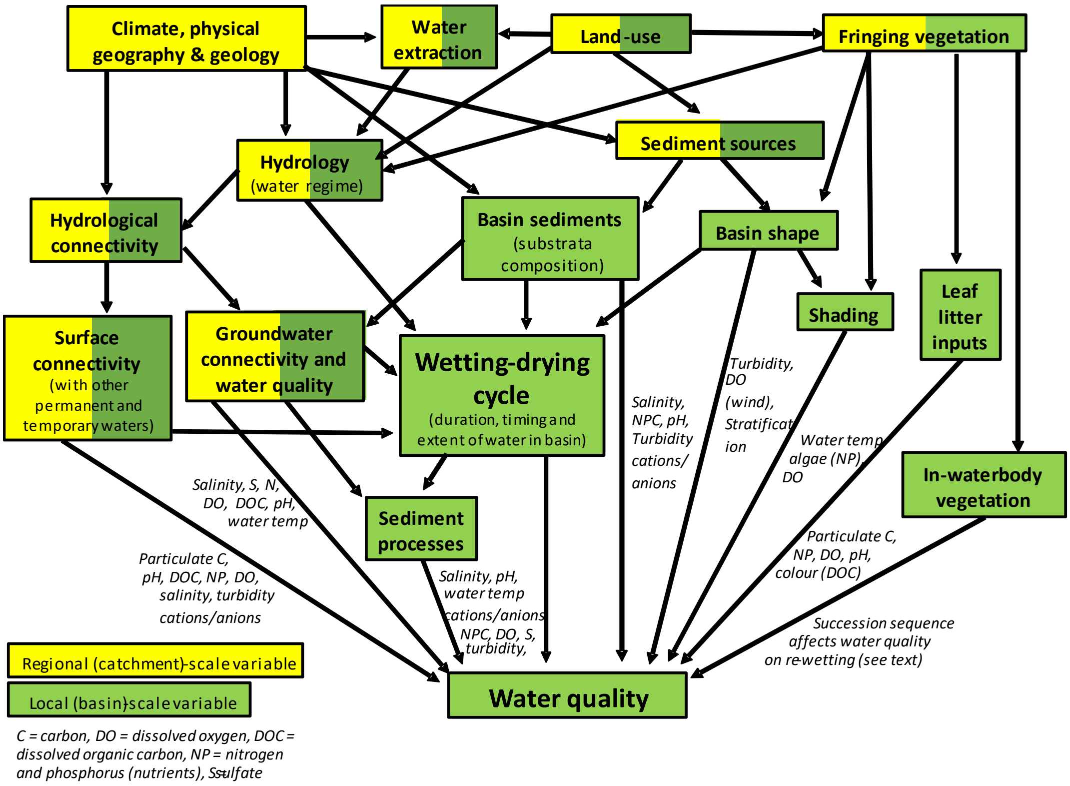


Figure 2-9 Conceptual diagram illustrating the interconnectedness and influence of various factors on water quality of temporary pools (ANZG 2018b).

2.5 MULTIPLE LINES OF EVIDENCE APPROACH

The monitoring approach applies a multiple lines of evidence approach (ANZG 2018a) to assess whether management goals are achieved, or if a detrimental impact has occurred. This approach gives greater certainty to assessment conclusions, and subsequent management decisions aimed to meet the water quality objective, compared to basing the evaluation on a single line of evidence.

Key indicators were selected across the following major groupings:

1. Pressure (Drivers): External activities or status that affect water quality
2. Stressor (Direct Effects): Physico-chemical quality elements and non-water quality stressors
3. Ecosystem receptor (Indirect Effects): Biological elements

Figure 2-10 presents an overview of the lines of evidence used in the monitoring approach and the assessment of management goals. Ecosystem receptors are an important line of evidence as these are what classify the health status of the system and ultimately determines whether a loss of environmental values has occurred. Stressor lines of evidence (physical, chemical, and non-water quality) provide cause-effect linkages to validate ecological status, are quantitative measures obtained more frequently in an ongoing sampling program and serve as early indicators to ecological impacts. Additionally, the selection of indicators across the surface water, sediment and biota systems of Site 12 Pool aims to provide a strong basis for meeting the EPA's (2018) objective of maintaining the quality of these so that the environmental values are protected.

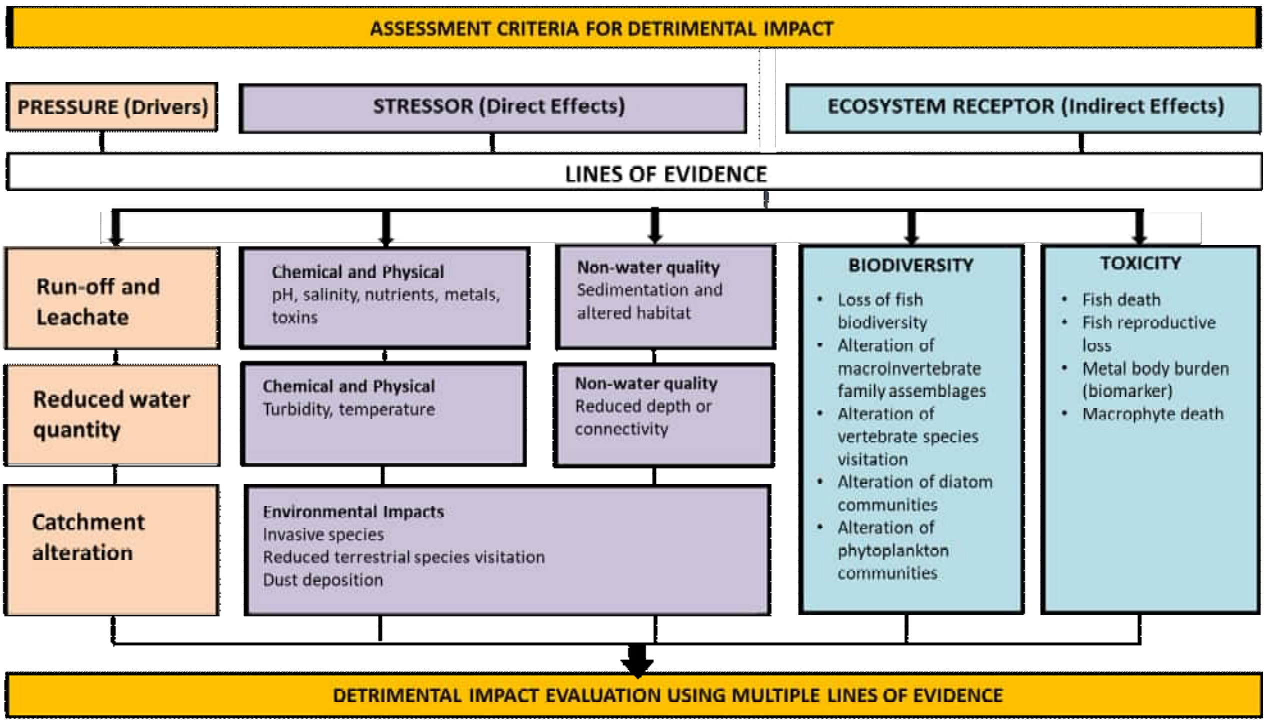


Figure 2-10 The multiple lines of evidence approach to monitoring water quality at Site 12 Pool

2.6 RATIONALE FOR INDICATORS

Site-specific indicators are listed in Table 6 (water quality) and Table 8 (ecological), which outlines the application of these indicators in the monitoring program. Site-specific indicators of water quality were selected for Site 12 Pool for the relevant stressors and anticipated ecosystem receptors identified for the system in Section 2.4 (Conceptual Model).

2.6.1 WATER QUALITY INDICATORS

The selected water quality indicators were developed into a monitoring program to utilise the stressors on the Site 12 Pool system (e.g. salinity, pH) as early detection for potential detrimental impacts to the ecosystem receptors (e.g. macrophytes).

