

SARAJI EAST MINING LEASE PROJECT

Environmental Impact Statement

Appendix E-1 Surface Water Quality Technical Report

BHP

Saraji East Mining Lease Project

Surface Water Quality Technical Report

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Surface Water Quality Technical Report

Client: BM Alliance Coal Operations Pty Ltd

ABN: 67 096 412 752

Prepared by

AECOM Australia Pty Ltd
Level 8, 540 Wickham Street, PO Box 1307, Fortitude Valley QLD 4006, Australia
T +61 7 3553 2000 F +61 7 3553 2050 www.aecom.com
ABN 20 093 846 925

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Prepared by Anna Hertle, Atena Roshani & Courtney Henderson

Reviewed by Nicky Lee and Elke Watts

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Abbreviations

AEP	Average Exceedance Probability
AHD	Australian Height Datum
BMA	BM Alliance Coal Operations Pty Ltd
CHPP	Coal Handling and Preparation Plant
DEHP	Department of Environment and Heritage Protection
DERM	Department of Environment and Resource Management
DES	Department of Environment and Science
DES manual	Manual for assessing consequence categories and hydraulic performance of structures (DES, 2016)
EA	Environmental Authority
EIS	Environmental Impact Statement
EPP (Water)	Environmental Protection (Water and Wetland Biodiversity) Policy 2019
EP Act	Environmental Protection Act 1994
ha	hectares
IRC	Isaac Regional Council
kL	kilolitres
kL/h	kilolitres per hour
km	kilometres
km ²	square kilometre
kV	kilovolts
L/d	litres per day
LGA	Local Government Area
m	metre
m ³	cubic metres
m ³ /d	cubic metres per day
m ³ /s	cubic metres per second
MIA	Mine Infrastructure Area
ML	Mining Lease
ML/d	mega litres per day
ML/year	mega litres per year
MLA	Mining Lease Application
mm	millimetres
MR Act	Mineral Recourses Act 1989
Mt	million tonnes
Mtpa	million tonnes per annum
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QR	Queensland Rail

RMP	Rehabilitation Management Plan
ROM	Run-Of-Mine
ROP	Fitzroy Basin Resource Operations Plan April 2009
STP	Sewage Treatment Plant
t	tonnes
t/yr	tonnes per year
the Project	Saraji East Mining Lease Project
ToR	Terms of Reference
tph	tonnes per hour
SDM	Slightly-to-moderately disturbed
Water Act	Water Act 2000
WQO	Water Quality Objectives
WRP	Water Resource (Fitzroy Basin) Plan 1999
WMP	Waste Management Plan
WTP	Water Treatment Plant

Executive Summary

BM Alliance Coal Operations Pty Ltd (BMA) has commissioned AECOM Australia Pty Ltd (AECOM) to recommence and finalise the environmental approvals for the Saraji East Mining Lease Project (the Project).

The Project Site is bound by Exploration Permit for Coal (EPC) 837, EPC 2103, Mining Lease Application (MLA) 70383, MLA 70459, Mining Lease (ML) 1775, ML 70142 and ML 1782. The Project Site encompasses approximately 11,427 hectares (ha) of land.

Mining and the infrastructure required to support the Project is not proposed within the full extent of the Project Site with direct impacts constrained to a smaller area of some 3,425 ha within MLA 70383, MLA 70459, ML 70142 and ML 1775. This area is referred to as the Project Footprint.

This surface water quality technical report provides an overview of existing surface water quality for the Project and assesses potential impacts to the environmental values of these surface water bodies as defined by the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water)). This report was designed to inform the Environmental Impact Statement (EIS) process for the Project. The assessment methodology was developed to meet the requirements outlined in the final Project Terms of Reference (ToR) document (DEHP 2017).

The Project is located within the headwaters of the Isaac-Connors sub catchment of the Fitzroy Basin. A number of watercourses have been defined within or adjacent to the Project Site, namely: Boomerang Creek, Plumtree Creek, Hughes Creek, One Mile Creek, Spring Creek, and Phillips Creek. These are all tributaries of the Isaac River.

Environmental values for the receiving waters in the Project Site were specified in Schedule 1 of EPP (Water) in September 2011 for the Isaac River sub-basin of the Fitzroy Basin. The following environmental values have been identified:

- aquatic ecosystems
- stock watering (e.g. cattle)human consumer (e.g. of wild or stocked fish)
- primary recreation (e.g. swimming)
- secondary recreation (e.g. sailing, fishing)
- visual appreciation (e.g. picnic, bushwalking)
- drinking water (e.g. raw water supplies taken from river)
- cultural and spiritual values (e.g. traditional customs).

Regionally the Isaac/Connors River System also provides a potable water supply (after treatment).

Relevant water quality objectives (WQO) for the Project Site were identified from the EPP (Water), local reference data and the Water Quality Guidelines (ANZG 2018). Water quality data from 2010 to 2020 was derived raw data collected for Receiving Environment Monitoring Programs or water quality trend assessments.

Water quality data shows that water quality were above relevant WQOs for a number of parameters indicating local watercourses and the downstream Isaac River have impaired water quality, being highly turbid with elevated nutrient concentrations. However, streams close to the Project Site (Boomerang, Hughes and One Mile Creeks) show higher electrical conductivity and sulphate concentrations in comparison to the downstream Isaac River. The local watercourses represent a slightly to moderately disturbed aquatic habitat.

Without adequate management and mitigation programs, the Project has the potential to have an adverse impact on ephemeral surface water resources during construction, operation and decommissioning. During construction the main areas of potential impact are activities associated with the construction of mine infrastructure, construction of access roads and stream crossings and earth moving activities. These activities may lead to increased potential for erosion and sediment mobilisation to surface waterways. In addition, these activities increase the potential for water quality deterioration through chemical and fuel spills.

Preliminary capacity estimates for all mine water management system (WMS) dams and the water transfer network have been determined through water balance assessment using 128 years of available climate data and conceptual operational rules. For the purpose of this assessment, a conservative approach has been adopted to sizing of each conceptual mine WMS storage such that:

- controlled releases of mine affected water (MAW) to the receiving environment are not required
- capacities are sufficient to prevent the uncontrolled (spillway) discharge of MAW to the receiving environment.

The proposed WMS has been designed with adequate capacity to avoid releases. The preliminary dam capacities presented herein are relevant to the input data, assumptions and adopted operational rules. However, any open system has the potential for uncontrolled discharge of MAW as a result of extreme rainfall events. As such, BMA will be seeking authority and licence conditions to conduct the controlled release of MAW from the Project Site. The indicative location for controlled release of MAW is located on Boomerang Creek adjacent to the proposed process water dam. Spillway discharges (uncontrolled) from the process water dam are also proposed to be directed to Boomerang Creek.

Potential adverse impacts may arise during the operational phase of the Project due to water management system infrastructure malfunctions (storages, pipes, embankments and levees), flooding of the mine area, chemical and fuel spills, and ponding of water within subsided areas.

During decommissioning the main areas of potential impact arise from transfer system failures during dewatering activities and increased erosion and sediment mobilisation potential during earthworks activities to establish a final landform for the sites.

Management and mitigation measures are recommended to reduce or avoid potential impacts identified in this study. The main mitigation measures required to address surface water quality involve development and implementation of erosion and sediment control measures and spill prevention (including documented and managed response procedures).

Development of a water quality monitoring program is proposed within this report, designed to measure the effectiveness of the impact mitigation measures implemented during the Project. Based on the implementation of recommended management and mitigation measures and validation through monitoring programs, the residual risk of the Project having adverse impacts on receiving surface waters is expected to be minor.

1.0 Introduction

BM Alliance Coal Operations Pty Ltd (BMA) have commissioned AECOM Australia Pty Ltd (AECOM) to recommence and finalise the environmental approvals for the Saraji East Mining Lease Project (the Project).

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This surface water quality technical report provides an overview of existing surface water quality for the Project and assesses potential impacts to the environmental values of these surface water bodies as defined by the Environmental Protection (Water and Wetland Biodiversity) Policy 2009 (EPP (Water)). This report was designed to inform the Environmental Impact Statement (EIS) process for the Project. The assessment methodology was developed to meet the requirements outlined in the final Project Terms of Reference (ToR) document (DEHP, 2017). Potential impacts to surface water hydrology are assessed separately in the technical report prepared by Alluvium (2019).

1.1 Project overview

BMA proposes to develop a greenfield single-seam underground mine development on MLA 70383 commencing from within ML 1775 (the Project).

The Project has been designed to utilise the existing approved Saraji Mine infrastructure, such as electricity lines, water supply pipelines, coal handling and preparation plant (CHPP), haul roads, workshops and warehouses, wherever practical. The Project will require upgrades to existing mine infrastructure and additional mine infrastructure. As such, the Project also includes a new CHPP, 66 kilovolt (kV) powerline, water pipeline and associated mine infrastructure area (MIA) and a new rail spur and balloon loop; each of which is proposed to be located on the existing Saraji Mine. A new infrastructure and transport corridor will be constructed on MLA 70383 and MLA 70459 to accommodate the reconfiguration of existing power and water networks and internal access roads. The key features of the Project are shown in Figure 1.

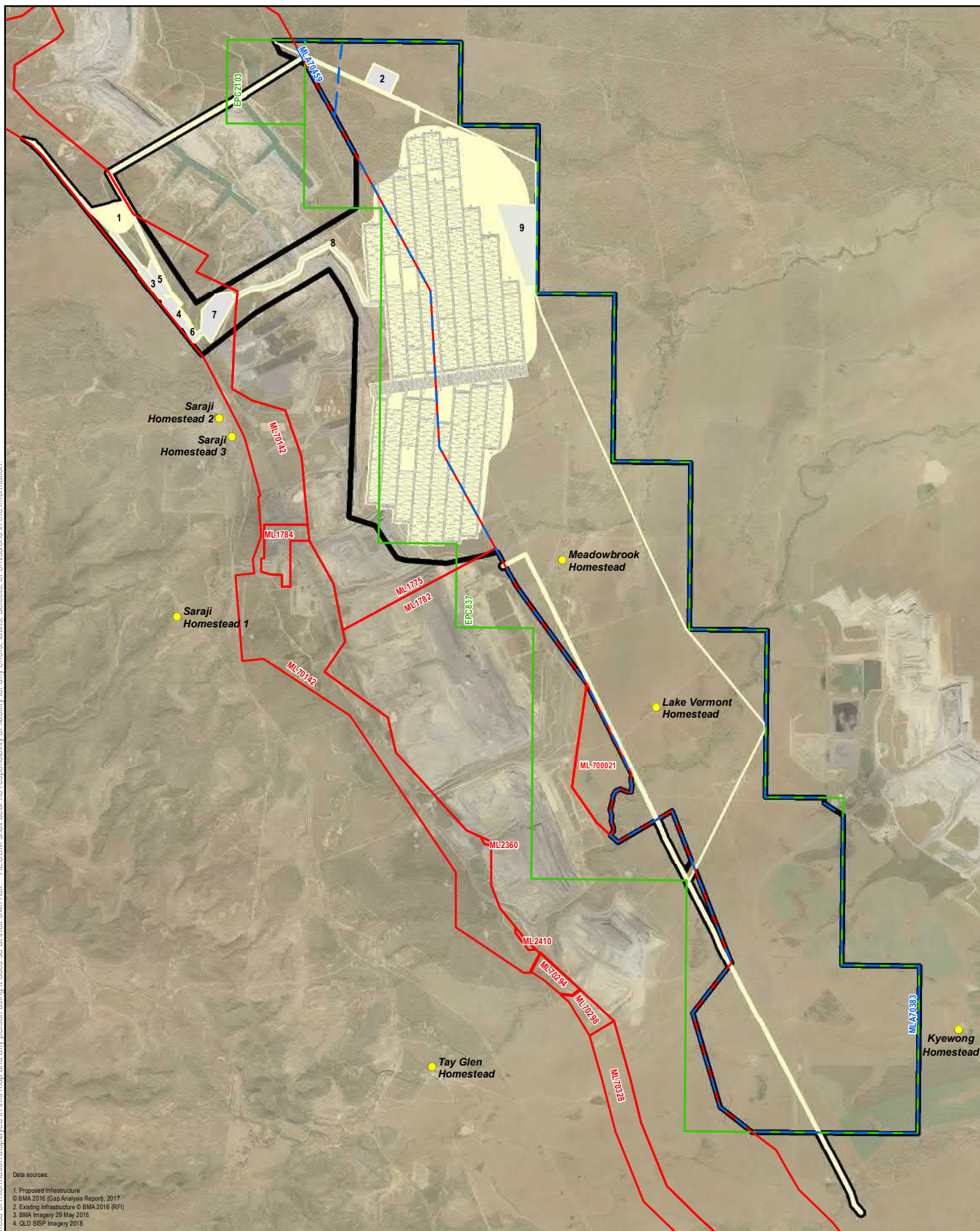
The Project will mine up to 11 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal and produce up to eight Mtpa of metallurgical product coal for the export market over a life of approximately 20 years.

1.2 Overview of the surface water receiving environment

The Project is located within the Isaac Regional Council (IRC) Local Government Area (LGA), approximately 30 kilometres (km) north of Dysart and approximately 170 km south-west of Mackay in Queensland.

The site topography comprises gently undulating country, descending to alluvial plains. The area is located within the Isaac River catchment (covering an area of approximately 19,000 square kilometres (km²)), with all mine affected water (MAW) potentially released into Isaac western upland tributaries. These catchments form part of the larger Fitzroy Basin. The Fitzroy River Basin extends from north of Nebo in the north to Injune in the south, Rockhampton in the east and Clermont in the west. The Fitzroy River Basin has a catchment area of over 140,000 km² and includes the majority of the Bowen Basin area. The basin eventually discharges into the Coral Sea east of Rockhampton, at the southern end of the Great Barrier Reef.

An overview of the Fitzroy River catchment and the Isaac River sub-catchment is provided in Figure 2.



LEGEND

Project Site	Underground layout (optimised)
Project Footprint	Surface Infrastructure
Exploration Permit Coal (EPC)	Homestead
Mining Lease (ML)	
Mining Lease Application (MLA)	

Surface Infrastructure

- 1 Rail Loading Balloon Loop
- 2 Process Water Dam
- 3 Product Stockpiles
- 4 CHPP
- 5 Raw Water Dam
- 6 ROM Pad
- 7 Future MIA
- 8 Conveyor
- 9 Construction Village



Figure 1
Project Site and Footprint

Environmental Impact Statement
Saraji East Mining Lease Project

0 0.5 1 2
Kilometres

Scale: 1:110,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

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LEGEND

- Locality
- Watercourse
- ▨ Isaac River Catchment
- ▭ Tenement
- ▭ Fitzroy River Basin
- ▭ Drainage Basin



Figure 2
Fitzroy River Basin

Surface Water Technical Report
Saraji East Mining Lease Project

0 25 50 100
Kilometres

Scale: 1:3,000,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 10/07/2020 VERSION: 3

The Project Site extends over several creeks including Hughes, One Mile, Phillips, Spring, Plumtree and Boomerang Creeks (refer to Figure 3). These creeks are diverted through the Peak Downs and Saraji Mine. Running approximately 8 km to the south of the Project Site is Phillips Creek, a large watercourse with a total catchment area of 452 km². Phillips Creek is diverted through the Saraji Mine site within the downstream reaches; however the Project Site does not extend into the Phillips Creek catchment.

The watercourses within the Project Site are ephemeral in nature and provide seasonal habitat for aquatic fauna and flora. The aquatic ecosystems are considered to be slightly to moderately disturbed from current mining and grazing activities and are classified accordingly in the EPP (Water). Stream substrates are dominated by coarse sand in all creeks across the site (Gauge Industrial and Environmental, 2014).

The dominant land use upstream of the proposed mine site is beef cattle grazing and native bushland. Tree clearing has occurred over time to improve pastures. There is also mining activity upstream of the Project Site and the Isaac River has been dammed upstream through the construction of Burton Gorge Dam. The catchments are therefore not in pristine condition and are susceptible to the impacts of existing land use activities. Existing land uses downstream of the Project Site include mining, grazing (modified pastures) and dryland cropping (SKM, 2012).

1.3 Assessment methodology

The assessment methodology identified environmental values with potential to be impacted by the Project and preventative and mitigation measures to demonstrate that the Project will not result in degradation of water quality related values. The surface water quality assessment involved the following steps:

1. Identification of the environmental values of surface waters within the Project Site and immediately downstream that may be affected by the Project (refer to Section 3.1)
2. Definition of relevant water quality objectives (WQOs) applicable to the environmental values (refer to Section 4.1)
3. Characterisation of the quality of surface waters within the area (refer to Section 4.3)
4. Identification of the quantity, quality, location and timing of all potential and/or proposed release of contaminants (such as controlled water releases to surface water streams) from water and waste water from the Project (refer to Section 4.3 and 4.4)
5. Assessment of the likely impact of any releases on all relevant environmental values of the surface water receiving environment (refer to Section 5.0)
6. Assessment of how the WQO and performance outcomes will be achieved, monitored and audited, and how corrective actions will be managed (refer to Section 6.0).

1.3.1 Information sources

Datasets used in this assessment comprise monitoring data from locations monitored as part of receiving environment monitoring programs (REMP) for Saraji Mine (SRM) and Peak Downs Mine (PDM) between 2010 and 2020, dependent on location. Most of this data was collected from downstream of the existing Saraji Mine and therefore would be similar to the existing baseline conditions of the Project Site.

In addition, the data from the Saraji Mine Trend Report 2011-2016 provides an indicative representation of water quality variability. There is some uncertainty in the trend analysis due to the methodology adopted in the study. However, data obtained from the REMP reports have been prepared in accordance with the approved REMP method and is therefore considered reliable for the purposes of this assessment.

2.0 Legislative framework and guidelines

2.1 Water Act 2000 (Qld)

The use of water for activities such as irrigation, stock water, drinking water and industrial use are regulated under the *Water Act 2000* (Qld) (Water Act). The Water Act provides a basis for the planning and allocation of Queensland water resources, which in turn must make allowances for the provision of water purely for the support of the natural processes that underpin the ecological health of natural river systems, that is, environmental flows. The watercourses potentially affected by the Project are subject to protection under the Water Act, which regulates the extraction of water from these watercourses and works that might disturb bed and banks of each watercourse.