Water quality indicators were selected from those recommended by *Managing Acid and Metalliferous Drainage* (DITR 2007), as per MS 993 Condition 12 – 3 (iv) and from the PSER causal pathway as recommended by ANZG (2018) to be informative of water quality changes that potentially impact environmental values. The selected indicators are conductivity, pH, turbidity, sulphate, total acidity, total alkalinity and dissolved iron.

Seasonal trigger levels for key water quality parameters were calculated from the baseline to accommodate the high temporal variability anticipated in temporary water systems (ANZG 2018b).

2.6.2 ECOLOGICAL INDICATORS

Threshold Criteria (Table 9) are derived from monitoring ecosystem receptor indicators, identified as resulting from changes to water quality in the conceptual impact mechanisms and as indicators of the loss of environmental values. These indicators are diatom communities, macrophyte communities, macroinvertebrate communities and fish communities.

Criteria are qualitatively assessed (Table 10) in order to accommodate the high natural seasonal variability anticipated in temporary waters, which impacts abundance and limits the applicability of quantitative assessment.

The rationale for the selected indicators is as follows:

- Algae (diatoms), macroinvertebrates, fish and macrophytes underpin the food web in temporary pools, providing habitat and/or food sources for a diversity of native species include terrestrial or semi-aquatic organisms that may utilise the pool such as the reptiles (e.g. Pilbara olive python), avian fauna and amphibians (Halse et al. 2001).
- The selection of these four communities spans multiple trophic levels and phyla, which is recommended in order to capture the variable impact of ecosystems stressors and detect, for example, impacts of bioaccumulation and biomagnification.
- Diatom communities – single-celled algae are effective indicators of ecological change in freshwater systems (Gale 2015). Quantitative sampling using periphytometers placed in situ for a defined period measures the capacity for growth, reproduction, and colonisation under current conditions.
- Macroinvertebrate communities – highly studied worldwide as indicators of water quality using a variety of bioindices and predictive models (e.g. EPT, SIGNAL, AUSRIVAS). As for diatoms, the taxonomic groups sensitive or tolerant to declines in water quality is well known, and the presence and abundance of these taxa are used to score the water condition of the pool.
- Macrophyte communities – effective indicators of ecological change, including indicators of when physical parameter thresholds are reached (e.g. turbidity blocking photosynthesis of

submerged macrophytes or impacts of sedimentation). Useful indicators of heavy metal bioaccumulation in a water body due to immobility. Provide an important habitat and refuge for fauna, especially in shallow water bodies such as Site 12 Pool.

- Fish communities – higher order organisms with relatively long-life spans. Useful for visually assessing health including bioaccumulation effects, interannual survivability and reproduction. Evidence of reproduction is sought (i.e. presence of juveniles) to detect sub-lethal effects impacting reproduction or vulnerable size classes.

2.7 TRIGGER LEVEL DERIVATION

The triggers selected for monitoring encompass multiple lines of evidence across the PSER pathway as per the Water Quality Guidelines (ANZG 2018a) and correspond to the strategies recommended by the guideline *Managing Acid and Metalliferous Drainage* (DITR 2007) to demonstrate the retainment of environmental values. The *Managing Acid and Metalliferous Drainage* guidance (DITR 2007) states that mining activities should not lead to water quality degradation such that the most conservative of environmental values defined for a water body is compromised. This does not mean that there must be no measurable impacts, but rather that impacts be minimised so that water quality is not degraded to the point where any existing environmental value is lost. Strategies the *Managing Acid and Metalliferous Drainage* (ANZG 2018a) guidance recommended to demonstrate the retainment of environmental values includes:

- Ensuring that relevant trigger values are not exceeded in receiving water bodies
- Ensuring that discharge does not result in a statistically significant change in key water quality parameters (no change occurs that is outside the seasonally relevant background concentration plus (or minus) two standard deviations).
- Demonstrating that the discharge will not have ecological impacts on the basis of site-specific ecotoxicological studies.

The Site 12 Pool WQMMP presents a three-step trigger assessment approach to align with the relevant guidelines:

1. **Early Response Trigger Levels** were developed for the receiving water body which ensures changes to key water quality parameters (as per MS 993 Condition 12) do not occur outside the seasonally relevant background concentration without triggering further investigation. To derive seasonally relevant site-specific trigger values, the median seasonal background concentration plus (and minus for pH) two standard deviations was applied as per the *Managing Acid and Metalliferous Drainage* guidance (DITR 2007). These were determined to be the most protective compared to values, where available, provided by the Water Quality Guidelines (ANZG 2018a).

   The Early Response trigger levels presented, while seasonal, are not yet refined to encompass the entire high site-specific variability in water quality associated with the hydrological cycle (such as first flush events and drying events). Therefore, they are intended to trigger further investigation and not to assess compliance.

2. **Early Response Trigger Investigation** triggered by exceedance of the Early Response Trigger Levels is supported by the Temporary Waters Guidance (ANZG 2018b) and involves assessing the water quality against the highly variable hydrological regime (Section 3.3.1). This may result in subsequent refinement of the trigger levels based on site-specific conditions. The outcome of the Early Response Trigger Investigation determines whether the Threshold Criteria is assessed.

3. **Threshold Criteria** is established from the exceedance of Early Response Trigger Levels, no natural hydrological cause identified by Early Response Trigger Investigation, and exceedance of Threshold Criteria. Criteria were developed under guidance from the Temporary Waters Guidance (ANZG 2018b) and to align with *Managing Acid and Metalliferous Drainage* (DITR 2007). These criteria demonstrate whether the Project has had an ecological impact on the basis of biological parameters reflecting toxicity. The Threshold Criteria are derived from the ecosystem receptor lines of evidence and assess the aquatic ecology. A 'traffic light system' of low, moderate and high-risk criteria is applied, where exceedance of a set number of validated moderate or high-risk criteria is defined as an exceedance and is reportable for purposes of further investigation and compliance monitoring.

The trigger levels contained in this report are interim values and will be reviewed at the completion of the baseline data collection phase.

2.8 KEY ASSUMPTIONS AND UNCERTAINTIES

2.8.1 ASSUMPTIONS

- Early Response Indicators selected adequately detect declining water quality that encompasses the range of potential impact mechanisms.
- Ecological parameters selected adequately detect declining aquatic ecosystem functionality and thereby detect loss of environmental value.
- Seasonal and annual variability in water quality and quantity that results in non-Project caused exceedances of Early Response Trigger Levels and Threshold Criteria are identified by the Early Response Trigger Investigation and validation step of Threshold Criteria.

2.8.2 UNCERTAINTIES

- Groundwater contribution is unquantified, however the groundwater contribution is linked to the natural local groundwater levels. When the local groundwater level is above the pool elevation, groundwater will sustain the pool. When the local groundwater level drops below the pool elevation (during the dry season), no groundwater will contribute to the pool water.
- The baseline surveys provide a representative degree of variability (within and between seasons and years) in the natural system.

3. SITE 12 POOL MONITORING PLAN

3.1 MONITORING LOCATIONS

The locations of sites for monitoring Early Response indicators and ecology are outlined in Table 4 and shown in Figure 3-1. Further sites are identified for the purposes of calibrating water quality logger data (Site 12 Pool Barometer) or conducting site investigations triggered by Early Response trigger level exceedance. The main Site 12 Pool sampling sites are located at the upper pools for the purposes of capturing effects impacting both upper pools and the downstream lower pools.

The monitoring sites shown in Table 4 are the existing surface water and groundwater monitoring location for Site 12 pool.

Table 4 Existing Monitoring locations at the Site 12 Pool area. Coordinates reference system: GDA 94/MGA Zone 50.