A number of watercourses identified under the Water Act flow through the Project Site, including Boomerang Creek, One Mile Creek, Hughes Creek, Plumtree Creek, Spring Creek and Phillips Creek. Of these streams, only Boomerang Creek, Plumtree Creek and Hughes Creek intersect the underground mining panels and the predicted area of subsidence.

The Water Act prescribes the process for preparing Water Resource Plans (WRP) and Resource Operation Plans (ROP) which are specific for catchments within Queensland. Under this process, the WRP identifies a balance between waterway health and community needs and are applied on a catchment scale. The WRP establishes Environmental Flow Objectives that are of importance for waterway health and sets Water Allocation Security Objectives which are important to maintain water availability for community needs. The ROP provides the operational details on how this balance can be achieved. The WRP and ROP determine conditions for granting water allocation licences, permits and other authorities, as well as rules for water trading and sharing. The WRP and ROP applicable to the Project are detailed below.

2.1.1 Fitzroy Basin Water Resource Plan

The Project is located within the Fitzroy Basin. The Water Resource (Fitzroy Basin) Plan was finalised in 1999, but was amended in 2005 to address overland flow water management and was again updated in 2011 (Queensland Government, 2011).

2.1.2 Fitzroy Basin Resource Operations Plan

The Fitzroy Basin ROP came into force in January 2004 and was amended in October 2011 (Revision 3) (DNRM, 2015). It details how the objectives of the Water Resource (Fitzroy Basin) Plan will be met on an operational level, and defines strategies to support the WRP's overall goals for water entitlement security and ecological health.

In general, it provides the basis and rules for trading of water allocations, allows for unallocated water to be identified and allocated and also details operating rules for the use of water management infrastructure such as weirs and dams. The Nogoia Mackenzie, Lower Fitzroy, and Fitzroy Barrage Supplemented Water Supply Schemes operate within the wider Fitzroy Basin catchment.

2.2 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The quality of Queensland waters is protected under the EPP (Water and Wetland Biodiversity) 2019 (the EPP (Water)). The EPP (Water) achieves the objectives of the *Environmental Protection Act 1994* (EP Act) to protect Queensland waters while supporting ecologically sustainable development. Queensland waters include water in rivers, streams, wetlands, lakes, groundwater aquifers, estuaries and coastal areas.

The EPP (Water) seeks to protect and enhance the suitability of Queensland waters for various beneficial uses. The Queensland Department of Environment and Science (DES) (formerly the Department of Environment and Heritage Protection (DEHP)) hold responsibility for administering the EPP (Water).

The policy identifies environmental values for waters in Queensland and guides the setting of WQOs to protect the environmental values of any water resource. Water quality guidelines or objectives are the minimum levels required to protect all of the beneficial uses of a waterway (DERM, 2009). In

accordance with the EPP (Water), environmental values, water quality guidelines and WQOs for the Fitzroy Basin were established (DEHP, 2011).

The document that is of relevance to the Project Site's receiving environment is the *EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives* (DEHP, 2011).

2.3 Regulated structures

The *Water Supply (Safety and Reliability) Act 2008* (WSSR Act) sets out the requirements for referable dams. Generally, these relate to dams that exceed certain height and volume criteria which defines the scope of failure impact assessment (FIA) required to determine the population at risk in the event of dam failure.

All structures which are dams or levees associated with the operation of an ERA environmentally relevant activity (ERA) are generally required to have their consequence category assessed in accordance with the *Manual for assessing consequence categories and hydraulic performance of structures* (DES, 2016) (the DES manual). Assessment is based on the potential environmental harm that would result from a number of failure event scenarios including seepage, overtopping and dam break. Each scenario is assessed against three assessment criteria - potential harm to humans, general environmental harm and general economic loss or property damage with the potential consequence category for each criteria being either low, significant or high. The consequence category of a structure is hence the highest consequence category determined under any of the assessment criteria for each failure scenario.

A consequence category assessment (CCA) will be completed during the detailed design stage for all proposed Project dams.

Regulated structures must be conditioned by DES in the Environmental Authority (EA) for the Project, designed according to specific hydrologic and hydraulic performance criteria set out in the DES manual, and inspected annually by a suitably qualified professional.

2.4 Other guidelines

Information on water quality has also been obtained from the *Queensland Water Quality Guidelines* (QWQG) (DEHP, 2009) and national information from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018).

3.0 Surface water environmental values

3.1 Environmental values

Environmental values for water are the qualities of water that make it suitable for supporting aquatic ecosystems and human water uses. These environmental values need to be protected from the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use. Different waters may have different environmental values. The range of environmental values and the waters to which they can potentially apply are listed in Table 1.

Table 1 Environmental value definitions. Source: DEHP (2011)

Environmental Value	Description
Aquatic ecosystem	A community of organisms living within or adjacent to water, including riparian or foreshore area (EPP (Water), Schedule 2). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas. For example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation. For example, irrigation of crops, pastures, parks, gardens and recreational areas.
Water supply/use	Suitability of domestic water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock watering	Suitability of water supply for production of healthy livestock.
Aquaculture	Health of aquaculture species and humans consuming aquatic foods (such as fish, molluscs and crustaceans) from commercial ventures.
Human consumption of aquatic foods	Health of humans consuming aquatic foods, such as fish, crustaceans and shellfish from natural waterways.
Primary recreation	Health of humans during recreation which involves direct contact and a high probability of water being swallowed, for example, swimming, surfing, windsurfing, diving and water-skiing. Primary recreational use, of water, means full body contact with the water, including, for example, diving, swimming, surfing, water-skiing and windsurfing.
Secondary recreation	Health of humans during recreation which involves indirect contact and a low probability of water being swallowed, for example, wading, boating, rowing and fishing.
Visual recreation	Amenity of waterways for recreation which does not involve any contact with water. For example, walking and picnicking adjacent to a waterway. Visual recreational use water means viewing the water without contact with it.
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.
Industrial use	Suitability of water supply for industrial use. For example, food, beverage, paper, petroleum and power industries. Industries usually treat water supplies to meet their needs.
Cultural and spiritual values	Indigenous and non-indigenous cultural heritage. For example: • Custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities • Symbols, landmarks and icons (such as waterways, turtles and frogs)

Environmental Value	Description
	- Lifestyles (such as agriculture and fishing). - Cultural and spiritual values of water means its aesthetic, historical, scientific, social or other significance, to the present generation or past or future generations.

The Project Site is located in the far upstream headwaters of the Fitzroy Basin and relatively high in the headwaters of the Isaac River sub-catchment. The major watercourses within the receiving environment include the upper to middle reaches of Hughes Creek, One Mile and Phillips Creeks.

The Project is located in the upper to middle reaches of Hughes, One Mile, and Phillips Creek, with water quality monitoring locations at approximately 180 m to 360 m AHD (Australian Height Datum) elevation. The upstream sites exhibit typical freshwater upland stream characteristics, whereas the downstream sites have characteristics of both upland and lowland freshwater streams.

The QWQG (DEHP, 2009) defines upland freshwater streams as “small (first, second and third order) upland streams with moderate to fast flows due to steep gradients. Substrate usually cobbles, gravel or sand – rarely mud.” The definition of lowland freshwater streams is “larger (third, fourth and fifth order or greater), slow-flowing and meandering streams and rivers with gradient very slight. Substrates rarely cobble and gravel, more often sand, silt or mud” (DEHP, 2009).

3.2 Scheduled Isaac River sub-catchment environmental values

Environmental values for waters in the Isaac River sub-basin are published in the DEHP 2011 document entitled ‘Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Isaac River Sub-basin (including Connors River)’. The following environmental values have been identified for the Isaac Western Uplands Tributaries sub-catchment (within which the Project Site is located):

- aquatic ecosystems
- stock watering (high) (e.g. cattle)
- human consumer (e.g. of wild or stocked fish)
- primary recreation (e.g. swimming)
- secondary recreation (e.g. sailing, fishing)
- visual appreciation (e.g. picnic, bushwalking)
- drinking water (e.g. raw water supplies taken from river)
- cultural and spiritual values (e.g. traditional customs).

3.3 Existing water users

The Project Site is within the Isaac River catchment. The Lower Fitzroy and Fitzroy Barrage Water Supply Schemes are located 250 km downstream of the confluence with the Isaac River. They have 28,621 mega litres (ML) and 62,335 ML of allocated water, respectively. The total catchment area of these tributaries upstream and within the Project Site is about 590 km², this equates to less than 0.4 per cent of the total catchment area for these water supply schemes (142,665 km²).

It should also be noted that the ROP explanatory notes state that the western tributaries of the Isaac River are significantly drier than those to the north, with annual rainfall less than 600 millimetres (mm) in the west and less than 1,600 mm in the north. This suggests that creeks in the vicinity of the mine (Phillips, Boomerang, Hughes and One Mile Creeks) provide a relatively small contribution to the water allocations in the Fitzroy River Basin.

Existing surface water users have been identified through a search of the Department of Natural Resources, Mines and Energy (DNRME) database on surface water extraction licences near to the Project Site prior to the confluence with the Isaac River. The search revealed five surface water

licences, consisting of two licences for stock watering purposes downstream of the site, with the remaining three licences belonging to BMA to divert a watercourse and for site water management of the existing Saraji Mine. The stock licences are all located within 8 km of the downstream extent of the Project Site. A summary of these licences is provided in Table 2 and illustrated in Figure 4.

Table 2 Surface water extraction licences

Lot/Plan	Creek	Purpose
9/CNS98	Ripstone Creek	Stock watering
11/KL135	Ripstone Creek	Stock watering

3.4 Existing water management system

Water supply for the Project will be provided via the existing water network allocations supplying Saraji Mine, however the Project water management system (WMS) has been designed to operate self-sufficiently with the benefits of being connected to the broader BMA network to allow water sharing where beneficial.

Under normal operating conditions, the Project mine water system will operate independently of the existing Saraji Mine water system. However, should sufficient MAW not be available for CHPP process and dust suppression at the Project, this may be imported from the existing Saraji Mine water system, following water quality testing to confirm that water is of an appropriate quality for the intended use. Similarly, where additional water demands at the existing Saraji Mine need to be met, water that satisfies water quality testing may be exported from the Project.

The initial water demand increase associated with the Project is in the order of 2.3 mega litres per day (ML/d) and is required by Financial Year (FY) 2021. The peak water demand for the Project is 6 ML/d and will be required by FY 2024.

Water will be managed through a series of existing diversion drains and dams designed to contemporary standards to comply with regulatory requirements. Runoff from undisturbed areas will be segregated from disturbed areas to convey clean water downstream.

The water from the raw water dam will be used to satisfy water demands of the Project, including dust suppression and a proportion of demand from the CHPP. Raw water from existing BMA surface water allocations will be piped to the Project Site in a raw water dam to supply clean water, including the water requirements of the CHPP and longwall mining equipment as well as to supplement site water demands as required.

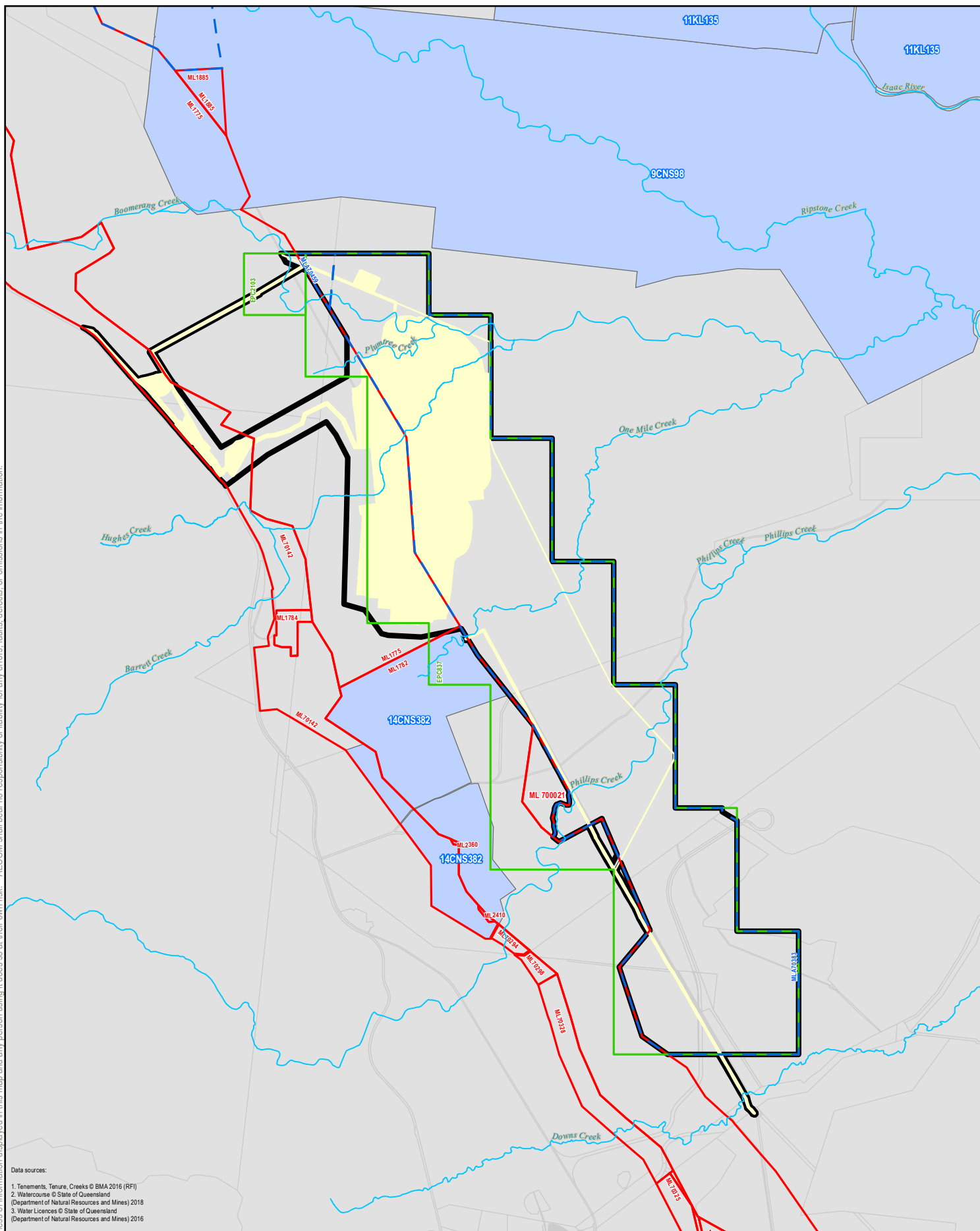
This raw water demand forms a very small portion of the overall site water use and includes:

- Water treated for potable uses (drinking, washrooms)
- A small quantity of water required for the CHPP. While most of the water demand for the CHPP is met through recycled water, a minor component (typically three per cent) of the CHPP water use requires raw water.

BMA holds allocations of water from the Fitzroy and Burdekin water catchments and numerous licences to take water across BMA's mine sites. BMA operates a water pipeline network in Central Queensland, servicing its mines, landholders and towns; BMA's current allocations are sufficient to meet the needs of the Project.

BMA will prepare, update and maintain a Water Management Plan. The Plan will recognise that water to be used for Project operations will be sourced via an off-take from the existing water pipelines developed to support BMA's current and future mining operations, along with various other purposes. Further, this Plan will recognise that water will be sourced from the Eungella Dam and/or the Burdekin Pipeline. The Project will have an internal BMA allocation to draw water from as part of the BMA-related water allocations.

These allocations are held by BMA directly or indirectly via contractual arrangements with SunWater in accordance with the Burdekin Water Resource Plan and the Water Act.



- LEGEND**
- Project Site
 - Project Footprint
 - Exploration Permit Coal (EPC)
 - Mining Lease (ML)
 - Mining Lease Application (MLA)
 - Existing Water User
 - Cadastre



Figure 4
Surface Water
Extraction Licences

Surface Water Technical Report
Saraji East Mining Lease Project



Scale: 1:150,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 24/07/2020 VERSION: 3

4.0 Existing water quality

4.1 Water quality objectives

WQOs to protect the environmental values defined for the upper Isaac River catchment and the corresponding guideline values have been defined within Schedule 1 of the EPP (Water) which came into effect during September 2011 and applied for purpose of assessing the water quality of the receiving environment. WQO are summarised in Table 3.

Prior to construction, REMP monitoring will be carried out to collect a minimum of 18 data values over at least two years to inform the development of site-specific surface WQO to be adopted for the Project. Prior to construction, BMA will develop site-specific water quality objectives to be incorporated into a REMP for the Project (refer to Section 7.0).