Monitoring site	Description	Easting	Northing
Site 12 Pool water quality sampling site (grab sample and field parameters)	Over bedrock on southern edge of stream.	715784	7649287
Site 12 Pool data logger	Within creek/pool, at the cross-section of gorge confinement	715784	7649287
Site 12 Pool barometer logger	Barometer logger to calibrate water level logger in a tree east of Bore NS 0064	715536	7649255
Site 12 Pool North Upstream rising stage sampler and data logger	Reference site – Creek upstream of Site 12 Pool with rising stage sampler and data logger	715575	7649414
Site 12 Pool West Upstream North Upstream data logger	Reference site – Creek upstream of Site 12 Pool upstream creek with data logger	715286	7649215
Site 12 Pool West Upstream North Upstream rising stage sampler	Reference site – Creek upstream of Site 12 Pool upstream creek with rising stage sampler	715352	7649178
Site 12 Pool South Upstream rising stage sampler and data logger	Reference site – Creek upstream of Site 12 Pool upstream creek with rising stage sampler and data logger	714848	7647015
Site 12 Pool groundwater bores	Existing bore: Bore NS 0064; west of Site 12 pool.	715498	7649266
Site 12 Pool ecological sampling site	Diatom periphytometers – within 2 m of data logger Fyke net – downstream 3 m from data logger Sediment – northern edge of data logger cross section Macrophytes – 50 m reach Habitat Assessment – upper pools to downstream pools prior to downstream junction Macroinvertebrates – southern and northern edge of channel at gorge entrance	715779	7649295

Table 5 Site 12 Pool monitoring record sheet locations

Name	Easting (MGAz51; GDA94)	Northing (MGAz51; GDA94)	Long. (WGS84)	Lat. (WGS84)
S12P Photo Point	715764	7649289	119.0792	-21.2453
S12P Macrophytes	715777	7649292	119.0793	-21.2452
S12P Logger	715779	7649290	119.0793	-21.2453
S12P Water Sample	715778	7649288	119.0793	-21.2453

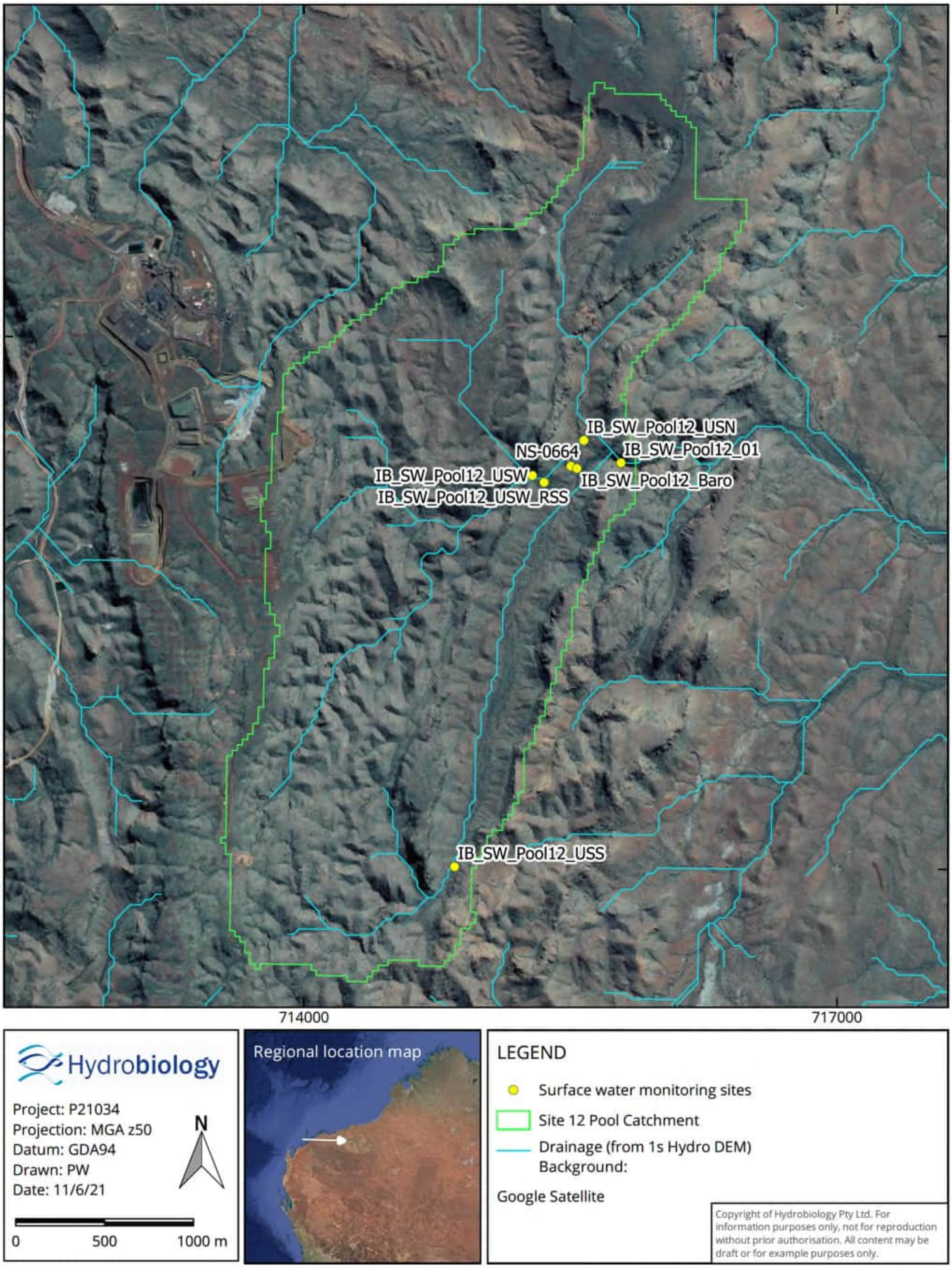


Figure 3-1 Site 12 Pool monitoring locations

3.2 MONITORING TIMING AND FREQUENCY

- Water quality monitoring at Site 12 Pool is undertaken biannually (Table 6), or as specified in Section 4 where trigger values are exceeded and may alter the sampling schedule.
- Water quality is sampled in the wet season and drying season. Sampling will align with these seasons based on the hydrological regime rather than the month (e.g. Figure 3).
- The wet season follows the wetting season and is approximately defined for the purposes of Site 12 Pool water quality monitoring as 1) the period following at least two large rainfall events/periods (greater than 20 mm over a 7 day period); and 2) prior to the drying season (see below). Sampling should occur more than 7 days following a substantial rainfall event. Figure 3-3 shows this period as occurring approximately between late January and May.
- The drying season follows the wet season and is approximately defined for the purposes of Site 12 Pool water quality monitoring as the period more than two months and less than four months following a substantial rainfall events/periods (greater than 20 mm over a 7 day period). The drying period typically occurs between June and November.
- Ecological monitoring (Table 7) is undertaken as required in Section 4 where a water quality trigger exceedance prompts further enquiry.

3.3 WATER QUALITY AND HYDROLOGICAL MONITORING

Table 6 shows the water quality monitoring parameters and frequency for Site 12 Pool.

Table 6 Water Quality Monitoring Parameters and Frequency.

Method	Monitoring parameters	Frequency[1]	Location[5]
Water loggers	Pool water level & Upstream channel water level	Automatic logging 3 hour for pool and 15 minutes for watercourse.[6]	IB_SW_Pool12_01 IB_SW_Pool12_Baro IB_SW_Pool12_USN IB_SW_Pool12_USW[2] IB_SW_Pool12_USS
	Groundwater level	Automatic logging min. 12h	NS-0664
Field measurements	Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Turbidity, Temperature	Monthly from Nov to Apr, Quarterly from May to Oct, and/or event based[1]	IB_SW_Pool12_01 IB_SW_Pool12_USN IB_SW_Pool12_USW_RSS [2] IB_SW_Pool12_USS
			NS-0664

Method	Monitoring parameters	Frequency[1]	Location[5]
Grab water samples for laboratory analysis	TSS, TDS, TOC, DOC Nutrients (Total Nitrogen, Total Phosphorus, Nitrate+Nitrite (NOx as N), Total Kjeldahl Nitrogen (TKN as N), Ammonia/ Ammonium) [9] Ions (Total Alkalinity, Cl, F, Sulphate, Bicarbonate/ Carbonate, , Ca, Mg, Na, K, Total Acidity SO_4, Hardness) Total and dissolved metals (Al, As, Cd, Cr, Cu, Fe, Pb, Ni, Zn, Hg, B, Ba, Be, Co, Mn, Se, V) [4, 7] AMD suit (Ag, Bi, Ce, Cs, La, Mo, Rb, Sb, Sc, Sn, Sr, Th, Ti, Tl, U, W)[8]	Monthly from Nov to Apr, Quarterly from May to Oct, and/or event based[1]	IB_SW_Pool12_01 IB_SW_Pool12_USN IB_SW_Pool12_USW_RSS [2] IB_SW_Pool12_USS
		Bi-annual monitoring [3]	NS-0664

1 'event based' is defined as rainfall that has resulted in visual streamflow across a floodway or down a designated river/pool/creek/stream. Monitoring following rainfall events will only be undertaken once it is considered safe to access monitoring sites.

2 It is expected very limited water quality at west upstream of site 12 pool, once the WRD access road is extended to block the stream flow from WRD.

3 Biannual ecology survey including water quality and sediment quality for laboratory analysis are conducted during pool late wet period (indicative Feb to Apr) and pool drying periods (indicative Sep to Nov), only when water is present.

4 Limit of Detection (LOD) on metals requested as meeting ANZG (2018) 99% EPL where applicable.

5 Site 12 pool is the primary monitoring location as the reporting location in accordance with MS993 Condition 12, the other monitoring sites are non-reporting locations to provide supplementary information to support multiple lines of evidence

6 Biannual data download from data logger or when required

7 For sites in the waterways (IB_SW_Pool12_USN, IB_SW_Pool12_USW_RSS, IB_SW_Pool12_USS) while all dissolved metal parameters are required, total metal parameters only Cu, Hg, Zn are to be measured.

8 AMD suits water quality analysis are applicable to the impacted waterways only (IB_SW_Pool12_USW_RSS, IB_SW_Pool12_USS)

9 TP, TN and NOx have a 28 day holding time, phosphate, nitrate and nitrite individually have a 2 day holding time. The remoteness of the site location prevents reliable laboratory delivery and analysis within less than 5 days (the laboratory recommendation is for samples to arrive at the lab with half the holding time remaining to allow for lab scheduling and processing).

Early Response Trigger Levels are presented in Table 7 as quantitative seasonal water quality trigger values which provide the first line of assessment at Site 12 Pool. These Trigger Levels are assessed on a biannual basis as per the water quality monitoring schedule.

In applying two standard deviations to the median seasonally relevant baseline value, exceedances exist within the baseline dataset. This is due to two standard deviations capturing 95% of data rather than 100% of data and, therefore, the most extreme events within the baseline fall outside the 95% statistical distribution.

Note that although the median of the dry season baseline data is higher or similar for some parameters (e.g. conductivity, turbidity), the high variability (and standard deviation) around wet season hydrological events results in a relatively higher wet season trigger value.

The values presented, while seasonal, are not yet refined to encompass the entire high site-specific variability in water quality associated with the hydrological cycle (such as first flush events and drying events). Therefore, the exceedance of an Early Response Trigger Level is intended to trigger further investigation (Section 3.3.1) and not to assess compliance.

The trigger values contained in this report are interim values and will be reviewed at the completion of the baseline data collection phase.

Table 7 Early Response Trigger Levels

Parameter	Uni	Trigger Level (median seasonal baseline ± 2 SD)	
		Wet season[1]	Dry season[1]
pH	-	<6.5 >9.0 [3]	<6.5 >9.03 [3]
Electrical conductivity (SPC)	µs/cm	>1854	>1517
Turbidity	NTU	>37	>1.6
Total alkalinity (as CaCO3)	mg/L	<82.2 >825.8	<364.1 >741.9
Total acidity (as CaCO3)	mg/L	>6.8	>5.5
Sulphate (SO4)	mg/L	>112.4	>65.0
Dissolved iron (Fe)	mg/L	>0.05[2]	>0.05[2]
Nitrate+Nitrite (NOx as N) [4]	mg/L	>0.6	>0.6

[1]Seasons vary interannually and are determined by the site-specific hydrological cycle. For guidance only; the dry season is typically from May – October and the wet season is typically from November - April.

[2] Dissolved Iron (Ferrous Iron mg/L) baseline concentrations consistently below LOD (0.05 mg/L), this LOD was applied as the trigger level as a reliable standard deviation could not be obtained.

[3] ANZG 2018 default pH guidelines.

[4] TP, TN and NOx have a 28 day holding time, phosphate, nitrate and nitrite individually have a 2 day holding time. The remoteness of the site location prevents reliable laboratory delivery and analysis within less than 5 days (the laboratory recommendation is for samples to arrive at the lab with half the holding time remaining to allow for lab scheduling and processing).

3.3.1 EARLY RESPONSE TRIGGER LEVELS INVESTIGATION

An Early Response Trigger Level Investigation is required when an Early Response Trigger Level exceedance is recorded. The aim is to validate and identify the cause of the exceedance.

This section provides guidance for assessment steps undertaken in response to an Early Response Trigger Level exceedance and can be adapted on a case by case basis. Note this Investigation forms a component of the Contingency Actions.

1. Re-examine water quality results by checking the QA/QC sample result is consistent and ensuring correct calibration of sampling equipment.

2. Resample and reassess to confirm the exceedance. This will also help to establish if the parameter in exceedance is increasing or decreasing in the timeframe since previous sampling.
3. Check Project related operations that have the potential to impact the water quality.
4. Acquire and use current Iron Bridge rain gauge data to ensure that the water quality parameter results are being assessed against the correct seasons Early Response Trigger Level (i.e. wet or drying season). Note that seasons vary interannually and the water quality parameters should be compared to the most representative seasons Early Response Tigger Levels based on rainfall events rather than sampling date. For example, if the wet season has not started prior to sampling in November, the November sample should be evaluated against the drying season Early Response Trigger Levels. For guidance only, the dry season is typically from May – October and the wet season is typically from November – April.
5. Assess the *Visual Inspection* results recorded during sampling for indications of causes to changes in water quality and preliminary evidence of ecological impacts (see Appendix A for field datasheet template). For example, check if the *Visual Inspection* notes nearly dry water levels, flood conditions, evidence of increased sedimentation or records of fish death.
6. Acquire and record logger data from the Site 12 Pool water level and water quality data logger and the Site 12 Pool Barometer (for locations see Section 3.1). Correct the water level for barometric pressure using the barometric data. Assess the water quality relative to the hydrological cycle by plotting the depth, temperature and specific conductivity over time and;
    a. Inspect the conductivity, depth and temperature data against the Iron Bridge rain gauge data and the sampled water quality parameters. Evaluate whether there is evidence of a natural hydrological cause that could have resulted in the exceedance. See Box 3.3.1 below for guidance '*Hydrological Regime Impacts on Water Quality*'.
    b. Assess for evidence that groundwater connectivity is being maintained. Baseline data shows the conductivity decline during a rainfall event and subsequently increase to near pre-rainfall conductivity levels over a 2-3 week period assuming no further significant rainfall (Figure 3-3). The lack of this pattern may be a preliminary indication that reduced groundwater inputs to Site 12 Pool are the cause of the Water Quality trigger exceedance. This may be further assessed by reviewing groundwater quality for changes in conductivity (similar surface water and groundwater levels may reduce the ability to discern connectivity through conductivity patterns) and check for declining groundwater water levels.
7. Investigate spatial trends upstream of Site 12 Pool and across the surface water pools at Iron Bridge. For locations, see *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2020). This may include;
    a. Assess water level data from loggers located at Site 12 North Upstream, Site 12 West and Site 12 Downstream.
    b. Check Site 12 Pool water quality relative to water quality from recent and baseline concentrations at Site 12 North Upstream, Site 12 West and Site 12 Downstream. This may include water quality from first flush sampling collected using rising stage samplers.
    c. Review water quality and levels across other monitored Iron Bridge pools (e.g. Cow Spring Pool, Central Creek Pool, South Star Pool, Fig Pool) for evidence of a spatial trend across the region.