Table 3 Water quality guidelines relevant to the upper Isaac River Catchment

Parameter	Unit	WQO	Guideline Source
Water quality objectives to protect aquatic ecosystem environmental values			
Total suspended solids (TSS)	mg/L	55	EPP (Water) (2019)
Turbidity	NTU	50	EPP (Water) (2019)
Electrical conductivity (EC)	µS/cm	Base flow: 720 High flow: 250	EPP (Water) (2019)
Sulfate (SO ₄)	mg/L	25	EPP (Water) (2019)
pH	-	6.5-8.5	EPP (Water) (2011)
Ammonia (as nitrogen)	µg/L	20	EPP (Water) (2019)
Oxidised nitrogen	µg/L	60	EPP (Water) (2019)
Organic nitrogen	µg/L	420	EPP (Water) (2019)
Total nitrogen	µg/L	500	EPP (Water) (2019)
Filterable reactive phosphorus	µg/L	20	EPP (Water) (2019)
Total phosphorus	µg/L	50	EPP (Water) (2019)
Dissolved oxygen (DO)	% saturation	85-110	EPP (Water) (2019)
Metals (Dissolved)			
Aluminium	µg/L	5,000	EPP Water (2011) Stock watering**
	µg/L	55	ANZG (2018)*
Arsenic (dissolved)	µg/L	500	EPP Water (2011) Stock watering**
		13	ANZG (2018)* for As(V)
Chromium (IV)	µg/L	1,000	EPP Water (2011) Stock watering**
	µg/L	1	ANZG (2018)*
Copper	µg/L	400	EPP Water (2011) Stock watering**
	µg/L	1.4	ANZG (2018)*
Iron	-	Not provided	EPP (Water) (2019)
	-	Not provided	ANZG (2018)*

Parameter	Unit	WQO	Guideline Source
Water quality objectives to protect aquatic ecosystem environmental values			
Molybdenum	µg/L	150	EPP (Water) (2011) Stock watering**
	µg/L	34	ANZG (2018)*
Nickel	µg/L	1,000	EPP (Water) (2011) Stock watering**
	µg/L	11	ANZG (2018)
Selenium	µg/L	20	EPP (Water) (2019) Stock watering
	µg/L	5	ANZG (2018)*
Uranium	µg/L	200	EPP (Water) (2019) Stock watering
	µg/L	0.5	ANZG (2018)*
Zinc	µg/L	20,000	EPP (Water) (2019) Stock watering
	µg/L	8	ANZG (2018)*

*ANZG trigger values for toxicants applied to slightly-moderately disturbed systems

**ANZECC guideline still applicable as ANZG has not been updated for stock watering.

4.2 Data management and interpretation

A number of watercourses identified under the Water Act flow through the Project Site, including Boomerang Creek, One Mile Creek, Hughes Creek, Plumtree Creek, Spring Creek and Phillips Creek. These are all tributaries of the Isaac River. Data was available for Hughes Creek, One Mile Creek, and Phillips Creek, Boomerang Creek and Isaac River.

The available water quality data are derived from several data sources, namely:

- Water quality data was collected for REMP reporting for the Saraji Mine (SRM, between 2010 and 2019) and Peak Downs Mine (PDM, between 2010 and 2020).
- Hydrobiology (2016) REMP reporting containing data from 2014 to 2015. Sampling was not done at all sites, and the number of sample events ranges from one to nine per site.
- Central Queensland University (CQU, 2016) trend report containing data from 2012 to 2016. Sampling was not done at all sites, and the number of sample events ranges from one to seven per site. This report concluded that there were “*no adverse impacts of mine discharge on macroinvertebrate composition and indices detected during the period 2011 – 2016*”.

Raw data from 2010 to 2020 was provided by BMA and analysed by AECOM. The water quality data is presented as follows:

- Box and whisker plots representing data from Gauge report appendices (Gauge, 2014) were generated. This data covers a period from 2010 to 2013, with the statistical summaries based on approximately 25 samples per parameter. This report concluded that changes in median water quality after mining (the existing operations only) were within acceptable limits for slightly-to-moderately disturbed (SMD) systems or remained within applicable guidelines for those operations. Raw data from 2010 to 2020 provided by BMA for Boomerang Creek and Isaac River was assessed and added to the box and whisker plots (where available) to provide a visual summary for comparison against the others.
- Charts and tables from the Gauge (2014) dataset are used to provide greater detail so that upstream and downstream percentile concentrations may be compared

- Comparisons are made with the other reports where data is available. Data in Hydrobiology (2016) and CQU (2016) was insufficient in number of samples or not in a form that could be compiled into a database.
- A summary table has been developed from the raw data and statistical summaries are compared against the ANZG (2018) guidelines (Table 15).

Table 4 Water quality sample locations for the Saraji REMP

Site Name	Approximate location relative to release locations for mine affected water from Saraji East
Hughes Creek upstream (MP1 SRM)	4,000 m upstream
Hughes Creek downstream (MP5 SRM)	2,000 m downstream
One Mile Creek upstream (MP2 SRM)	6,000 m upstream
One Mile Creek downstream (MP6 SRM)	2,000 m downstream
Boomerang Creek upstream (MP2 / MP24 PDM)	12,000 m upstream
Boomerang Creek downstream (MP10 PDM)	3,000 m upstream
Phillips Creek upstream (MP3 SRM)	9,000 m upstream
Phillips Creek downstream (MP7 SRM)	1,000 m downstream
Isaac River Soleh Nolem downstream (SNDS) (MP9 SRM / MP18 PDM / Regional 2)	24,000 m downstream

The locations of the monitoring points are shown on Figure 3.

The existing water quality data was compared against the WQOs listed in Table 3 to identify water quality parameters of concern.

4.3 Physio-chemical water quality

The following section provides a summary of existing background water quality data and compares the data to applicable guidelines. For each water quality parameter, box and whisker plots showing the minimum, 20th percentile, median, 80th percentile and maximum values are presented (see Figure 5 for an example). For the comparisons, 'downstream' refers to the downstream comparison in the Saraji Mine REMP reporting, and is typically downstream of the release points for the Project Site (refer Table 4). However, for Boomerang Creek, a new release point is proposed downstream of the Boomerang Creek (downstream) site, and hence new monitoring points are proposed further downstream (refer Figure 3).

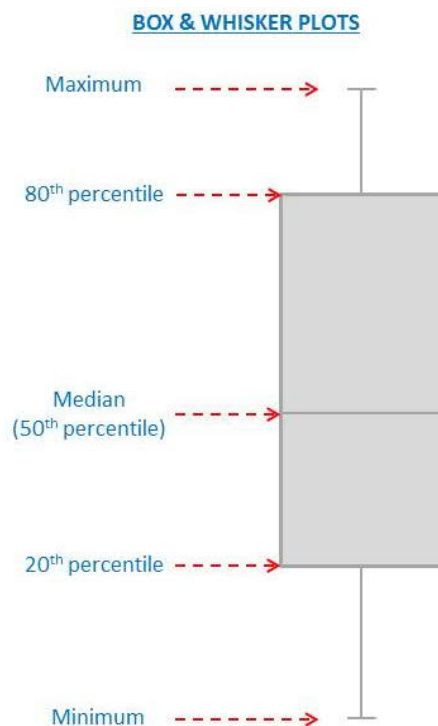
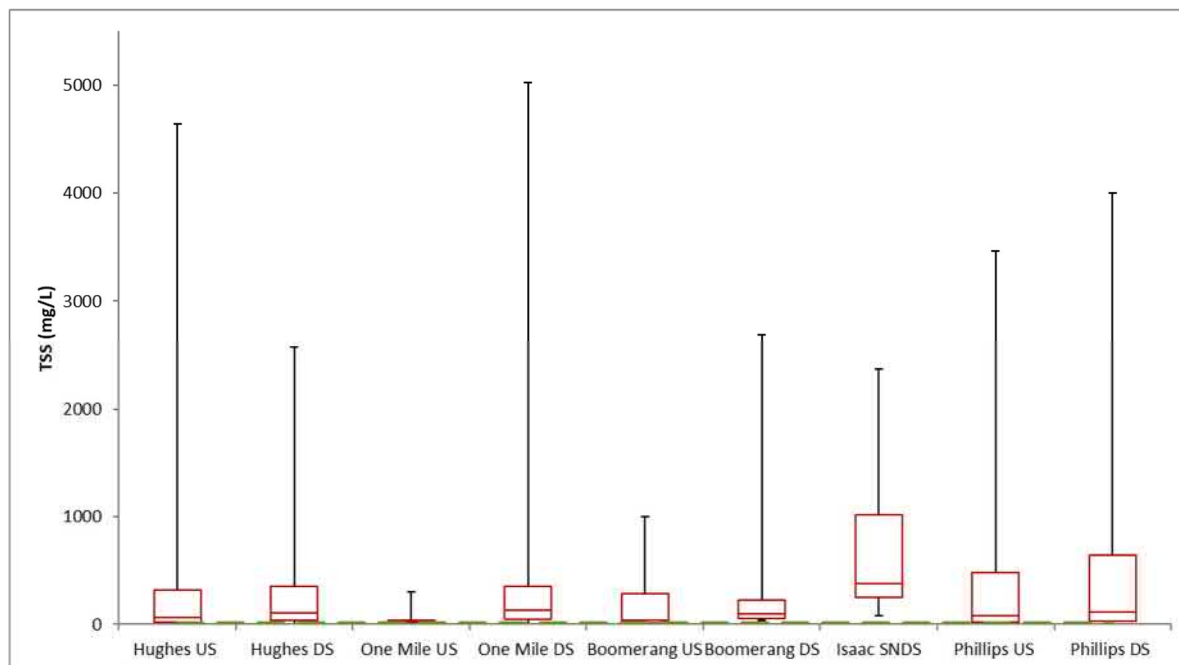


Figure 5 Example box and whisker plot structure

4.3.1 Total suspended solids

Summary water quality data for total suspended solids (TSS) is provided in Figure 6.



Note: The green dashed line represents the applicable guideline.

Figure 6 Statistical summary of total suspended solids

TSS median concentrations in Hughes, One Mile, Boomerang and Phillips Creek ranged from 55 milligrams per litre (mg/L) to 121 mg/L. The range of TSS data varies greatly, from 2.5 mg/L to 5,020 mg/L.

Results for individual streams are (Figure 6 and below):

- Hughes Creek: Median TSS range was 67 mg/L to 109 mg/L.
- One Mile Creek: Median TSS range was 17 mg/L to 134 mg/L. The low end of the range is attributed to the One Mile Creek upstream monitoring site being located on a large dam just upstream of the spillway. The dam acts as a sedimentation basin, and hence little suspended matter is likely to remain in suspension in water samples collected from this site.
- Boomerang Creek: Median TSS range was 34 mg/L to 101 mg/L.
- Philips Creek: Median TSS ranges 82 mg/L to 119 mg/L.
- Isaac River: Median TSS was 379 mg/L.

All data was well above applicable guideline for lowland streams (55 mg/L). This indicates that a new site-specific benchmark may be required (DEHP, 2009).

4.3.2 Electrical conductivity

Electrical conductivity (EC) results are shown in Figure 7. A comparison of water quality data collected shows that the median conductivities are often above the applicable WQO for high flows (250 microsiemens per centimetre ($\mu\text{S}/\text{cm}$)), but below the WQO for low flows (720 $\mu\text{S}/\text{cm}$). A single outlier was identified in the data for Hughes Creek, which is not representative of typical site conditions. The available data was not split into high and low flows so assessment against a flow objective was not possible. However, it is recommended that future data collection compare high and low flows to these criteria, and a new site-specific benchmark may need to be considered (as per DEHP, 2009).

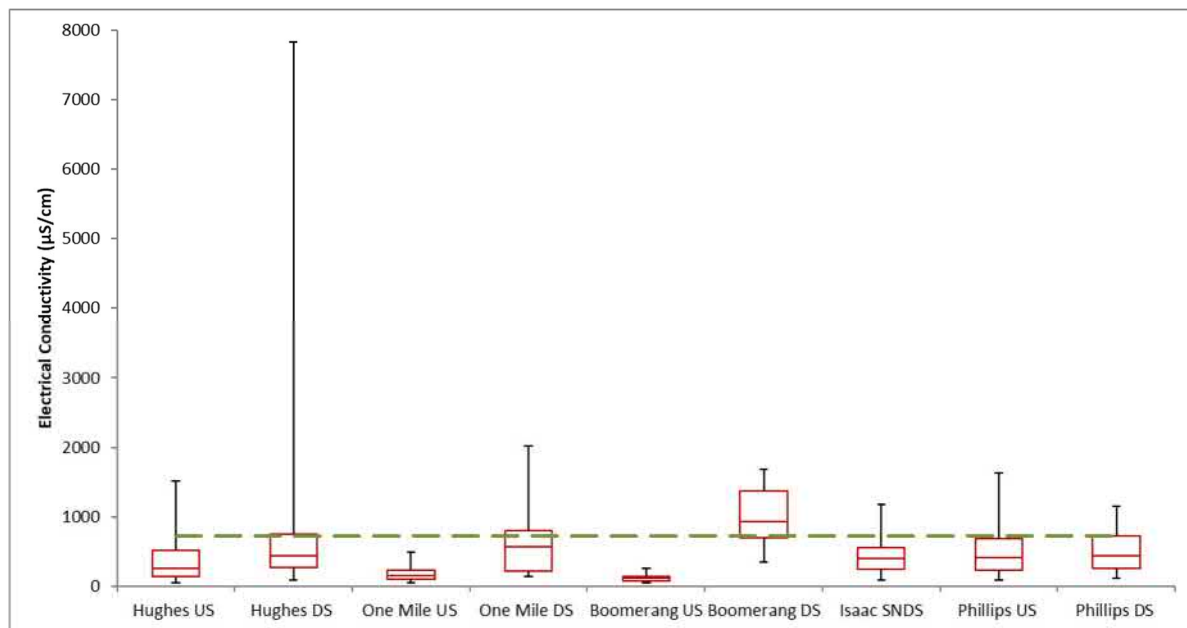
Results for individual streams (median) are:

- Hughes Creek: 257 $\mu\text{S}/\text{cm}$ to 439 $\mu\text{S}/\text{cm}$

- One Mile Creek: 149 $\mu\text{S}/\text{cm}$ to 269 $\mu\text{S}/\text{cm}$
- Boomerang Creek: 116 $\mu\text{S}/\text{cm}$ to 926 $\mu\text{S}/\text{cm}$
- Phillips Creek: 418 $\mu\text{S}/\text{cm}$ to 436 $\mu\text{S}/\text{cm}$.
- Isaac River: 400 $\mu\text{S}/\text{cm}$.

The Central Queensland University trend report (CQU 2016) indicates that EC was above the WQO for high flows ($> 250 \mu\text{S}/\text{cm}$) for most samples.

The Hydrobiology (2014 to 2015 sampling) data indicates that EC in Phillips Creek was consistently higher than the WQO. This was attributed to mine water releases at the time. One Mile and Hughes Creeks were below the WQO for this period (ranging from 372 $\mu\text{S}/\text{cm}$ to 470 $\mu\text{S}/\text{cm}$).



Note: The green dashed line represents the applicable guideline.

Figure 7 Statistical summary of electrical conductivity

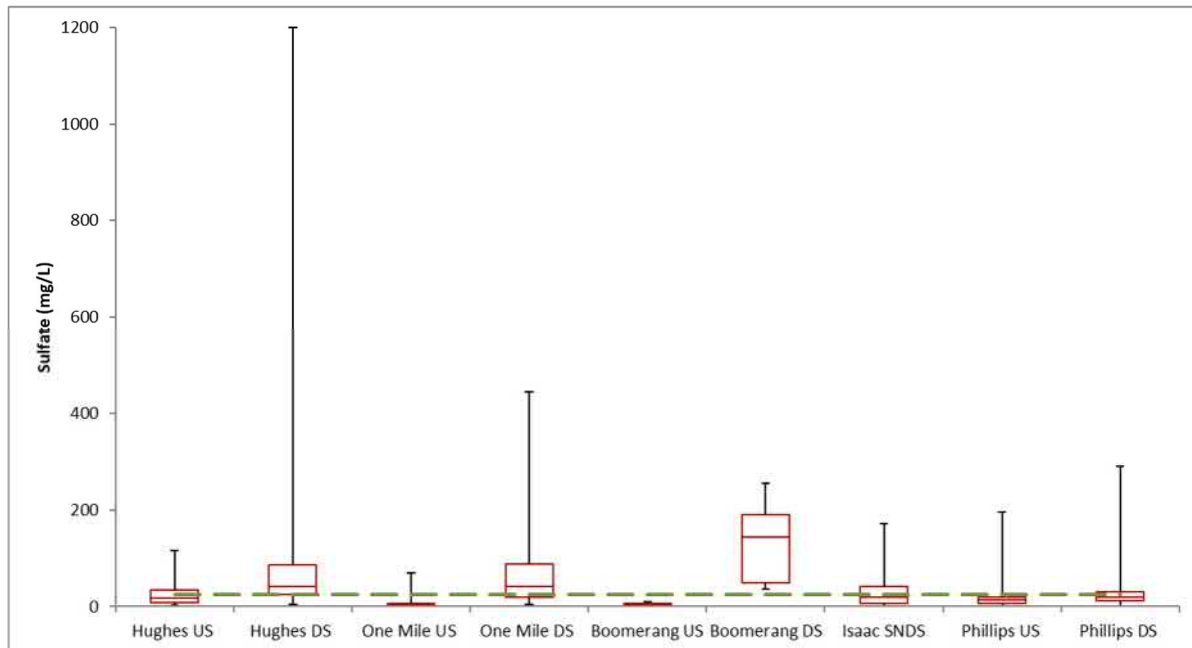
4.3.3 Sulfate

Sulfate concentrations were highly variable and above the water quality guideline of 25 mg/L for the majority of sampling occasions at most sites (Figure 8), but typically less than the WQO for drinking water supply (200 mg/L). This indicates that a new site-specific benchmark may be required (DEHP, 2009).

Results for individual streams (median concentration):

- Hughes Creek. 17 mg/L to 43 mg/L
- One Mile Creek. 2 mg/L to 42 mg/L
- Boomerang Creek. 5 mg/L to 144 mg/L
- Phillips Creek. 13 mg/L to 19 mg/L.
- Isaac River: 20 mg/L.

The CQU trend report (CQU 2016) indicates that sulfate was above the WQO for high flows for most samples. These increases caused the median sulfate concentrations to be above the draft water quality guidelines in both Hughes and One Mile creeks. The increase in sulfate concentrations is attributed to groundwater interaction or dissolution of mineral salts (Hart, 2008).