3.3.2 HYDROLOGICAL REGIME IMPACTS ON WATER QUALITY

The following key features are intended to assist the Primary Trigger Level assessment of the impact the hydrological regime has potentially had on the water quality at Site 12 Pool.

- Extended periods of no to low rainfall would be expected to cause evaporation and lower groundwater levels, resulting in decreased surface water levels, increased conductivity, increased sulphate, and lower pH.
- Recent rainfall events may result in a decrease in conductivity, increased turbidity, increased sulphate and increased dissolved iron. Note that the conductivity may have rebounded to pre-rainfall levels prior to other parameters stabilising.
- Rainfall, and consequently run-off, has a varying impact on the water quality depending on when it occurs relative to the wet season and large rainfall events. Minor rainfall in the early or late wet season infiltrates into the drier soil and has a relatively low impact to the water quality compared to similarly sized rainfall that occurs during the mid-wet season once the soil is more saturated. For example, a 21 mm rainfall event in May 2020 had negligible impact on the EC, whereas a 31 mm rainfall event in March 2020 decreased EC by over 60%.
- Figure 3-2 illustrates the relationship between the displacement of higher conductivity water in Site 12 Pool with fresher rainwater, which results in a rapid decrease in conductivity (EC). Conductivity change (%) can be used to guide the expected difference in other parameters. For example, where rainfall has occurred but has caused a small (<1%) change in EC, it has likely infiltrated into soil and significant changes to other water quality parameters (e.g. SO4, turbidity) are not expected to naturally occur. Likewise, where a significant change to EC occurs during or following rainfall, significant changes to other parameters (e.g. turbidity) are expected as a result of substantial surface run-off and may be due to the natural seasonal variability.

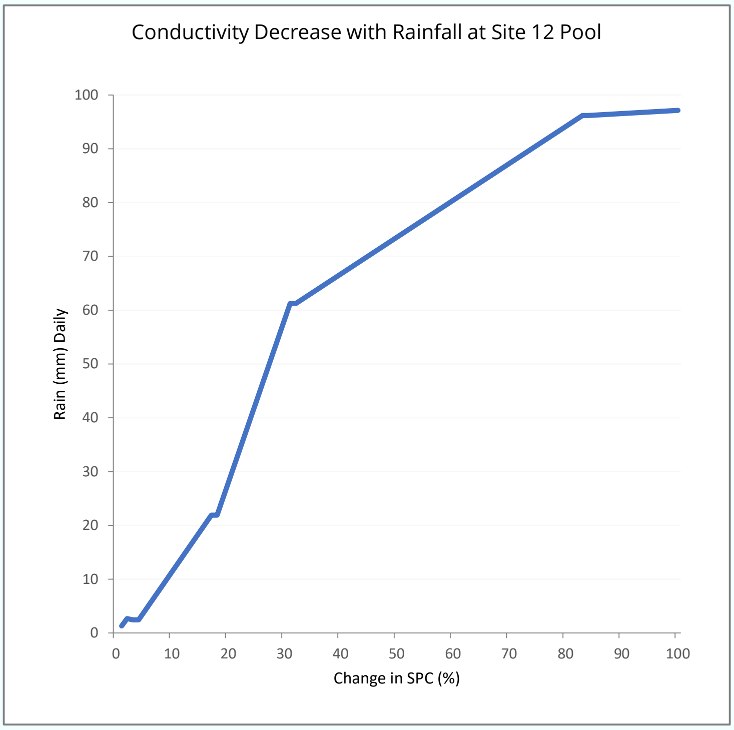


Figure 3-2 Conductivity (EC) decreases with increasing rainfall (mm) at Site 12 Pool. To be used as a guide only. Based on North Star rain gauge data (2019-2020) and Site 12 Pool water quality logger data (2019-2020) during the mid-wet season (Jan-Mar).

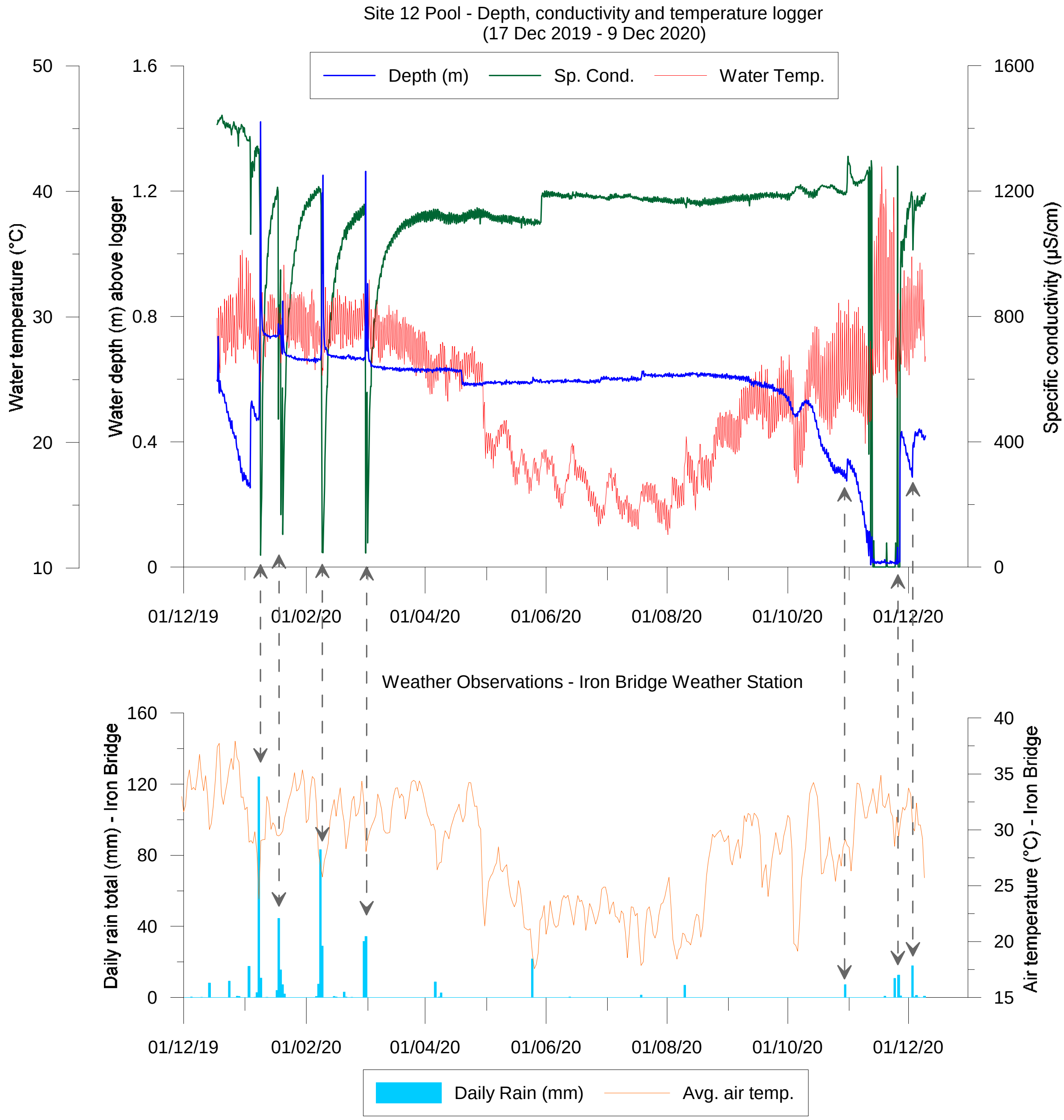


Figure 3-3 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below). Rainfall events fill Site 12 Pool with relatively fresh water that decreases conductivity (green). Following rainfall events, conductivity increases with the infiltration and displacement of rainwater with the relatively high conductivity groundwater water.

3.4 ECOLOGICAL MONITORING

The indicators sampled for ecological monitoring include the ecosystem receptor lines of evidence (biodiversity) identified from the PSER causal pathway (Section 2.6).

Ecological monitoring is undertaken as required in Section 4 where a water quality trigger exceedance (Table 7) prompts further enquiry.

Table 8 Ecological monitoring plan

Indicator	Parameter(s)	Collection method[1]
Diatom community	DSIAR scores and diversity	Diatom plates (periphytometers)
Aquatic macroinvertebrate community	EPT abundance index	Sweep nets
Fish community	Presence/absence Size structure	Fyke nets
Sediment quality	Total Alkalinity, Total Acidity SO4, TSS, Nutrients (nitrite, nitrate, phosphate), Ions (Cl, F, Ca, Mg, Na, K), total metals (As, Cd, Cr, Cu, Fe, Pb, Ni, Zn, Hg, B, Ba, Be, Co, Mn, Se, V), TOC	Sediment sampling
Habitat assessment	Wider habitat health	Visual inspection of habitat quality/health record on habitat sheet
Macrophyte diversity	Presence/absence	Habitat sheet

[1]Collection methods described in *Surface Water Monitoring and Aquatic Ecology Survey Baseline Report* (Hydrobiology 2020).

3.4.1 THRESHOLD CRITERIA

Threshold Criteria are defined in Table 9 (Table 10 displays the matrix) and these refer to Table 11 for ecological criteria.

Threshold Criteria are assessed subsequent to the following occurring:

1) Exceedance of Early Response Trigger Levels; and

2) Early Response Trigger Levels Investigation determines no natural hydrological cause for exceedance.

Meeting the above criteria 1) and criteria 2) prompts Ecological Monitoring (Table 8) and subsequently Threshold Criteria assessment (Table 11).

By assessing Threshold Criteria using multiple ecological indicators after water quality and hydrological assessments have been conducted, this approach uses the multiple lines of evidence approach to determine whether a Threshold exceedance has occurred.

Where a parameter is deemed a 'High Risk' or 'Moderate Risk' of indicating a potential ecological impact, this is assessed in the context of the Early Response Trigger Level Investigation findings, baseline variability and transferability of baseline climatic conditions to current sampling conditions, and based on professional knowledge by experts in ecology of the applicability of environmental parameters to water quality assessments. A such, a sampling event may produce a result that is High or Moderate Risk, and subsequent analysis by ecological expertise may determine the result is not valid (e.g. due to erroneous data or technical failure) or not comparable to the baseline (e.g. a natural cause not identified by the Early Response Trigger Investigation caused the impact such as detection of introduced species impact).

Table 9 Threshold Criteria.

Criteria	Assessment Parameters
Threshold Criteria	≥2 High Risk Criteria
	≥2 Moderate Risk and ≥1 High Risk Criteria
	≥3 Moderate Risk Criteria

Table 10 Threshold Criteria matrix. Y= threshold criteria exceeded, N=threshold criteria not exceeded.

Threshold Criteria Decision Matrix

MODERATE RISK CRITERIA (number of moderate risk ecological parameters met)	HIGH RISK CRITERIA (number of high-risk ecological parameters met)					
		0	1	2	3	4
	0	N	N	Y	Y	Y
	1	N	N	Y	Y	Y
	2	N	Y	Y	Y	Y
	3	Y	Y	Y	Y	Y
	4	Y	Y	Y	Y	Y

Table 11 Threshold Criteria Assessment Table.

Environmental parameters	LOW RISK[1]	MODERATE RISK[1]	HIGH RISK[1]
Macroinvertebrate communities[2]	Presence of EPT taxa > 0.5*B*	EPT index < 0.5*B* OR SIGNAL2 score < the lower of 2 or *B*-1	No EPT taxa present
Fish communities	*Melanotaenia australis* present including small size classes (<60 mm)	*Melanotaenia australis* present and no small size classes present	No fish species present
Diatom communities[3]	DSIAR score > 0.5*B*	0.5*B* > DSIAR score > 0.2*B*	DSIAR score less than 0.2*B*
Macrophyte communities	Emergent (reed like and tussock/rush like species) present in ≥ isolated abundance	Emergent macrophytes present, with evidence of deteriorating health > *B* maximum	Emergent and submerged macrophytes absent

[1] *B*=Baseline seasonally relevant mean (i.e. wet or dry season ecological baseline values).

[2] The EPT Richness Index estimates water quality by the relative abundance of three major orders of stream insects that have low tolerance to water pollution: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). SIGNAL (Stream Invertebrate Grade Number – Average Level) is a scoring system for macro-invertebrate samples from Australian rivers that indicates water quality based on tolerance or sensitivity of macroinvertebrate families present to water quality.

[3] DSIAR score (Diatom Species Index for Australian Rivers score) estimates water quality by the relative abundance of diatom species sensitive to water quality stressors.

4. CONTINGENCY MANAGEMENT PLAN

4.1 CONTINGENCY ACTIONS

Further assessment is required if Early Response Trigger Levels are exceeded at Site 12 Pool. This section outlines the assessment process, contingency actions and the adaptive management process. See Figure 4-1 for the Contingency Actions Flow Diagram. Refer to the *Surface Water Management Plan: North Star* (FMG 2020a) for further details on the corrective actions and adaptive management process.

1. Has an Early Response Trigger Level exceedance been recorded (Table 7)?

   a. NO – Resume standard monitoring frequency.

   b. YES – Proceed to Step 2.

2. Validate and investigate the cause for the exceedance as outlined in Early Response Trigger Level Investigation (Section 3.3.1) and proceed to Step 3.

3. Has a natural cause been identified by the Early Response Trigger Level Investigation as the cause of the Early Response Trigger Level exceedance?

   a. YES – Resume standard monitoring frequency.

   b. NO – Proceed to Step 4.

4. Has a Threshold Criteria exceedance been recorded?

  a. NO – Conduct a follow-up visual inspection and re-sampling within two weeks. Record for the purposes of reassessing the trigger levels as part of an active management review.
  b. YES – Report trigger exceedance as per Reporting Requirement (see *Surface Water Management Plan: North Star* (FMG 2020a)) and proceed to Step 5.

5. Develop a case-specific *Site 12 Pool Recovery Plan* and implement the contingency management measures as determined by the plan (see Section 4.2 for guidance). A period of time or event (such as substantial rainfall) will likely be required to occur before an assessment of the effectiveness of the *Site 12 Pool Recovery Plan* can be made. Therefore, proceeding the agreed and case-specific time after implementation of the *Site 12 Pool Recovery Plan*, proceed to Step 6.

6. Reassess from Step 1 following the implementation of the *Site 12 Pool Recovery Plan*. Depending on the contingency actions implemented, the monitoring parameters or frequency may require review. Where reassessment of Early Response trigger parameters (and any other parameters, if warranted) finds they are below trigger levels, standard monitoring (or the revised monitoring plan) is resumed. Where the reassessment records an exceedance of Threshold Criteria, proceed to step 7.

7. If monitoring indicates that implemented management measures are not mitigating impacts to Site 12 Pool, consider the following:

  a. Review management measures with an adaptive management response. For example;
    - Re-evaluate trigger levels and threshold criteria.
    - Measure other indicators to assess if Site 12 Pool environmental values have been detrimentally impacted by the guideline value exceedance event.
    - Workshop potential management measures with site (FMG) stakeholders (e.g. mining, environment, water departments) and potentially bring in expert/regulator advice. Implement appropriate measures.
  b. Carry on monthly monitoring frequency until Water Quality monitoring results do not exceed the Early Response Trigger Levels (see Table 6) for two consecutive sampling events, or as determined by the case-specific *Site 12 Pool Recovery Plan*.
  c. Conduct sampling and analysis of biomarker lines of evidence to provide further evidence to establish cause and effect e.g. fish tissue analysis for heavy metal toxicity.