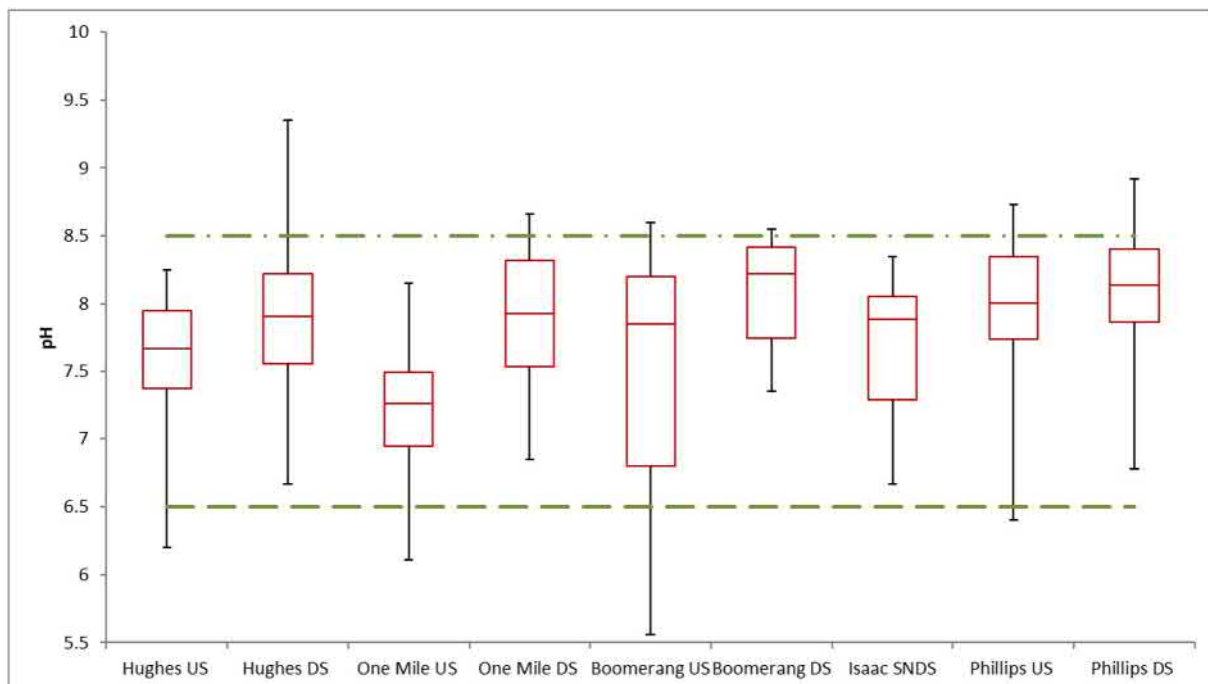
Note: The green dashed line represents the applicable guideline.

Figure 8 Statistical summary of Sulfate

4.3.4 pH

pH levels at all sites were generally within the upper and lower bounds of the applicable guideline of 6.5 to 8.5 (Figure 9). The pH in Hughes, One Mile, Boomerang, Phillips Creek and Isaac River is generally neutral, to slightly basic. These results are supported by data presented by CQU (2016) and Hydrobiology (2016).

pH increases may be linked to the dissolution of mineral salts from the sandstones and siltstones liberated by the mining process (Hart, 2008).



Note: The green dashed line represents the applicable guideline.

Figure 9 Statistical summary of pH

4.3.5 Total nitrogen

Available information for total nitrogen from the CQU trend report (CQU, 2016) indicates that the WQO for total nitrogen (500 micrograms per litre ($\mu\text{g/L}$)) was above the guideline during some sampling runs for the following sites:

- Phillips Creek downstream (December 2011)
- Hughes Creek downstream (December 2011) and upstream (February 2013)
- One Mile Creek downstream (June 2013).

In 2015 and 2016 most results were above the WQO. The source of nitrogen was not identified.

Data from Peak Downs Mine monitoring records indicated that total nitrogen was above the guideline in Isaac River DS on January 2015, March 2016 and March 2020

4.3.6 Organic nitrogen

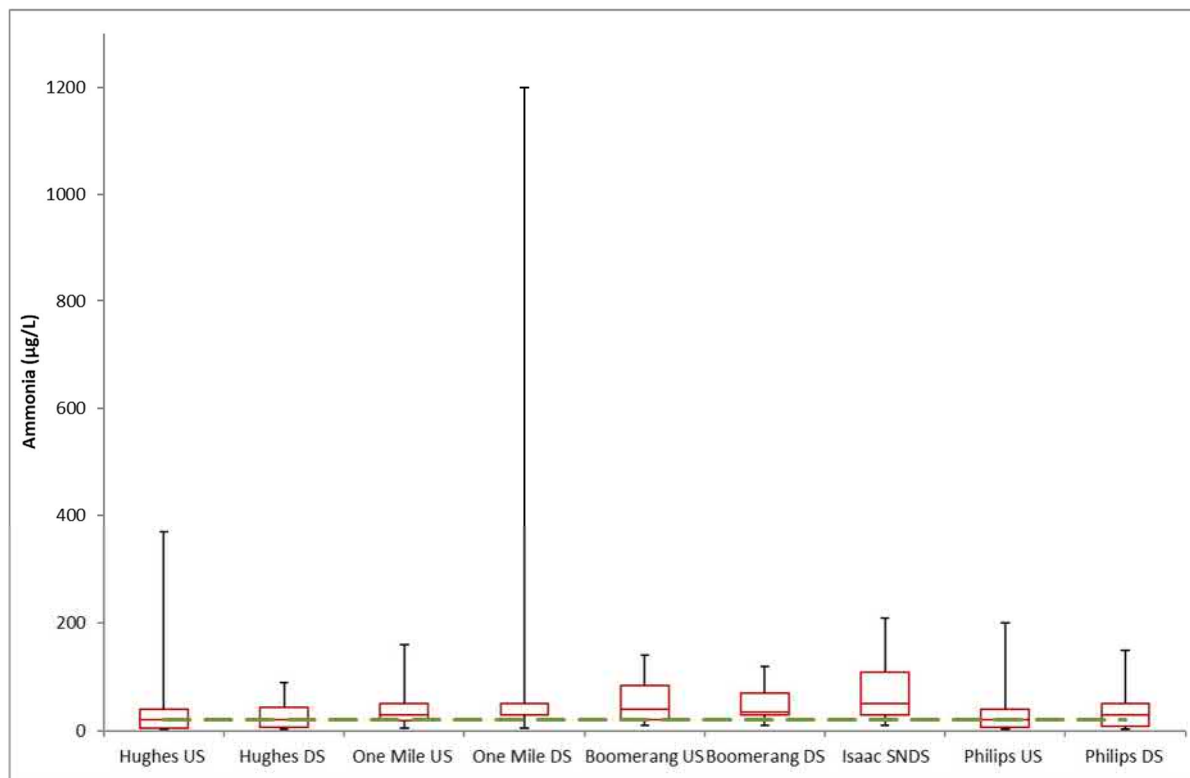
No samples have been analysed specifically for organic nitrogen, but this component can be inferred from other nitrogen species. The CQU trend report (CQU, 2016) indicates that ammonia and nitrate nitrogen concentrations are typically less than $100 \mu\text{g/L}$, whereas total nitrogen is typically $200 \mu\text{g/L}$ to $1000 \mu\text{g/L}$. Therefore, it is inferred that the organic nitrogen component of total nitrogen is in the range of $100 \mu\text{g/L}$ to $900 \mu\text{g/L}$.

4.3.7 Ammonia nitrogen

Median ammonia concentrations for Hughes, One Mile, and Phillips Creek were $20 \mu\text{g/L}$ to $30 \mu\text{g/L}$, which are at or above the WQO of $20 \mu\text{g/L}$ (Figure 10). This indicates that a new site-specific benchmark may be required (DEHP, 2009). Results for individual streams (median concentration) are:

- Hughes Creek $20 \mu\text{g/L}$
- One Mile Creek: $30 \mu\text{g/L}$
- Boomerang Creek: 35 to $40 \mu\text{g/L}$
- Phillips Creek: $20 \mu\text{g/L}$
- Isaac River: $50 \mu\text{g/L}$.

The CQU trend report (CQU, 2016) indicates that ammonia was above the WQO for most samples.



Note: The green dashed line represents the applicable guideline.

Figure 10 Statistical summary of ammonia

4.3.8 Nitrate and oxidised nitrogen

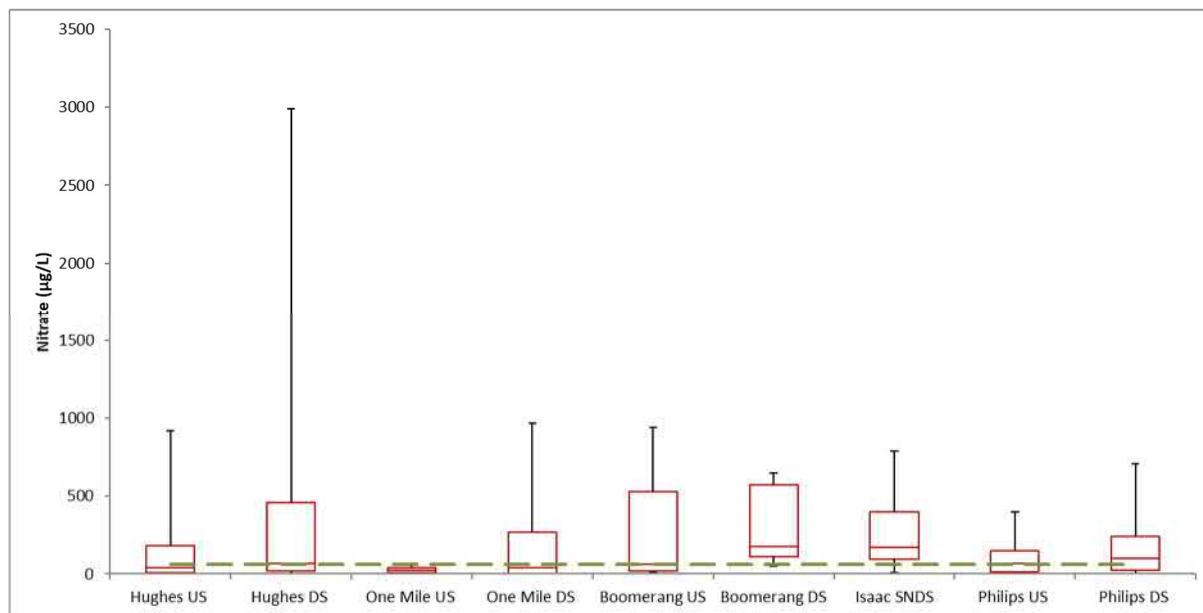
Nitrate concentrations (median) were above the applicable guideline of 60 µg/L (Figure 11).

Results for individual streams (median concentration) are:

- Hughes Creek: 40 µg/L to 70 µg/L
- One Mile Creek: 25 µg/L to 40 µg/L
- Phillips Creek: 70 µg/L to 100 µg/L
- Boomerang Creek: 70 µg/L to 100 µg/L
- Isaac River: 10 µg/L.

The CQU trend report (CQU, 2016) supports this data.

Similar to sulfate, nitrate concentrations in runoff may be linked to groundwater interaction (Hart, 2008), and from agricultural land uses within the catchment.



Note: The green dashed line represents the applicable guideline.

Figure 11 Statistical summary of nitrate

4.3.9 Total phosphorus

The CQU trend report (CQU, 2016) data shows that total phosphorus concentrations are typically 0.010 mg/L to 0.100 mg/L, sometimes above the WQO of 0.05 mg/L. Sampling in Phillips Creek in March 2015 (Hydrobiology 2016) returned a concentration of 0.026 mg/L upstream of the Project Site (base flow conditions), which is less than the WQO.

4.3.10 Filterable reactive phosphorus

The CQU trend report (CQU, 2016) indicates that filterable reactive phosphorus (FRP) concentrations are typically less than 0.020 mg/L. The WQO is 0.020 mg/L.

Sampling in Phillips Creek in March 2015 (Hydrobiology 2016) returned a FRP concentration of 0.002 mg/L upstream of the Project Site (base flow conditions), which is less than the WQO.

4.3.11 Dissolved Oxygen

Low dissolved oxygen (DO) concentrations are of concern for the environment, with impacts on warm water biota expected at concentrations below 5 mg/L to 6 mg/L (ANZECC, 2000), or 63 per cent to 76 per cent saturation at 28 degrees Celsius (°C).

The concentration of DO was within the guideline values of 90 per cent to 100 per cent for upland waters and 85 per cent to 110 per cent for lowland waters. The median ranged from 7.1 mg/L to 7.8 mg/L (Figure 12), which equated to 90 per cent to 98 per cent saturation at the median water temperature of 28°C.

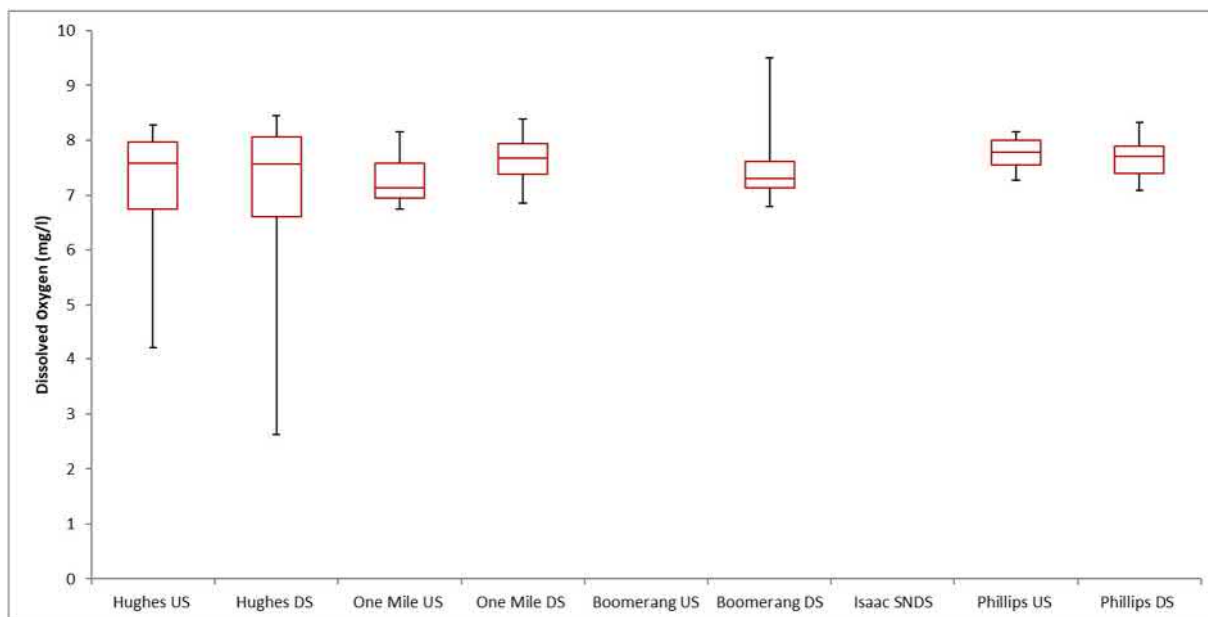


Figure 12 Statistical summary of dissolved oxygen

The CQU trend report (CQU 2016) indicates that DO concentrations are highly variable, varying between 10 per cent and 140 per cent saturation.

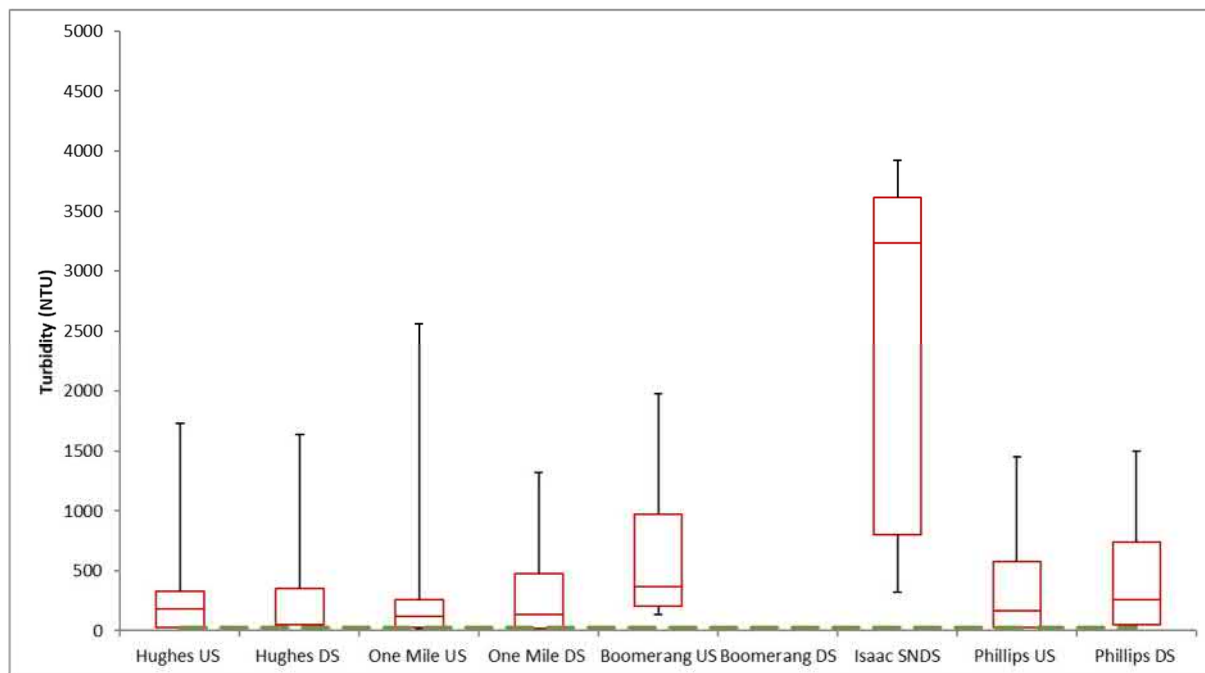
In 2014 and 2015, medians ranged from 4.7 mg/L to 9.0 mg/L, (Hydrobiology 2016) which is consistent with background data.

4.3.12 Turbidity

Turbidity levels were highly variable, with the majority of samples at both upstream and downstream sites above the WQO of 50 nephelometric turbidity units (NTU) (Figure 13). Within Hughes Creek, turbidity decreased moderately from upstream to downstream. Within One Mile and Phillips Creek, turbidity increased moderately from upstream to downstream. The Isaac River is more turbid than the other streams.

The median values were above the suggested interim guidelines by Gauge Industrial and Environmental (2014), indicating that further sampling for interim guideline development is required.