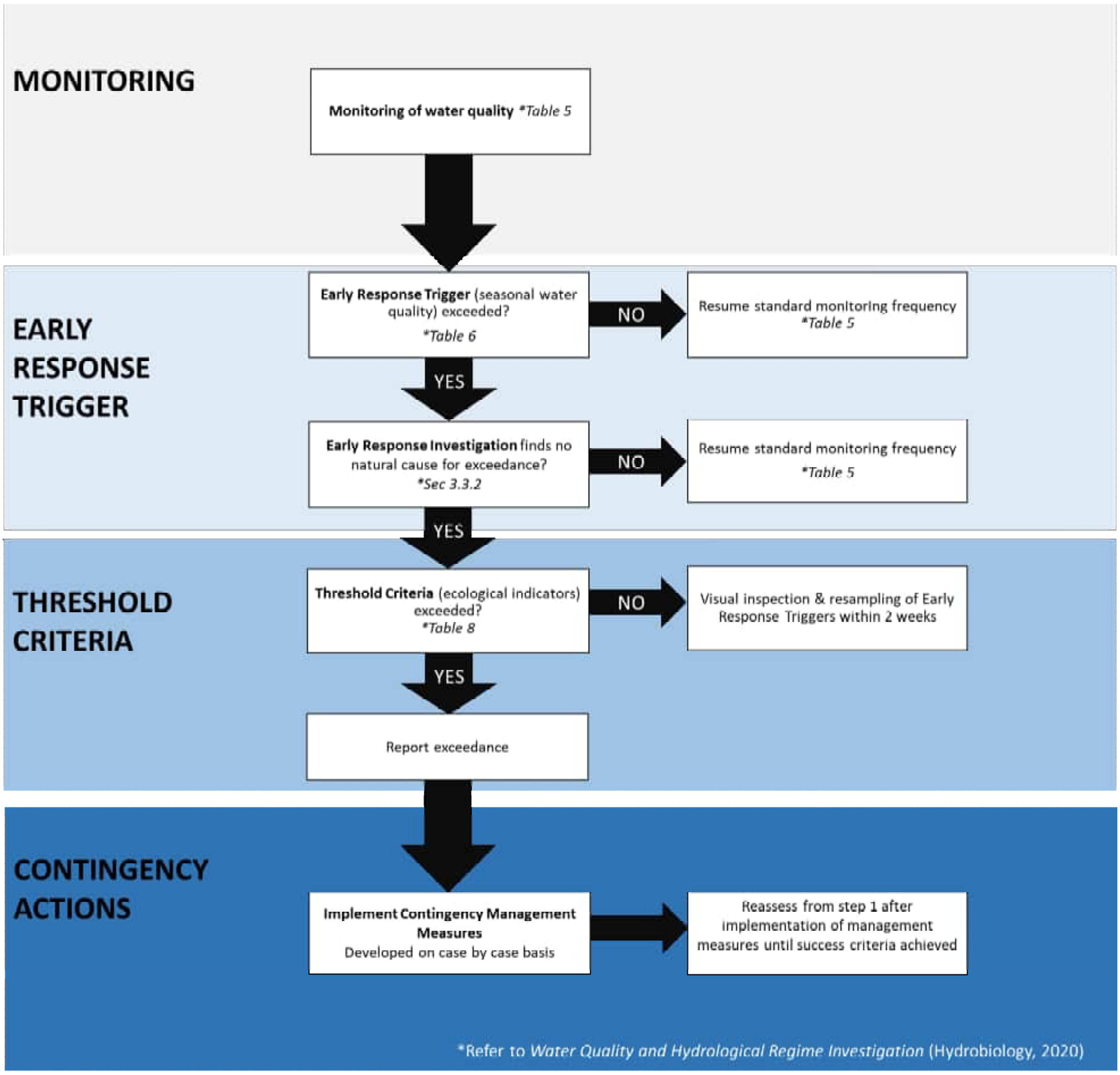


Figure 4-1 Contingency action diagram

4.2 CONTINGENCY MANAGEMENT MEASURES

This section conceptually outlines potential management measures for mitigating the immediate water quality and/or ecological impact to avoid a detrimental impact to water quality or hydrological regime of Site 12 Pool. The contingency actions are developed to be responsive to detected exceedances and allow for case-specific response to exceedances caused by the Project. The contingency actions are captured by the *Site 12 Pool Recovery Plan* as part of a multi-disciplinary approach.

Monitoring, preventative and review measures proposed to manage the potential environmental impacts associated with surface water at Site 12 Pool include:

- Implementation of the Site 12 Pool WQQMP, which is informed by this report.

- The monitoring approach incorporating the use of Early Response Indicators to detect early changes to water quality and quantity parameters, and ecological parameters that link changes in water quality and quantity to changes to flora and fauna.
- Monitor groundwater quality and level, as well as surface water quality and quantity upstream of Site 12 Pool to allow for early detection of changes.
- Where investigations deem the exceedance to be a result of the Project, the monitoring frequency will be increased to monthly until the Water Quality monitoring results are below the Early Response Trigger Levels (or a non-project cause is identified by the Early Response Trigger Investigation).
- Review Early Response Trigger Level, risk assignment of Ecological Parameters and Threshold Criteria. Evaluate whether the baseline remains representative, whether they are overprotective, under protective or otherwise not adequately reflective of the high natural variability.
- Implementation of the following preventative management measures to ensure no detrimental impact to water quality and water quantity:
    - Construct bunds at each bench to prevent mining impacted water from being released to the catchment.
    - Install toe bund downstream of WRD tip face to minimise the sediment discharge from WRD catchment to site 12 pool.

5. REFERENCES

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APPENDIX A. VISUAL INSPECTION FIELD DATASHEET

Site 12 Pool Visual Inspection Field Data Sheet

Date: / /

Name:

Undertake the following visual inspection during routine water quality monitoring at Site 12 Pool Water Quality Monitoring Site. This will form part of the site investigation assessment in the event of Primary Trigger Levels being exceeded. See below for visual guide for conducting inspection, and example of site photo.

Record YES or NO below as an indication of observed status of the ecological health.

Habitat health parameter	YES	NO
Fish presence	☐	☐
Macrophyte presence	☐	☐
Recent sedimentation presence	☐	☐
Observations of change (i.e. nearly dry, flooding, dead animals/plants)	☐	☐
Site photos taken	☐	☐