Data presented by CQU (2016) indicates that the turbidity WQO was above the guideline on many occasions for the occasions sampled. Similarly, data from 2014 and 2015 shows that turbidity was above the WQO.



Note: The green dashed line represents the applicable guideline.

Figure 13 Statistical summary for turbidity

4.3.13 Temperature

There is no WQO for temperature. However, the temperature data supports the interpretation of dissolved oxygen results above. Results for individual streams are:

- Hughes Creek: water temperature remained consistent through the existing mine lease at 27.7°C
- One Mile Creek: water temperature decreased slightly through the existing mine lease, from 28.5°C to 27.6°C
- Phillips Creek: water temperature slightly decreased through the existing mine lease, from 28.0°C to 26.9°C.

4.4 Metals

DEHP (2011) does not provide WQOs for metals. Therefore, median concentrations of metals are compared to the water quality trigger concentrations for SMD ecosystems in ANZG (2018).

Sample data from the most comprehensive dataset available (Gauge, 2014) is summarised in the following tables as per:

- Hughes Creek: dissolved metals (Table 5) and total metals (Table 6)
- One Mile Creek: dissolved metals (Table 7) and total metals (Table 8)
- Phillips Creek: dissolved metals (Table 9) and total metals (Table 10)

Sample data from the REMP monitoring dataset provided to AECOM from BMA is summarised in the following tables:

- Boomerang Creek: dissolved metals (Table 11) and total metals (Table 12).
- Isaac River: dissolved metals (Table 13) and total metals (Table 14).

Commentary relating to other datasets is provided for each metal.

Table 5 Dissolved metals in Hughes Creek

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	5,600	760	185	26
	Downstream		4,500	360	90	36
Arsenic	Upstream	13 (as V)	2	0.5	0.5	25
	Downstream		3	0.5	0.5	35
Chromium	Upstream	1 (as IV)	1.8	0.68	0.5	25
	Downstream		1.3	0.52	0.3	35
Copper	Upstream	1.4	7	2	2	26
	Downstream		12	2	2	36
Iron	Upstream	None available	1,720	1,100	420	26
	Downstream		4,580	600	210	36
Molybdenum	Upstream	150 34 [#]	1	0.5	0.5	25
	Downstream		1	0.5	0.5	24
Nickel	Upstream	11	9	3.2	2	25
	Downstream		59	11.8	7	24
Selenium	Upstream	20 11 [#]	1	0.4	0.3	24
	Downstream		1.2	0.54	0.4	24
Uranium	Upstream	200 0.5 [#]	0.9	0.37	0.2	25
	Downstream		3.4	0.736	0.44	25
Zinc	Upstream	8	32	2.5	2.5	26
	Downstream		96	22.4	13	25

*shading indicates that the sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 6 Total metals in Hughes Creek

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	38,300	8,722	3,830	25
	Downstream		42,600	15,000	2,780	35
Arsenic	Upstream	13 (as V)	4	3	1.5	24
	Downstream		6	3.4	1	34
Chromium	Upstream	1 (as IV)	14	2.44	0.5	25
	Downstream		25	1.2	0.3	35
Copper	Upstream	1.4	47	9	4	25
	Downstream		49	11	4	35
Iron	Upstream	None available	50,400	12,300	4,580	25
	Downstream		59,400	17,080	3,310	35
Molybdenum	Upstream	150 34 [#]	1	0.5	0.5	24
	Downstream		23	1.4	0.5	34
Nickel	Upstream	11	59	11.8	7	24
	Downstream		63	17.4	6	34
Selenium	Upstream	20 11 [#]	1.2	0.54	0.4	24
	Downstream		9.7	1.58	0.6	34
Uranium	Upstream	200 0.5 [#]	3.4	0.736	0.44	25
	Downstream		7.09	2.344	0.8	35
Zinc	Upstream	8	96	22.4	13	25
	Downstream		101	32.4	10	35

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 7 Dissolved metals in One Mile Creek

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	1,170	450	230	
	Downstream		9,360	616	195	22
Arsenic	Upstream	13 (as V)	3	1	0.5	21
	Downstream		4	1	0.75	22
Chromium	Upstream	1 (as IV)	2	1.22	0.5	20
	Downstream		1.6	0.6	0.3	21
Copper	Upstream	1.4	2	2	0.5	21
	Downstream		22	2	1	22
Iron	Upstream	None available	4,580	1,330	960	21
	Downstream		6,790	1,138	355	22
Molybdenum	Upstream	150 34 [#]	0.5	0.5	0.5	21
	Downstream		29	2	0.75	22
Nickel	Upstream	11	5	4	2	21
	Downstream		50	3.8	2	22
Selenium	Upstream	20 11 [#]	0.5	0.4	0.25	20
	Downstream		4.6	1.9	0.8	21
Uranium	Upstream	200 0.5 [#]	0.25	0.182	0.025	20
	Downstream		3	0.31	0.21	21
Zinc	Upstream	8	12	2.5	2.5	21
	Downstream		55	2.5	2.5	21

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 8 One Mile Creek - Total Metals

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	4,710	1,826	475	20
	Downstream		75,100	4,370	1,500	21
Arsenic	Upstream	13 (as V)	2	1.2	1	20
	Downstream		76	2	2	21
Chromium	Upstream	1 (as IV)	2	1.22	0.5	20
	Downstream		2	0.8	0.3	21
Copper	Upstream	1.4	4	2	0.5	20
	Downstream		31	5	4	21
Iron	Upstream	None available	4,540	3,294	2,265	20
	Downstream		22,600	6,950	2,910	21
Molybdenum	Upstream	150 34 [#]	0.5	0.5	0.5	20
	Downstream		49	1	0.5	21
Nickel	Upstream	11	6	5	2	20
	Downstream		5,700	10	5	21
Selenium	Upstream	20 11 [#]	0.5	0.4	0.35	20
	Downstream		9	2.7	0.9	21
Uranium	Upstream	200 0.5 [#]	0.37	0.222	0.025	20
	Downstream		300	0.59	0.42	21
Zinc	Upstream	8	12	8	2.5	20
	Downstream		66	19.6	8.5	20

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 9 Phillips Creek - Dissolved Metals

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	3,210	288	95	32
	Downstream		14,400	344	75	30
Arsenic	Upstream	13 (as V)	5	1	0.5	30
	Downstream		10	1	0.5	28
Chromium	Upstream	1 (as IV)	1	0.7	0.5	31
	Downstream		1	0.64	0.4	29
Copper	Upstream	1.4	12	2	2	32
	Downstream		10	3	2	30
Iron	Upstream	None available	2,910	482	190	32
	Downstream		9,670	444	175	30
Molybdenum	Upstream	150 34 [#]	2.5	0.5	0.5	29
	Downstream		2.5	1	0.5	27
Nickel	Upstream	11	33	3.2	2	30
	Downstream		21	7.4	3	28
Selenium	Upstream	20 11 [#]	0.5	0.3	0.3	29
	Downstream		1.5	0.5	0.4	27
Uranium	Upstream	200 0.5 [#]	1.47	0.64	0.36	31
	Downstream		1.62	0.73	0.42	29
Zinc	Upstream	8	25	2.5	2.5	32
	Downstream		19	2.5	2.5	30

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 10 Total metals in Phillips Creek

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	170,000	20,400	4,485	30
	Downstream		68,200	29,880	9,315	28
Arsenic	Upstream	13 (as V)	20	3	2	28
	Downstream		8	4	2	26
Chromium	Upstream	1 (as IV)	110	23.6	0.7	30
	Downstream		66	32.4	0.65	28
Copper	Upstream	1.4	1,050	18.8	8	30
	Downstream		72	31	9.5	28
Iron	Upstream	None available	198,000	25,200	4,420	30
	Downstream		86,900	44,400	9,870	28
Molybdenum	Upstream	150 34 [#]	5	1	0.5	27
	Downstream		2	1	0.5	25
Nickel	Upstream	11	21,000	47.6	8.5	28
	Downstream		31,000	55	18.5	26
Selenium	Upstream	20 11 [#]	1.2	0.5	0.4	28
	Downstream		1.5	0.7	0.4	26
Uranium	Upstream	200 0.5 [#]	1.88	1.1	0.805	30
	Downstream		2.36	1.628	0.97	28
Zinc	Upstream	8	290	38.6	13.5	30
	Downstream		150	61	27.5	28

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 11 Boomerang Creek - Dissolved Metals

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	3,240	1,032	650	19
	Downstream		5,170	2,420	440	6
Arsenic	Upstream	13 (as V)	1	1	1	14
	Downstream		2	1.2	1	5
Chromium	Upstream	1 (as IV)	4	1	1	15
	Downstream		4	2.4	1	5
Copper	Upstream	1.4	3	2	1	19
	Downstream		4	2	2	6
Iron	Upstream	None available	2,100	660	580	19
	Downstream		2,140	1,340	475	6
Molybdenum	Upstream	150 34 [#]	1	1	1	14
	Downstream		0.1	0.1	0.1	5
Nickel	Upstream	11	6	2	2	19
	Downstream		4	3	2	6
Selenium	Upstream	20 11 [#]	10	10	10	19
	Downstream		10	10	10	6
Uranium	Upstream	200 0.5 [#]	1	1	1	19
	Downstream		1	1	1	6
Zinc	Upstream	8	10	10	10	19
	Downstream		9	7.4	6	6

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 12 Total metals in Boomerang Creek

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Upstream	55	9,820	5,908	3,830	19
	Downstream		18,200	6,330	4,270	6
Arsenic	Upstream	13 (as V)	2	2	1	14
	Downstream		6	4	2	5
Chromium	Upstream	1 (as IV)	7	4	2	15
	Downstream		19	8	3	5
Copper	Upstream	1.4	11	5	3	19
	Downstream		22	8	5	6
Iron	Upstream	None available	11,200	6,820	3,770	19
	Downstream		29,200	8,430	5,410	6
Molybdenum	Upstream	150 34 [#]	1	1	1	14
	Downstream		6	5	3	5
Nickel	Upstream	11	15	7	4	21
	Downstream		27	8	6	6
Selenium	Upstream	20 11 [#]	10	10	10	25
	Downstream		2	2	2	7
Uranium	Upstream	200 0.5 [#]	1	1	1	15
	Downstream		0.51	0.50	0.49	5
Zinc	Upstream	8	38	21	10	25
	Downstream		53	25	31	7

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 13 Dissolved metals in Isaac River

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Downstream	55	3,770	622	280	22
Arsenic	Downstream	13 (as V)	1	1	1	14
Chromium	Downstream	1 (as IV)	3	1	1	18
Copper	Downstream	1.4	5	3	2	22
Iron	Downstream	None available	1,570	470	225	22
Molybdenum	Downstream	150 34 [#]	3	1.4	1	14
Nickel	Downstream	11	3	2	2	22
Selenium	Downstream	20 11 [#]	10	10	10	22
Uranium	Downstream	200 0.5 [#]	3	1	1	22
Zinc	Downstream	8	7	5	5	21

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

Table 14 Total metals in Isaac River

Analyte (µg/L)	Site Location	Guideline	Max	80th %ile	Median	Total Samples
Aluminium	Downstream	55	75,300	28,640	12,600	22
Arsenic	Downstream	13 (as V)	4	4	3	14
Chromium	Downstream	1 (as IV)	60	40	19	18
Copper	Downstream	1.4	75	33	14	22
Iron	Downstream	None available	56,700	30,580	15,050	22
Molybdenum	Downstream	150 34 [#]	2	1	1	14
Nickel	Downstream	11	88	57	21	21
Selenium	Downstream	20 11 [#]	10	10	10	25
Uranium	Downstream	200 0.5 [#]	5	1	1	18
Zinc	Downstream	8	162	68	35	24

*shading indicates that sampling is above the guideline

ANZG 2018 default trigger value for ecosystem protection, protection of species (95%) for SMD ecosystems

4.4.1 Aluminium

Dissolved aluminium data shows that the median concentrations in all streams were well above the ANZG (2018) ecosystem guideline (55 µg/L) at all sites, indicating a new or interim guideline may be suggested (DEHP, 2009).

Data presented by CQU (2016) indicated that the WQO for dissolved aluminium was above the guideline on several occasions. Similarly, data from 2014 and 2015 (Hydrobiology 2016) indicates that medians for high flow conditions in Hughes and Phillips Creek were below the limit of reporting (LOR) (two samples).

Total aluminium data also shows that the median concentrations were above the WQO. Data presented by CQU (2016) indicated that the WQO for total aluminium was frequently above the guideline. Additionally, data from 2014 and 2015 (Hydrobiology 2016) indicates that medians under high flow conditions in Hughes and Phillips Creek was also above the WQO (two samples).

It should be noted that a significant proportion of total aluminium in natural waters may be present as biologically inert aluminosilicates in soil, and may not impact environmental health.

4.4.2 Arsenic

For dissolved arsenic, the average 80th percentile values (2.4 µg/L) for all streams were well below the ANZECC trigger value for the protection of SMD ecosystems of 13 µg/L.

Total arsenic concentrations in Hughes, One Mile, Phillips Creek, Boomerang Creek and the Isaac River were mostly below the WQO.

4.4.3 Chromium

Dissolved chromium median concentrations for Hughes, One Mile, and Phillips Creek range of 0.3 µg/L to 0.7 µg/L. Most samples were below the ANZECC ecosystem SMD guideline of 1.0 µg/L. However, the One Mile Creek upstream 80th percentile value (1.22 µg/L) the Boomerang Creek 80th percentile value (2.4 µg/L) and the Isaac River 80th percentile value (2.15 µg/L) suggest that the guideline value is overly stringent for local conditions in these streams.

Dissolved chromium reported by CQU (2016) was mostly below the ANZECC (2000) guideline.

Total chromium concentrations in Hughes, One Mile, and Phillips Creek showed that most median values were below the ANZECC ecosystem SMD guideline of 1.0 µg/L. The average upstream 80th percentile (9.1 µg/L) was below the ANZECC guidelines for stock (1,000 µg/L), irrigation (100 µg/L) and recreational (52 µg/L), but higher than the ANZECC ecosystem SMD guideline (1.0 µg/L).

Total chromium concentrations reported by CQU (2016) were similar to the Gauge (2014) data presented in the tables.

4.4.4 Copper

Dissolved copper 80th percentile concentrations were mostly above the ANZECC (2000) guidelines (1.4 µg/L). for Hughes, One Mile, and Phillips Creek through the mine lease, and at sites on Boomerang Creek and the Isaac River.

Total copper concentrations were typically higher than the guideline for the protection of SMD ecosystems. Therefore it is recommended that a site-specific guideline be developed through a Receiving Environment Monitoring Program (refer Section 9.1).

4.4.5 Iron

Median dissolved iron concentrations in Hughes, One Mile, Phillips Creek, Boomerang Creek and the Isaac River ranged from 175 to 960 µg/L. No current guideline exists, and therefore a new or interim guideline may be suggested (DEHP, 2009). This data was similar to the results from the CQU trend report (CQU, 2016).

Median total iron concentrations ranged from 2,265 to 9,870 µg/L. The CQU trend report (CQU, 2016) reports similar high total iron concentrations in many samples.

4.4.6 Molybdenum

Median dissolved molybdenum concentrations in Hughes, One Mile, Phillips Creek, and Boomerang Creek were mostly (>75 per cent of samples) below detection limits. All median and 80th percentile values were lower than the ANZG (2018) ecosystem SMD default trigger value (34 µg/L).

Total molybdenum concentrations for all samples were well below the ANZECC guidelines for stock (150 µg/L). Only one sample was reported in Hydrobiology (2016) for Phillips Creek; dissolved and total molybdenum were below the LOR, downstream site during base flow conditions. The CQU trend report (CQU, 2016) indicates that most samples had dissolved and total molybdenum concentrations less than 7 µg/L.

4.4.7 Nickel

Dissolved nickel 80th percentile concentrations were within the ANZG (2018) guideline (11 µg/L), with the exception of Hughes Creek (11.8 µg/L).

Median total nickel concentrations were below the ANZG (2018) guidelines. The 80th percentile concentrations for Phillips and Hughes Creek were higher than the ANZECC guidelines for SMD ecosystems.

The CQU trend report (CQU, 2016) reports similar ranges of concentrations in many samples, however the trends are not clear in this limited dataset.

4.4.8 Selenium

Median dissolved selenium concentrations in Hughes, One Mile, and Phillips Creek range from 0.25 µg/L to 0.8µg/L. All samples from Hughes, One Mile, Phillips and Boomerang Creeks were lower than the ANZG (2018) SMD ecosystem guideline of 5 µg/L, or EPP (Water) 20 µg/L for stock watering. Median dissolved concentration of selenium in the Isaac River was 10 µg/L, higher than the SMD ecosystem guideline.

Total selenium 80th percentile concentrations were well below the EPP (Water) guidelines for stock watering (20 µg/L), and the ANZG (2018) SMD guideline for ecosystem protection (11 µg/L).

4.4.9 Uranium

Dissolved uranium concentrations showed that most data points were below the EPP (2011) WQO for stock watering (200 µg/L). All median values were lower than the ANZG (2018) ecosystem SMD default trigger value (0.5 µg/L), but the 80th percentile values exceeded the trigger.

Median dissolved concentration of uranium in the Isaac River was 1 µg/L, higher than the SMD ecosystem guideline.

Likewise for total uranium concentrations, all of the 80th percentiles (0.7 µg/L) were well below the ANZECC guidelines for stock watering (200 µg/L), but the median and 80th percentile values were higher than the ANZG (2018) ecosystem SMD guide.

Sample data reported in Hydrobiology (2016) for Phillips Creek and Hughes Creek (dissolved and total uranium) were below the LOR. The limited dataset provided in the CQU trend report (CQU, 2016) indicates some data above the guideline, and that the concentrations of dissolved and total uranium in these streams are within the range of the Gauge (2014) dataset.

4.4.10 Zinc

Median dissolved zinc (Zn) concentrations were mostly (> 85 per cent) below detection limits (2.5µg/L, was reported, which is 50 per cent of the LOR) in all streams, and hence were below the ANZECC ecosystem SMD guideline of 8 µg/L. 80th percentile concentrations for Hughes Creek and Boomerang Creeks exceeded the trigger value.

The CQU trend report (CQU, 2016) indicates that most samples had dissolved zinc concentrations less than 8 µg/L. Samples reported in Hydrobiology (2016) were less than the LOR.

Total zinc remains at relatively low concentrations, although there were some results above the ANZECC SMD ecosystem guideline (8 µg/L). The range of median concentrations was 2.5 µg/L to 27.5 µg/L.

The CQU trend report (CQU, 2016) indicates that most samples had dissolved zinc concentrations less than 8 µg/L. When the guideline trigger values were adjusted for hardness based on calcium carbonate (dissolved Zn was 42 µg/L and total Zn was 72 µg/L) all samples had concentrations below the ANZG (2018) guidelines (Gauge, 2014). Only two samples were reported in Hydrobiology (2016): 244 µg/L for Hughes Creek (downstream under high flow conditions) and below the LOR for Phillips Creek (downstream under baseflow conditions).

4.5 Summary of surface water quality

Raw data collected over the period 2010 to 2020 for REMPs for existing Saraji and Peak Downs operations was provided by BMA and statistical summaries for the downstream environments were prepared. Summary water quality data for downstream monitoring sites closest to the proposal are summarised in Table 15. The Queensland Water Quality Guidelines (DEHP 2009) recommend that:

- For physico-chemical stressors, the median concentration/value should be compared to the relevant guideline
- For toxicants such as metals, the 95th percentile of the dataset should be compared against the relevant guideline.

Comparisons were made primarily to the EPP (Water). Where relevant objectives were not listed in that document (e.g. for metals), comparisons were made to ANZG (2018) for the protection of SMD streams and to ANZECC (2000) for stock watering (as this remains unchanged with the ANZG 2018 revision). For this table, dissolved metals were compared to guidelines because that represents the bio-available portion.

Statistical summaries were mostly generated from a minimum of 18 sampling events (exceptions indicated), sufficient to meet the requirements of the Queensland Water Quality Guidelines (DEHP 2009) for a reference data set.

In summary, comparing the data to the trigger levels appropriate for the site:

- Of the physico-chemical parameters, pH was the only trigger level that was not exceeded at any of the waterways
- For metals, arsenic, iron, molybdenum and selenium did not exceed the trigger levels at any of the waterways.

All of the local waterways and the downstream Isaac River have impaired water quality, being highly turbid with elevated nutrient concentrations. However, streams close to the project site (Boomerang, Hughes and One Mile Creeks) show higher electrical conductivity and sulphate concentrations in comparison to the downstream Isaac River.

For metals, all streams show elevated concentrations of aluminium, chromium, copper, uranium, and zinc. Streams close to the project site (Boomerang, Hughes and One Mile Creeks) show higher concentrations of aluminium and iron than the downstream Isaac River. One Mile and Phillips Creeks have appreciably higher concentrations of copper, nickel and zinc in comparison to the downstream Isaac River.

Table 15 Summary of water quality data from 2010-2020

Water quality parameter	Water quality guideline	Boomeran g Creek	Hughes Creek	One Mile Creek	Phillips Creek	Isaac River
Physico-chemical stressors, median value of parameter						
Total suspended solids (TSS)	55 mg/L	101	92	108	698	379
Electrical conductivity (EC)	Base flow: 720 µS/cm High flow: 250 µS/cm	926	536	1,180	336	400
Sulfate (SO ₄)	25 mg/L	144	76	75	34	20
pH	6.5-8.5	8.22	7.48	7.91	7.88	7.9
Total nitrogen	500 µg/L	-	(605)	(1,235)	(1,700)	(920)
Ammonia nitrogen	20 µg/L	(35)	20	30	25	50
Oxidised nitrogen (NO _x)	60 µg/L	-	109	929	140	(128)
Total phosphorus	50 µg/L	-	(104)	(61)	(600)	(353)
Filterable reactive phosphorus	20 µg/L	-	(9)	(1)	(-)	(28)
Dissolved oxygen	85% -110 % saturation	(103)	87.5	113.0	85.6	97
Turbidity	50 NTU	(281)	1,379	1,980	1,200	(3,230)
Toxicants (metals), 95 th percentile of parameter						
Aluminium (dissolved)	55 µg/L	(4,483)	4,500	1,255	2,485	1,248
Arsenic (dissolved)	13 µg/L	(2)	1	2	4	1
Chromium (dissolved)	1 µg/L	(4)	1	2	4	2
Copper (dissolved)	1.4 µg/L	(4)	2	12	6	3
Iron (dissolved)	No guideline	(1940)	2,300	2,396	725	730
Molybdenum (dissolved)	150 µg/L (stock) 34 µg/L (Ecosystem)	(5)	2	9	2	2
Nickel (dissolved)	11 µg/L	(4)	5	39	18	3
Selenium (dissolved)	20 µg/L	(10)	10	10	3	10
Uranium (dissolved)	200 µg/L (stock) 0.5 µg/L (Ecosystem)	(1)	2	1	4	1
Zinc (dissolved)	8 µg/L	(9)	5	13	66	6

Result indicates that the guideline is exceeded.

Result from interim dataset comprising a minimum of 8 sampling events, sufficient to comprise an interim reference dataset in accordance with the requirements of the Queensland Water Quality Guidelines (2009).

(Result) indicates that fewer than 8 sampling events contribute to the dataset for that parameter.

5.0 Impacts to surface water

5.1 Construction phase

The construction phase, approximately three years between FY 2021 and FY 2023, would comprise construction of infrastructure and mine facilities to support the Project. The mining activities (e.g. mine development, subsidence and gas drainage) are considered with the operational phase and post mining impacts of the Project.

Construction activities associated with Project mining and water management infrastructure will involve earthmoving activities including removal of vegetation, topsoil stripping and stockpiling, earthworks including cut, fill and compaction, and trenching for any underground pipelines and services. These activities may contribute to increased erosion and sedimentation of receiving waters and mobilisation of other contaminants in runoff from the construction site.

5.1.1 Erosion and sedimentation

At certain times during construction, bare earth and uncovered stockpiles will be present that may generate silt and contaminant-laden runoff. Vegetation clearance, ground disturbance and soil compaction associated with the construction of the Project may also expose soils. Soils may be transported as sediment in runoff during wet periods to flowing rivers. Sediment mobilised during construction activities may enter surface water runoff during rainfall events and discharge to watercourses, leading to adverse effects on water quality. Sediment exposed or generated during construction may also be carried by wind into surface water bodies.

Suspended sediments in the water column reduce light penetration, consequently affecting the primary productivity of benthic ecosystems. Such impacts may exacerbate the already high turbidity concentrations in the receiving waterways. Background concentrations of suspended solids in streams adjacent to the Project (median 280 mg/L) were well above applicable WQO for upper Isaac River catchment waters (55 mg/L), indicating that the streams are quite turbid in their existing condition. While a large, long term increase in suspended solids may further degrade aquatic ecosystems, short term increases in storm events are unlikely to have any significant impact.

Deposition of suspended sediment within watercourses can lead to geomorphological changes within the streams. However, given the relatively high existing sediment loads that have already influenced the bed characteristics of these streams, short-term impacts from runoff from construction areas during storm events is unlikely to significantly change the geomorphological characteristics of these streams.

Sediments mobilised by erosion may have other contaminants associated with sediment particles including heavy metals derived from the local geology. When sediment particles containing heavy metals enter water, the metals may, under certain conditions, be released into the water column and become bioavailable. This in turn can affect the health of aquatic plants and animals.

The water quality results indicate that the majority of metals detected are bound to sediment particles, since total metal concentrations are typically much higher than dissolved metal concentrations. Metals released from sediments to the water column can be influenced by lower pH; however, pH results indicate that surface water pH is generally within the range of 6.5 to 9.0, thus minimising this mechanism for metal release from sediment particulates.

Controls will be installed prior to and during construction in accordance with International Erosion Control Association (IECA) Best Practice Erosion & Sediment Control guidelines. With erosion and sediment controls in place, the quantities of sediment likely to be mobilised from construction activities is likely to be low.

5.1.2 Chemicals and contaminants

Accidental spills of fuel stored on-site or any other chemicals used during construction could enter the drainage lines and waterways. Contaminants may be mobilised during construction activities through chemical and fuel spills from:

- temporary refuelling facilities

- temporary chemical storage facilities (including oil and waste oil)
- installation and operation of the incidental mine gas system
- temporary vehicle washdown areas
- construction and commissioning of permanent fuel and chemical storage facilities.

The main areas where aqueous waste streams may be produced will be associated with the construction of the MIA. However, there is also a possibility that contaminant spills may occur during construction of internal access roads.

Without appropriate mitigation measures, potentially contaminated drainage generated through these activities could enter into drainage lines, altering the physical and chemical characteristics of the receiving waters. This in turn may have acute or chronic toxicity effects on aquatic plants and animals. These pollutants can also have the potential to be a public health and safety issue if moderate to large quantities are released directly to watercourses.

The main potential impact on surface water quality will arise from accidental spills and leaks. The main contaminants of concern in this regard are fuels and oils. While some other chemicals will be utilised during construction, the quantities and natures of these chemicals is such that the risk of significant environmental harm in the event of a spill is low.

The significance of potential impacts on surface waters will depend on the quantity and nature of contaminants as well as whether the contaminants are directly released to surface waters. If spills or leaks occur in construction areas, contaminants will either soak into soils or be captured by sediment containment devices and/or permanent stormwater systems.

Small quantities of aqueous waste will be generated from removal of stormwater and contaminants from bunded areas and sumps. Provided this is treated in accordance with the management measures outlined below, this should not cause any impact on surface water quality.

5.2 Operational phase

Mining operations associated with the Project will involve the following activities:

- dewatering and degassing target coal seams
- underground longwall operations
- coal handling, preparation (screening and washing) and transportation.

All mine water from dewatering the underground mine and from incidental mine gas production will be stored and managed through the proposed mine WMS; potential water quality impacts will only arise from the operation of this system rather than from direct discharges of mine water.

5.2.1 Discharge of mine affected water

The proposed WMS has been designed with adequate capacity to avoid releases. Preliminary assessment has sized the dam to contain all inflows without controlled or uncontrolled releases, based on 128 years of available climate data.

The design is based on historical climate data and the assumed mine operating conditions. The influence of flooding and subsequent pumping from the highwall entry pit was considered in the water balance modelling with minimal risks of uncontrolled releases.

An indicative release point at Boomerang Creek is proposed in the event that a controlled release is required (Figure 3).

Three scenarios were considered to assess the potential impacts from a hypothetical discharge of mine affected water which is not caused by a system failure.

- Discharge during dry climatic conditions – refer to section 5.2.1.1
- Discharge during normal operating conditions – refer to section 5.2.1.2
- Discharge during wet conditions – refer to section 5.2.1.3.

5.2.1.1 Discharge of mine affected water during dry conditions

Section 4.4.1 of Appendix E-2 Mine Water Balance Technical Report (AECOM, 2021) provides estimates of salinity concentrations during dry conditions, represented by periods where MAW volumes in the Process water dam¹ are lower than 20 per cent the total capacity. According to the water balance model results, the corresponding MAW salinity levels in the Process water dam range between approximately 5,000 $\mu\text{S/cm}$ and 14,000 $\mu\text{S/cm}$, with the higher concentrations corresponding to the lowest levels in the dam (i.e. driest climate).

Based on historical climate and flow gauging data, dry conditions in the MAW system will occur in conjunction with minimal to no flow in the creeks and rivers around the Project Site. During these conditions, discharge will be avoided as a hypothetical discharge of MAW could lead to important impacts in the receiving environment.

In this scenario, at least 800 ML of MAW storage would be available in the Process water dam, which is adequate to manage all system inflows (over approximately one year without accounting for mine water use or evaporation) without the need for controlled or uncontrolled releases. A hypothetical increase of process MAW inflows (for example from dewatering of underground operations) will not lead to an increase in MAW inventory levels, as the WMS is designed to use MAW as a priority source to meet process water demands. In this case, MAW inventory levels will be managed by reducing the reliance on make-up water from the EWPC Southern Extension (Table 21 of Appendix E-2 Mine Water Balance Technical Report shows that the volume of annual raw water input is approximately 10 times the groundwater input).

As such, MAW releases are not expected during dry climatic conditions, hence there are no impacts to the receiving environment.

An increase of MAW inventory levels caused by increased rainfall would lead to one of the two scenarios described in sections 5.2.1.2 and 5.2.1.3.

5.2.1.2 Discharge of mine affected water during normal climate conditions

Water balance modelling results show that salinity concentrations in the Process water dam are expected to vary between approximately 4,000 $\mu\text{S/cm}$ and 6,000 $\mu\text{S/cm}$ during normal climate conditions (defined as conditions leading to Process water dam volumes between 20 per cent and 80 per cent of the total capacity of the dam). Additionally, BMA indicated that the expected pH levels in the Process water dam are similar to the values observed in the dams used for controlled releases in the existing Saraji operations. Average pH values for these dams (Dudleys and Farmhouse) are 7.18 and 7.55 respectively, whilst 20th and 80th percentile values are 7.02 and 7.35 (Dudleys), and 7.30 and 8.14 (Farmhouse).

¹ At any given time during the simulated period, the Process water dam contains more than 90 per cent the total MAW inventory; thus, it has been adopted as representative of the overall MAW dam system.

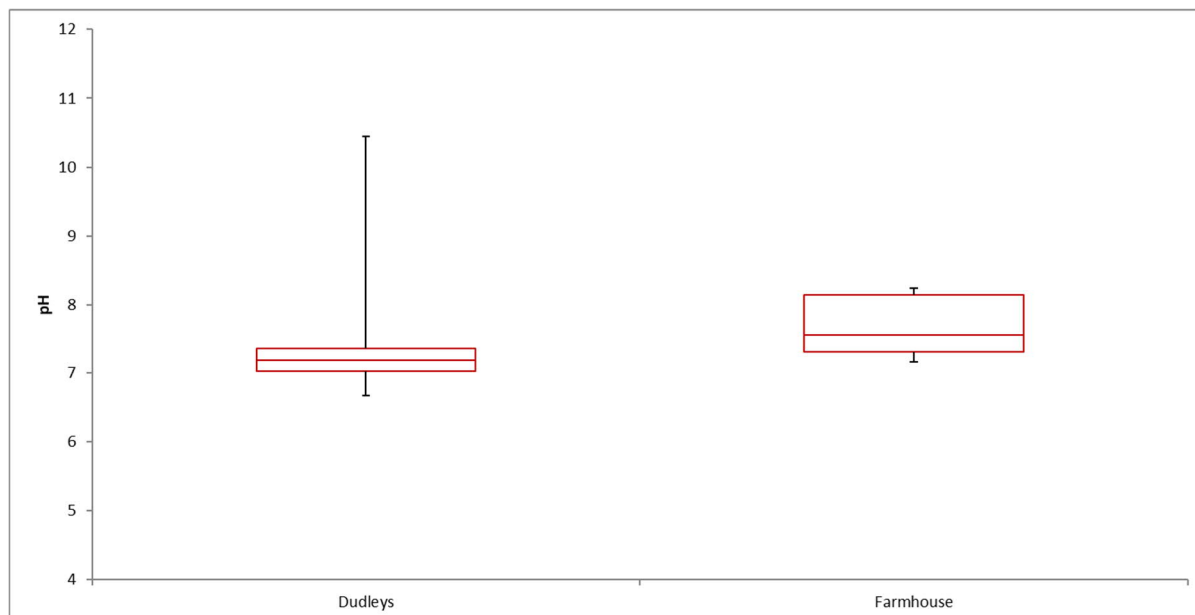


Figure 14 Statistical summary for pH in representative process water dams

Additionally, Section 4.0 shows background salinity and pH levels for Boomerang Creek, for the two monitoring locations upstream and downstream the mine. Based on this, median salinity concentrations are 116 $\mu\text{S}/\text{cm}$ and 926 $\mu\text{S}/\text{cm}$, whilst median pH values are 7.85 and 8.22 (upstream and downstream locations respectively, in both cases).

Review of water release reports dating from 2016 and 2019 for MAW discharges of 13-37.5 ML over 10-28 hours from existing mining operations provided representational data indicating that during a MAW managed release event:

- pH levels in the receiving environment remain mostly unvaried, as MAW and receiving environment pH levels are similar (refer Figure 15)
- Salinity concentrations in the receiving environment increase during the release event, as MAW salinity levels are higher than those in the creek (refer Figure 16) and EC values return to background levels shortly after the end of the release, indicating no residual impacts.

A hypothetical managed MAW release from the proposed Project is expected to have similar characteristics to the observed managed releases from existing mining operations, given that:

- MAW and receiving environment water quality (EC and pH) are similar for the existing mining operations and the proposed Project
- MAW controlled releases in the proposed project will be managed using similar infrastructure and methodology than existing mining operations.

Although releases are not planned under normal climate conditions, this assessment indicates that impacts from managed MAW release during normal climate conditions will be similar to those from MAW releases from existing mining operations, which comply with the regulatory requirements and the existing Environmental Authority. Additionally, the designed MAW total dam storage includes adequate contingent volume to contain all inflows to the system, such as managed releases are not planned as a tool to actively manage MAW inventory levels.