Comments

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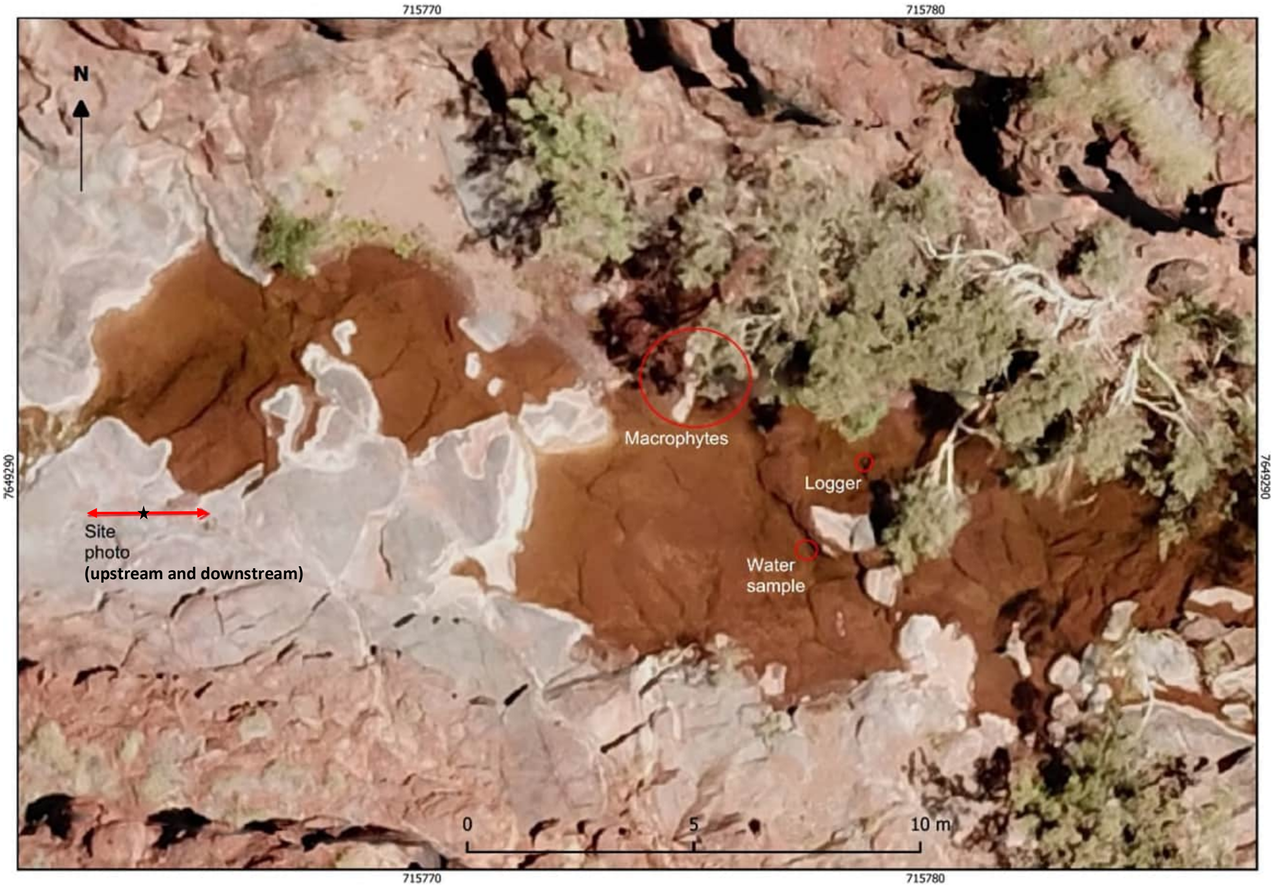

Guide for conducting visual inspection at Site 12 Pool

Monitoring record sheet location coordinates

Name	Easting (MGAz51; GDA94)	Northing (MGAz51; GDA94)	Long. (WGS84)	Lat. (WGS84)
S12P Photo Point	715764	7649289	119.0792	-21.2453
S12P Macrophytes	715777	7649292	119.0793	-21.2452
S12P Logger	715779	7649290	119.0793	-21.2453
S12P Water Sample	715778	7649288	119.0793	-21.2453

Above: Site photo downstream field of view (taken July 2020) – note macrophytes on left bank of pool

Above: Site photo upstream field of view (taken May 2020)

APPENDIX B. WATER QUALITY SEASONAL DATA

Table 12 Dry season water quality

Sample Date	(Acidity as CaCO3) Acidity as CaCO3 (mg/L)	(EC @ 25 Deg C) EC @ 25 Deg C (uS/cm)	(Ferrous Iron) Ferrous Iron (mg/L)	(pH) pH (pH units)	(SO4 - Turbidimetric) SO4 - Turbidimetric (mg/L)	(Alkalinity) Tot Alkalinity as CaCO3 (mg/L)	(Turbidity) Turbidity (NTU)	Nitrate + Nitrite (NOx as N; mg/L)
9/12/2020	<1	1090	-	8.60	28	590	1.85	<0.05
17/12/2019	<1	1479	-	8.21	20	685	<0.1	<0.05
28/06/2019 13:35:00	10	1,150	0.025	8.24	77	629	0.3	0.01
23/05/2017 15:00:00	0.5	1,160	0.025	8.48	48	508	0.3	0.12
15/06/2017 09:00:00	0.5	1,150	0.025	8.38	44	568	0.3	<0.01
13/07/2017 15:00:00	0.5	1,220	0.025	8.61	40	595	0.2	<0.01
10/08/2017 15:00:00	0.5	1,230	0.025	8.61	41	482	0.2	<0.01
20/09/2017 15:00:00	0.5	1,300	0.025	8.73	42	535	0.7	<0.01
01/07/2018 08:00:00	0.5	1,370	0.025	8.6	44	543	0.4	
26/08/2018 08:25:00	0.5	1,380	0.025	8.8	53	536	0.5	<0.01
29/09/2018 08:35:00	0.5	1,720	0.025	8.98	71	739	1.7	0.01
025/07/2019 07:40:00	0.5	1,130	0.025	8.64	27	653	0.2	<0.01
29/08/2019 07:40:00	0.5	1,160	0.025	8.63	26	665	0.3	<0.01
22/09/2019 08:34:00	0.5	1,180	0.025	8.68	28	642	0.3	<0.01
28/10/2019 11:23:00	0.5	1,270	0.025	8.9	28	688	0.5	
21/06/2020 15:34:00	0.5	1,160	0.025	8.62	18	619	0.3	
28/06/2020 09:00:00	0.5		0.025		21	646		
13/07/2014 0:00		1290		8.28	41	502		<0.01
04/08/2015 09:00:00		1,100		8.25	22	633		<0.01
23/09/2015 02:00:00		1,350		8.81	47	682		<0.01

Table 13 Wet season water quality

Sample Date	(Acidity as CaCO3) Acidity as CaCO3 (mg/L)	(EC @ 25 Deg C) EC @ 25 Deg C (uS/cm)	(Ferrous Iron) Ferrous Iron (mg/L)	(pH) pH (pH units)	(SO4 - Turbidimetric) SO4 - Turbidimetric (mg/L)	(Alkalinity) Tot Alkalinity as CaCO3 (mg/L)	(Turbidity) Turbidity (NTU)	Nitrate + Nitrite (NOx as N; mg/L)
23/05/2021	<1	1,120	0.014	8.42	14	592	0.2	<0.01
31/5/2020	<1	1,227	<0.05	8.26	22	478	0.16	0.05
24/11/2019 08:18:00	0.5	1,460	0.025	9.09	34	803	0.7	
16/03/2016 13:00:00	0.5	1,790	0.025	8.9	119	516	1.4	
15/11/2017 12:06:00	0.5	1,800	0.025	8.8	90	600	1.9	<0.01
20/10/2017 15:00:00	0.5	1,440	0.025	8.79	48	756	1.3	<0.01
19/04/2020 08:36:00	0.5	1,080	0.025	8.65	14	559	0.4	
15/03/2017 15:00:00	0.5	1,280	0.025	8.64	105	411	0.3	<0.01
28/01/2020 08:18:00	0.5	992	0.025	8.64	21	544	0.3	
11/05/2020 12:54:00	0.5	1,130	0.025	8.61	16	572	0.4	
31/03/2020 07:50:00	0.5	1,080	0.025	8.58	16	540	0.4	
28/04/2017 15:00:00	0.5	1,120	0.025	8.55	51	514	0.3	<0.01
18/02/2020 08:30:00	0.5	917	0.025	8.52	18	533	0.5	
04/03/2018 09:15:00	0.5	1,180	0.025	8.44	44	471	0.6	<0.01
11/02/2018 15:00:00	0.5	1,010	0.025	8.39	51	416	1	<0.01
03/04/2018 09:00:00	0.5	1,210	0.025	8.35	44	406	0.5	<0.01
06/05/2018 08:20:00	0.5	1,180	0.025	8.3	41	429	1.4	<0.01
29/05/2020 00:00:00	0.5	1,227	0.025	8.26	21	478	0.16	
17/12/2019 11:17:00	0.5	1479		8.21	28	685	0	
08/03/2015 00:00:00		750	0.01	8.1	58	210		<0.5
29/01/2016 13:00:00		334		8.04	32	82		0.32
10/02/2017 15:00:00	7	661	0.025	7.76	124	123	37.7	0.37

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