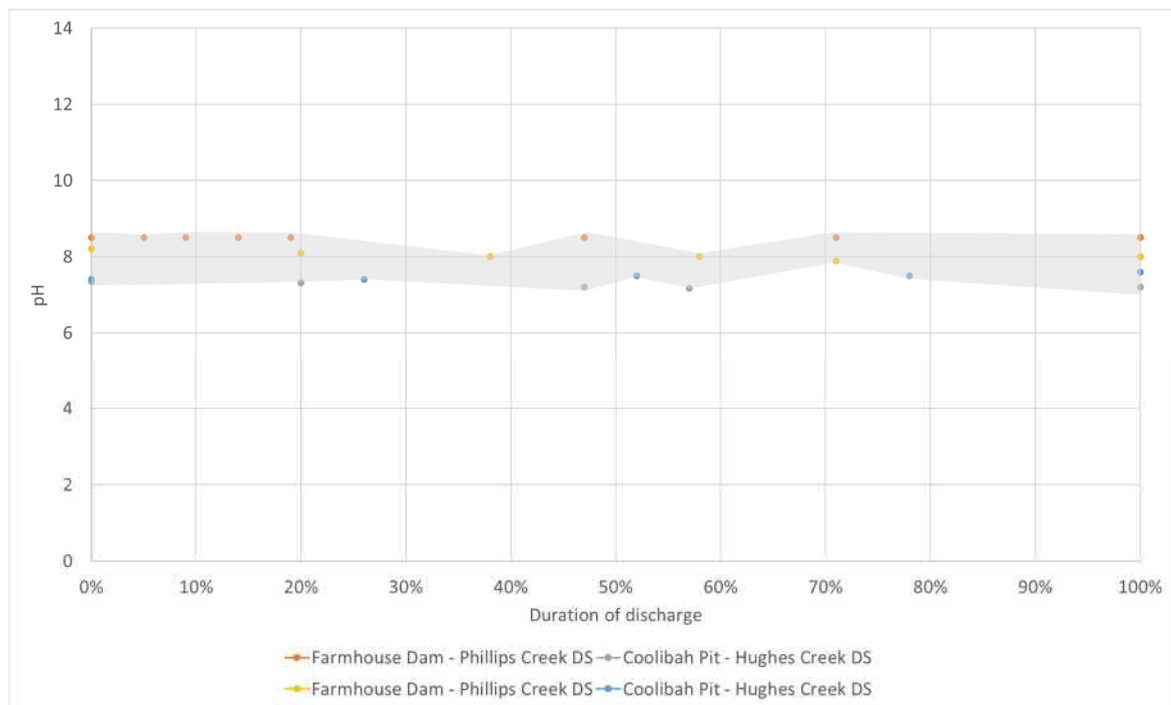


Figure 15 Water release representation showing range of pH concentrations in receiving environment with time

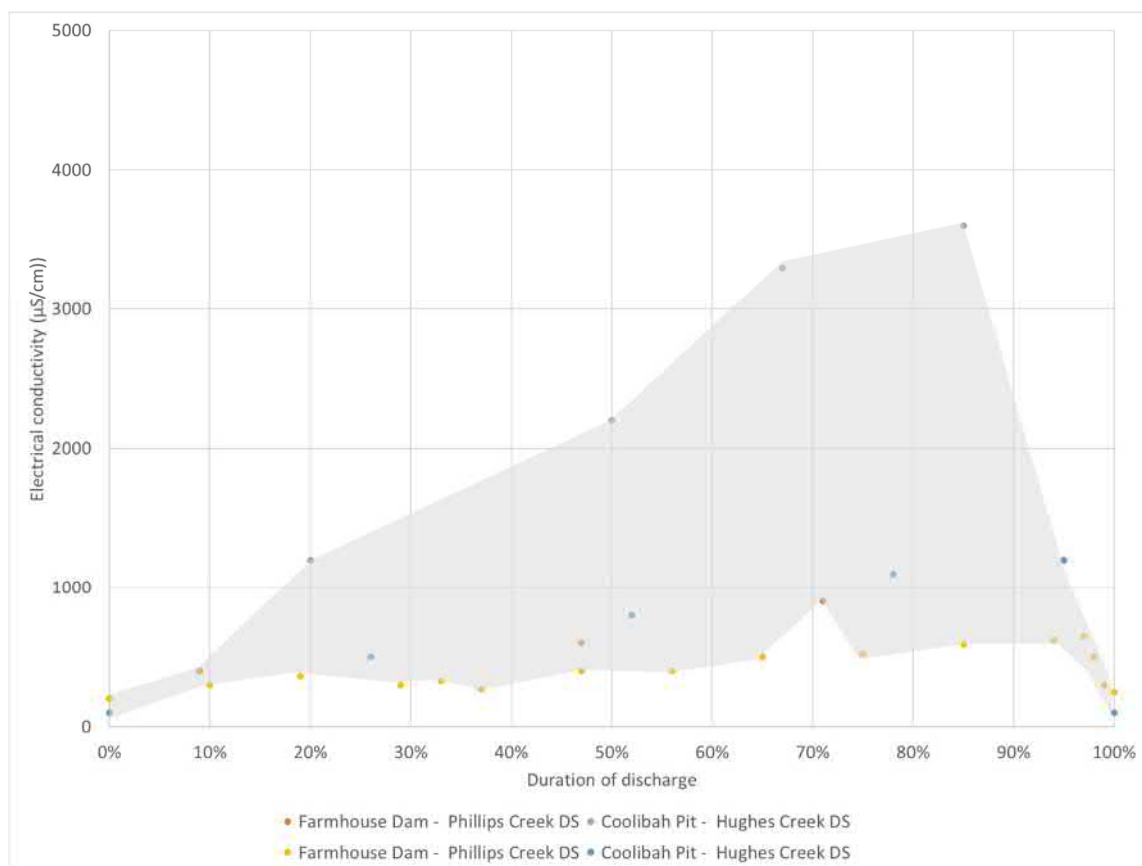


Figure 16 Water release representation showing range of EC concentrations in receiving environment with time

5.2.1.3 Discharge of mine affected water during wet conditions

MAW inventory levels over 80 per cent of the total Process water dam capacity (1,050 ML x 80% = 840 ML) might lead to uncontrolled releases, should a weather event cause a dam spill.² In such conditions:

- MAW salinity concentrations in the Process water dam would oscillate between 2,500 $\mu\text{S}/\text{cm}$ and 3,500 $\mu\text{S}/\text{cm}$, according to modelling results (refer to Section 4.4.1 of Appendix E-2 Mine Water Balance Technical Report (AECOM, 2021))
- Based on historical climate and flow gauging records, wet conditions would also prevail in the receiving environment, promoting background dilution due to high flows (or even potentially flood conditions) in the creeks and rivers around the project area

Impacts from a discharge of MAW in this scenario will be negligible due to the lower MAW salinity concentrations and the significant availability of background dilution.

The scenarios described in sections 5.2.1.1, 5.2.1.2 and 5.2.1.3 indicate that impacts on the receiving environment from a hypothetical MAW release from the proposed project are not expected.

5.2.2 Water management system failures

The proposed WMS has been designed with adequate capacity to avoid releases. Preliminary assessment has sized the dams to contain all inflows without releases.

However, WMS failures could lead to discharge of potentially contaminated water to the receiving environment where mine water is able to migrate from the containment area into Boomerang and/or Hughes Creek. A network of pipes and pumps will be used to transfer water to the process water dam and these facilities have the potential for failure.

Potential failures include:

- Storage containment failure caused by inadequate storage capacity, overfilling of storage, inadequate diversion of clean catchment or extreme storm events
- Storage embankment failure caused by piping failure (related to poor construction of embankment maintenance) or overtopping
- Water management system infrastructure failure including pipeline, pumps, drains, bunds and/or levee failures (caused by machinery damage, weathering, channel erosion, incorrect placement or during relocation).

Storage dams and levees will be managed in accordance with the *DES Manual for assessing consequence categories and hydraulic performance of structures* (2016) and WMS infrastructure in accordance with BHP operational requirements.

Failure of any component of the water management system could potentially lead to a discharge of mine water which has potential for adverse water quality impacts for downstream receiving waters, ecosystems and water users. A catastrophic failure of a large storage may also result in flash flooding.

The process water dam will be located in MLA 70383. A new pipeline co-located with the powerline on the western extent of the Project Site will pipe water to an indicative discharge point at Boomerang Creek. Runoff from disturbed areas of the Project, including the new MIA, the CHPP, stockpiles, rail loop and spur, will be collected from disturbed areas and transferred via the pipeline to the process water dam.

The pre-drainage of incidental mine gas will result in the production of water. This water will be collected in local facilities near the well heads. These facilities will act as a balancing storage to allow transfer at a constant rate to the process water dam.

Failure of pipes transporting MAW from dewatering operations would also result in low volume releases of saline water. The external impact would depend on the location of the failure. Failures of

² According to Table 1 Appendix E-2 Mine Water Balance Technical Report (AECOM, 2021), the combined DSA and ESS volume for the process water dam is 149 ML, which is less than the 210 ML available volume when the Process water dam is 80 per cent full.

water pipelines transporting incidental mine gas production water would result in water being released to land and then flowing overland to Hughes Creek.

Failure of pumps could result in an accumulation of MAW upstream of the pump location and/or (depending on water volumes, system configuration and system storage capacity) an overflow towards downstream surface waters may occur. Generally the quantities of water being transferred by pumps is low, however larger capacity pumps will be in place to transfer water to the process water dam, from:

- ROM pad and product stockpile pad
- CHPP and MIA area
- underground mine portal
- groundwater – water from both the bore field and underground mine dewatering.

Failure of these pumps and the pipeline would result in MAW not being removed from the underground workings; this results in operational production impacts rather than environmental impacts. Further details regarding the probability of overflows occurring and resulting in adverse impacts to the surface water environment are included in the Mine Water Balance Technical Report (AECOM, 2021).

Community safety risks are not likely to arise from any of these failure events and environmental impacts will be relatively low provided that leaks are detected and repaired promptly. Overland flow of the water may cause erosion through scouring, resulting in sediment-laden and saline releases to surface waters. If salty water remains on land and evaporates, soils may become saline, although this would probably leach out in subsequent rain events and is unlikely to have a significant impact from a single isolated event.

If failure of pipes and pumps at the MIA or within the mine WMS occurred, water would be contained within the MIA stormwater system and mine WMS and the external environmental impact would be minimal. Some scouring may occur at the point of failure and would need to be stabilised to avoid potential exacerbation of erosion.

5.2.3 Erosion and sedimentation

During operation, land disturbing activities may result in increased erosion potential and mobilisation of sediment to surface waters. Erosion may also occur around diversion drains.

Erosion and sediment mobilisation can lead to detrimental impacts on downstream water quality and aquatic habitats. The installation and operation of incidental mine gas management infrastructure poses the most significant risk in terms of mobilisation of sediment, as disturbance will occur across the area of the underground mine footprint, and access tracks and gas well pads will remain exposed for some time.

Hughes, One Mile, Spring and Phillips Creek have high turbidity concentrations, attributable to the level of disturbance in the upper catchment. Therefore, relatively small sediment inputs from mine-related activities are unlikely to cause significant changes to water quality and to the aquatic ecology.

As for construction, controls will be installed during operation in accordance with International Erosion Control Association (IECA) Best Practice Erosion & Sediment Control guidelines. With design and mitigation measures in place, water quality impacts associated with erosion and sedimentation on the downstream creeks are expected to be minimal.

5.2.4 Subsidence

The hydrological report produced by Alluvium (2019) assessed the effects of subsidence within the region.

Subsidence has the potential to impact water quality. The subsidence resulting from the Project's underground mining may create surface cracks and buckling. This is likely to cause tensile cracking, thus resulting in erosion responses in colluvial and alluvial sediments. Cracks in erodible sediment pose the greatest threat when orientated downslope and have the potential to cause rill erosion or gully formation.

Subsidence could affect the geomorphic response of surface water to subsidence impacts. It has been determined that subsidence will create an undulating bed profile, thus causing variations in localised hydraulics.

Subsidence can potentially alter the interactions between surface water and groundwater due to goaf induced fracturing, which could increase groundwater to surface water hydraulic connections. This interaction can potentially increase salinity levels in surface water if groundwater is more saline than the surface water. An assessment of groundwater resources, levels and seasonality in the shallow aquifers (Quaternary alluvium and Tertiary sediments) across the Project Site indicates limited shallow groundwater resources (dry bores), seasonal potential surface water discharge to groundwater, and thick clay-rich Tertiary sediments. Thus the risk of enhanced hydraulic connection due to subsidence is limited (i.e. the clay-rich sediments drape and fold in response to subsidence and self-seal (swelling clays) during surface water flow events). It is also noted that the groundwater resources associated with the Tertiary sediments occur in discrete / discontinuous basal sands in excess of 10 m below the surface, which further indicates that the risk of water intrusion to the tertiary aquifer is considered low.

Based on water quality in pools in local streams, water quality in subsidence ponds is likely to be variable over time. Initial inflows will be from surface water runoff and hence relatively low in salinity but potentially containing suspended solids collected from the catchment. As water is ponded in the altered (subsided) topography, it is lost through evaporation and the concentration of salts and any dissolved contaminants are expected to increase over time, as is observed in ponds forming in existing waterways in the Project Site. There may also be changes to other physicochemical characteristics which, however, are expected to be consistent with naturally ponded areas.

The reduction in flows due to the ponding within subsided areas also has the potential to impact on water quality downstream through reduced dilution flows.

5.2.5 Chemicals and contaminants

Diesel fuel will be stored at the MIA. Refuelling facilities will also be located at fuel storages and some mobile refuelling of equipment involved in incidental mine gas management activities may take place across the mine footprint.

Small quantities of chemicals for use in water and wastewater treatment will also be stored at the MIA, CHPP and accommodation village. Small quantities of oils and oily wastes will also be stored at the MIA and CHPP associated with vehicle and equipment maintenance. All fuel and chemical storages will be designed and operated in accordance with Australian Standards (AS), including AS 1940 and AS 3780.

Minor spills and leaks of fuels and oils may occur across the mine footprint from refuelling and operation of equipment involved in installation and operation of incidental mine gas management infrastructure. Likely quantities of fuel or oils that may be spilled would be low, typically in the order of 10 L to 20 L. If spills occur to soils, mobilisation of contaminants to surface waters is unlikely to reach a receiving aquatic environment and hence unlikely to result in any significant water quality degradation. Spills occurring within or immediately adjacent to watercourses may cause localised water quality degradation, but this is likely to be short lived.

5.2.6 Licensing water management infrastructure

The process water dam will receive saline water from gas drainage and returns from the underground mining equipment, with concentrations that have the potential to exceed the guideline thresholds for some water quality parameters. It is therefore anticipated that the process water dam will be classified as a regulated dam and will need to be designed and licensed accordingly. The remaining dams on-site are unlikely to be considered regulated dams as they are unlikely to exceed the water quality guidelines as they will contain either raw water or local run-off. The management of water in these dams will be managed under the mine WMS, and is discussed in detail in the Mine Water Balance Technical Report (AECOM, 2021).

5.2.7 Flooding of mine areas

The hydrology report produced by Alluvium (2019) assessed the impacts of flooding of the Project Site for events of a two year, 50 year, 100 year and 1,000 year average recurrence interval (ARI) with pre- and post-subsidence. A range of potential contaminants will be present in the MIA, including fuels, oils,

chemicals and particulates. Flooding of this area would lead to mobilisation of these contaminants into flood water and these contaminants would then be conveyed downstream. In addition, if the mine entrance becomes flooded and waters flow into the mine access and underground workings, this water would become contaminated with particulates and possibly dissolved salts. This water would need to be removed from the mine workings before mining could re-commence.

If flooding of the MIA occurs, floodwaters may become contaminated with:

- hydrocarbons from residues of fuel and oils on land surfaces and from oily wastes stored in the MIA
- chemicals from chemical stores (if these are inundated) and from waste storage areas
- particulates from coal dust and other sediment present on land surfaces.

5.3 Decommissioning phase

The decommissioning phase will involve the following activities:

- Dewatering of water storage dams which will not be suitable for ongoing beneficial use
- Earthworks associated with the removal of infrastructure on the site and rehabilitation establishment.

The MIA dam will need to be dewatered at decommissioning as would the incidental mine gas production water dam, should it contain any water. Both dams can be pumped into the adjacent mine complex's WMS using existing water transfer systems. The dams would then need to be decommissioned so that it does not capture water in future. As the quantities of water to be transferred are small, and as existing equipment will be used, it is unlikely that any accidental release to the environment would occur during this activity.

The release of contaminated water from a pipeline failure during decommissioning has the potential to have adverse impacts on water quality within the receiving environment, and may compromise downstream environmental values. However, the likelihood of failure, and the quantities potentially involved are low and significant environmental impact is unlikely.

6.0 Mitigation and management measures

6.1 Subsidence

A subsidence management plan (SMP) has been prepared for the Project (AECOM, 2019). It provides a plan for documenting and reporting annual progress and management of impacts against objectives. The key components of the SMP are:

- ongoing subsidence monitoring, evaluation, review and improvement program
- managing bed and bank stability
- vegetation management
- panel catchment management, including rehabilitation of subsidence cracking
- infrastructure protection or relocation, where necessary.

The SMP identifies a number of mitigation measures for managing the impacts of subsidence upon surface waters. These include:

- ripping
- tyning
- grading
- compaction
- crack infilling with concrete or clay
- progressive rehabilitation
- embankment arming
- bed stabilisation such as pervious weirs
- geomorphological modelling to predict high energy areas of the subsided landform
- additional grazing access / controls to mitigate vegetation stripping and bank damage
- channel re-profiling and construction of contour banks
- vegetation planting
- erosion control matting in high energy or erosive areas
- construction of drop structures at head cut erosion features.

6.2 Erosion and sediment control

Erosion and sediment control practices will be applied to construction works and mining operations, in accordance with International Erosion Control Association (IECA) Best Practice Erosion & Sediment Control guidelines to mitigate the generation of sediment and its transport to waterways.

Areas of disturbed or exposed soil will be managed to reduce sediment mobilisation and erosion. The following general mitigation measures are proposed:

- An erosion and sediment control plan will be prepared and executed
- Erosion and sediment control protection measures will be installed prior to the commencement of land disturbance activities. Sediment control structures, such as sediment ponds, will be designed and constructed on site to trap runoff.
- Permanent stormwater management systems will be installed as early as possible in the construction program

- Diversion bunds will be constructed to divert clean water flows around the construction site where practical
- Erosion and sediment control structures will be regularly inspected and maintained
- Topsoil will be stockpiled away from drainage lines to protect it from erosion by surface water runoff
- Dust suppression measures will be implemented
- Vehicle washdown will take place in designated areas away from flood plains and drainage lines
- Water from vehicle washdown areas should be treated to remove seeds, oils and other contaminants before reuse for dust suppression or other on-site use or directed to the mine complex water management system for reuse
- Road crossings of streams should be stabilised to minimise wash outs and bank erosion. Stabilisation may include placement of matting along banks
- Regular inspections of road and pipeline alignments will be undertaken to ensure that disturbed surfaces are stable and not subject to concentration of flows or erosion. Repair works will be undertaken proactively to mitigate erosion from occurring or worsening.

The operational areas will be inspected regularly to check that stormwater management systems are effective and concentration of flow or scouring is not occurring.

Detailed design of the MIA and CHPP will address design of stormwater collection and retention systems to ensure that stormwater can be captured and adequately treated.

6.3 Chemicals and contaminants

The storage of chemicals and fuel on-site will be kept to minimum levels. Storage units will be bunded as per AS 1940 and staff will be trained in appropriate chemical handling and emergency management procedures.

The following general mitigation measures are required to manage impacts of spills and leaks of fuels, oils and other contaminants on receiving waters:

- Temporary and permanent fuel storage areas to be designed in accordance with AS 1940 *The storage and handling of flammable and combustible liquids*. This includes provision for secondary containment.
- Chemical storage areas to be designed and operated in accordance with AS 3780 *The storage and handling of corrosive substances*
- Refuelling to occur within contained, hardstand areas in accordance with AS 1940 wherever possible. Where this is not possible, refuelling activities should be located away from streams and drainage lines and be closely supervised, with a spill kit available that is capable of containing spills of around 100 L.
- Storage and refuelling areas to be located away from areas subject to stormwater inundation
- Storage and refuelling areas to be designed to minimise the ingress of clean stormwater either from overland flow or incidental rainfall
- Spill clean-up kits are to be located in appropriate locations, based on the risk of a spill occurring and potential volume of material that might be spilled at the particular location
- Instructions on spill containment and clean-up to be available at refuelling locations and in vehicles where there is a moderate risk associated with spill events
- Spills are to be contained and cleaned up immediately to mitigate the mobilisation of pollutants in drainage lines or watercourses
- Bunds and sumps should be emptied after each rainfall event. Water and oily water from fuel and oil storage areas removed from bunds and sumps should be treated through an oil water

separator and then reused for dust suppression or other on-site use. Water and other contaminants from other chemical storage areas should be treated through on-site wastewater treatment plants and then utilised in dust suppression or irrigated in accordance with the site Environmental Authority.

- Items are not to be stored or placed within bunds or sumps
- Contaminants and major spills will be collected by a licensed waste collection and transport contractor for disposal at an offsite licensed facility
- Wastewater from vehicle washdown areas should be directed through oil and grease separators and effluent utilised for dust suppression or other use, or directed to the mine complex water management system for reuse.

6.4 Site water management

The objectives of the water management system of the Project are to:

- achieve optimal reliability of water supply for coal processing and dust suppression
- minimise the risk of flooding to the underground workings thereby maximising operability and workforce safety
- minimise the take from the surface water allocation
- direct water from undisturbed areas away from Project operations
- minimise uncontrolled releases from the sites.

The Project will adopt the following principles to achieve these objectives:

- Runoff from undisturbed areas of the Project Site and its vicinity will be diverted away from disturbed areas by diversion bunds and drains which will drain via diverted creeks and natural watercourses of Hughes and Boomerang Creek
- Runoff from disturbed areas of the Project will be diverted away from undisturbed areas and pumped to the process water dam and used preferentially to satisfy the Project's, dust suppression and CHPP process water demands
- Direct rainfall over the Saraji Mine's existing pit areas that comprise the access for the Project's underground workings would be captured and managed as part of the Project. The highwall portal will be designed to provide '1 in 1,000 year' annual exceedance probability (AEP) flood immunity to the underground workings. This will be provided through in-pit sumps and an elevated entry to the underground workings. Water will be captured in the pits and will be transferred to the process water dam when required to maintain the flood immunity.
- Raw water from the BMA's surface water allocations will be piped to the Project Site and used to satisfy the Project's potable water and longwall mining equipment demands. Raw water will be used to supplement CHPP make-up water as required.

Preliminary capacity estimates for all mine WMS dams and the water transfer network have been determined through water balance assessment using historical climate conditions and conceptual operational rules. For the purpose of this assessment, a conservative approach has been adopted to sizing of each conceptual mine WMS storage such that:

- controlled releases of MAW to the receiving environment are not required
- capacities are sufficient to mitigate the uncontrolled (spillway) discharge of MAW to the receiving environment.

The proposed WMS has been designed with adequate capacity to avoid releases. The preliminary dam capacities presented are relevant to the input data, assumptions and adopted operational rules. However, any open system has the potential for uncontrolled discharge of MAW as a result of extreme rainfall events. As such, BMA will be seeking authority and licence conditions to conduct the controlled release of MAW from the Project Site. The indicative location for controlled release of MAW is located

on Boomerang Creek adjacent to the proposed process water dam. Spillway discharges (uncontrolled) from the process water dam are also proposed to be directed to Boomerang Creek.

The following mitigation strategies will be considered to address WMS failure risk:

- mine water storages will be designed with consideration given to the predictions of the water balance model which considers all inputs and outputs, and which has run through a long-term period of climatic data to test storage capacities particularly in high rainfall wet season. If such discharge were to occur this would only be during rare and large events, therefore any release would be subject to dilution and would be similar to the receiving environment
- all dams for the Project will be constructed in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (DES, 2016). Pipes and pump systems to be designed with consideration to volume requirements predicted from water balance modelling and designed by a suitably qualified engineer
- regular inspections of mine water storages, pipeline, drain, bund and levees will be undertaken particularly in relation to integrity of constructed embankments.

Water transfers with Saraji Mine

Under normal operating conditions, the Project mine water system will operate independently of the existing Saraji Mine water system. However, should sufficient MAW not be available for CHPP process and dust suppression at the Project, this may be imported from the existing Saraji Mine water system, following water quality testing to confirm that water is of an appropriate quality for the intended use. Similarly, where additional water demands at the existing Saraji Mine need to be met, water that satisfies water quality testing may be exported from the Project.

A water inventory will be established for the Project with a respective Trigger Action Response Plan (TARP) that identifies excess and insufficient water inventory levels and corrective actions to prevent an impact to mine production.

6.5 Mine dewatering

The following mitigation and management measures apply to dewatering of water storage dams for operational requirements, such as maintenance:

- Ensure water is disposed of in accordance with the project EA and relevant legislation
- Ensure that pipe and pump network is operating properly before commencing dewatering.

7.0 Monitoring

7.1 Receiving Environment Monitoring Program

A REMP will be developed and implemented prior to construction to monitor potentially affected waterways and assess effectiveness of management strategies, including but not limited to:

- confirm location of release point for controlled discharge of mine-affected water (MAW) (indicatively located on Boomerang Creek adjacent to the proposed process water dam)
- include baseline data on surface water flows and quality, trigger levels for investigations and a monitoring program
- monitoring EC and pH (acidity or alkalinity) and other water parameters in potentially affected waterways (upstream and downstream of impact)
- development of a Trigger Action Response Plan (TARP) to identify the corrective actions and responses required in the event that operations result in exceedances in surface water quality or adverse changes in stream health.

The REMP will incorporate a baseline water quality monitoring program to monitor pH, electrical conductivity, total suspended solids and total dissolved solids at upstream and downstream locations. New monitoring locations will be established downstream of the Project Site (refer to Figure 17). Existing upstream locations would continue to be monitored.

Monitoring will be undertaken in accordance with the Monitoring and Sampling Manual – Environmental Protection (Water) Policy 2009 (DES, 2018b) (or guideline current at the time of construction). Field monitoring equipment, such as electrical conductivity and pH meters will be calibrated. QA/QC laboratory samples will be collected. All external laboratories will be National Association of Testing Authorities (NATA) accredited for the analytical procedures they are performing.

Baseline water quality monitoring will inform the development of site specific surface WQO and trigger values based on 20th and 80th percentiles. Queensland Water Quality Guidelines (2009) recommend a minimum of 18 data values collected over two years to derive guidelines. While the Queensland Water Quality Guidelines (2009) permits the derivation of guidelines based on less than two years of monthly sampling, this should be considered as interim—until a full data monitoring program can be undertaken. Monitoring will be carried out for at least two years and will incorporate both upstream and downstream locations. Site specific WQO will be developed for the Project based on the results of the REMP monitoring program.

The relevant environmental values as defined under EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) are outlined in Section 3.2 and will be confirmed based on a review of Deciding aquatic ecosystem indicators and local water quality guidelines (DES, 2018d). Prior to the development of site specific water quality objectives, these will be as defined for the Isaac River catchment within Schedule 1 of the EPP (Water).

For Boomerang Creek, a mine water release point is proposed downstream of the Boomerang Creek (downstream) site, and hence new monitoring points are proposed further downstream (refer Figure 17).

Further, complementary to this dataset, REMP data will continue to be collected via the adjacent sites' REMPs during wet weather.

7.2 Monitoring during Construction

During construction, surface water that becomes ponded in excavations would be tested and managed in accordance with the stormwater management system to determine whether suitable for discharge to the receiving environment or otherwise disposed of at a licenced facility. Monitoring of the receiving water during construction would be in accordance with the REMP outlined in Section 7.1.

Boomerang Creek

Boomerang US MP2/MP24 (PDM)

Boomerang DS MP10 (PDM)

Hughes Creek

Hughes US MP1 (SRM)

Hughes DS MP5 (SRM)

One Mile Creek

One Mile US MP2 (SRM)

One Mile DS MP6 (SRM)

Spring Creek

Phillips Creek

Phillips US MP3 (SRM)

Phillips DS MP7 (SRM)

Isaac DS MP9 (SRM), MP18 (PDM), Regional 2

ML1724

ML1723

ML1722

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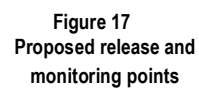
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 Project Site
 Project Footprint
 Exploration Permit Coal (EPC)
 Mining Lease (ML)
 Mining Lease Application (MLA)

-  Monitoring Locations
 Indicative Proposed Monitoring Point Location
 Indicative Proposed Mine Water Release Point
 Watercourse



**Environmental Impact Statement
Saraji East Mining Lease Project**



Scale: 1:150,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 26/03/2021 VERSION: 3

7.3 Monitoring during Operation

Monitoring of MAW dam water levels will be automated and dam water levels will be managed in accordance with the site water management to minimise uncontrolled releases (refer to Section 5.2).

Where safety and access permit, the receiving water will be monitored at upstream and downstream locations during process dam release events. Monitoring will also be carried out during normal operation of the mine to in accordance with DES guidelines.

BMA will implement the Subsidence Management Plan (**Appendix K-2**) to manage impacts on landform, surface water, groundwater, ecology and infrastructure prior to subsidence impacts. The Plan will outline SMART controls for mitigation, monitoring and rehabilitation, including monitoring erosion and sedimentation, surface cracking across the subsidence impacted areas.

7.4 Preliminary Response Plan

Actions that would be taken in response to an exceedance of water quality criteria are outlined in Table 16, including the timing, responsibilities and reporting requirements.

A TARP will be developed prior to construction, as part of the Water Management Plan, with the primary objective of providing trigger values for further investigation and outlining the corrective actions and responses required in the event that:

- a. monitoring identifies the potential for an exceedance of water quality objectives or overtopping of water storages
- b. water quality monitoring identifies an exceedance of water quality objectives or an adverse change in stream health; or
- c. overtopping of the process water dam spillway occurs.

Under normal conditions the mine will operate as a closed system, so discharges to the downstream catchment are considered unlikely to occur.

The TARP will apply to the construction, operation and decommissioning stages of the Project. Site-specific water quality objectives or trigger values will be developed for the Project in line with the REMP. The TARP may also include ground condition, vegetation cover, erosion and other rehabilitation completion criteria described in the Project's rehabilitation management plan.

Table 16 Preliminary response plan for exceedance of water quality objectives

Trigger	Response	Timing	Outcome / reporting
Water quality monitoring in the receiving environment identifies exceedance of water quality objectives	STEP 1 Review potential causes of exceedance via the following: Visual inspection of potential diffuse sources (e.g. seepage from reject disposal areas or waste rock dumps). Where a potential source of an exceedance is identified, samples should be collected for testing where feasible and practicable. Visual inspection of site infrastructure to identify any visible damage (e.g. a damaged pipe or broken monitoring equipment) Visual inspection of site equipment and plant, and review of maintenance records Review of recent weather and rainfall data (Note that some physico-chemical parameters such as conductivity and turbidity may be influenced by large rainfall).	STEP 1 As soon as practicable, once the exceedance is identified	STEP 1 Record exceedance in the REMP
	STEP 2 Determine the extent of the exceedance or impact on receiving waters: Conduct additional water quality testing sufficient to delineate extent of impacts and assess trends	STEP 2 As soon as reasonably possible	STEP 2 Record additional water quality testing results in the REMP
	STEP 3 If it is identified that the exceedance is a result of construction or operation of the Project and has resulted in the release of contaminants not in accordance, or reasonably expected to be not in accordance with the EA, BMA must notify DES by written notification within 24 hours of becoming aware, or in accordance with the EA conditions at the time.	STEP 3 If the exceedance meets reporting requirements, notify DES within 24 hours of becoming aware	STEP 3 Document correspondence in the site Environmental Management System Carry out incident reporting requirements in the EA
Overtopping of process dam spillway	STEP 1 Determine impact on receiving waters: Carry out water quality testing of impacted water bodies to determine if trends are present and to delineate extent of impacts	STEP 1 Carry out water quality testing as soon as reasonably possible (where safety and access permits)	STEP 1 Record water quality testing results in the REMP
	STEP 2 If it is identified that overtopping has resulted in the release of contaminants not in accordance, or reasonably expected to be not in accordance with the EA, BMA must notify DES by written notification within 24 hours of becoming aware, or in accordance with the EA conditions at the time.	STEP 2 If the release of contaminants meets reporting requirements, notify DES within 24 hours of becoming aware	STEP 2 Document correspondence in the site Environmental Management System Carry out incident reporting requirements in the EA

8.0 Residual impacts

The creeks within the Project Site are part of the Isaac River catchment which flows into the Fitzroy River. The total catchment area for all creeks and tributaries upstream and within the Project Site is approximately 590 km². Therefore, the total catchment area represents less than three per cent of the Isaac River catchment and approximately 0.4 per cent of the Fitzroy River catchment (142,665 km²).

The Lower Fitzroy River and Fitzroy Barrage Water Supply Schemes have 28,621 ML and 62,335 ML of allocated water, respectively. The Lower Fitzroy and Fitzroy Barrage Water Supply Schemes are approximately 250 km downstream of the confluence with Isaac River. The total catchment area upstream and within the Project Site is less than 0.4 per cent of the total catchment area for these water supply schemes. Therefore, the Project is not expected to impact these water supply schemes.

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Appendix A

Gauge Industrial and Environment REMP Report



RECEIVING ENVIRONMENT MONITORING PROGRAM (REMP)

Annual Report – end June 2013

FINAL REPORT

SARAJI MINE
BHP BILLITON MITSUBISHI ALLIANCE
ENVIRONMENTAL AUTHORITY EPML00862313

19th June 2014

Version 1.0 (Final)



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EXECUTIVE SUMMARY

The Receiving Environment Monitoring Program (REMP) was implemented as a requirement of the mine's Environmental Authority (EA). The purpose of the REMP is to monitor the receiving environment and record the effects of contaminant release. The EA requires this report to present the findings of monitoring, and include assessment of background conditions and the applicability of the current limits in protecting the environment.

The study area included the waters of Hughes, One Mile, Phillips and Spring creeks and tributaries in the vicinity of Saraji Mine. This area has a history of agriculture and mining, and retains local environmental values including slightly-to-moderately disturbed ecosystems and stock watering.

The study monitored water quality, stream flow, sediments and bio-indicators between January 2010 and June 2013. Monitoring sites included control or reference sites up gradient of mining activity and test sites downstream of mining.

Stream Flow

The local streams recorded similar ephemeral flow patterns throughout the REMP study, with extended nil flow periods interspersed with sporadic flow events. Hughes and Phillips creeks experienced major flows during the 2010/2011 wet season, whereas the 2011/2012 and 2012/2013 wet seasons were drier for all streams, with only a few isolated flow events including significant flows in March 2012 and January 2013. The flows in One Mile and Spring creeks were similar in pattern, although discharge rates were an order of magnitude smaller.

Water Quality

Local reference conditions for water quality were assessed by monitoring water during flows in Hughes, One Mile, and Phillips creeks. Data from these reference sites were used to offer potential local water quality guideline values. Spring Creek data was limited to two events taken by an auto-sampler and was not included in this year's analysis. This report does not consider whether any particular analyte should or should not be included in the mine's EA list of triggers, but rather suggests what guideline value may be appropriate should it be included.

For analytes of interest, data sets of between 78 – 358 samples were obtained, with most analytes per site surpassing the minimum 18 samples recommended by the Queensland Water Quality Guidelines for proposing local guidelines. Data sets were evenly spread between reference sites, and between reference and test sites.

Suggested changes and comments with regard to the current guideline values are detailed in Table 11, and summarised as:

- New local guidelines are proposed for ammonia, dissolved aluminium, chromium and vanadium.
- A new EA trigger is proposed for dissolved aluminium.
- There was insufficient data to derive local guidelines for dissolved oxygen and temperature.
- Retention of existing guidelines or the EA trigger values is suggested for the remaining analytes.

Proposed local guidelines are qualified for One Mile Creek as the upstream reference site was located at the spillway of One Mile Dam, an in-stream storage which receives pipeline water from Bedford Weir, and as such, may not be representative of true conditions for this catchment.

Impacts from mining were assessed by monitoring Hughes, One Mile, and Phillips creeks at the upstream, western section of the mine lease through to the downstream eastern section. Data from manual monitoring was statistically analysed to ascertain change between control and test sites. The level of change was reviewed for acceptability and the concentrations of analytes were compared to guidelines applicable for local environmental values. Water quality monitoring data derived from on-line automated equipment was not used in the statistical analysis.

The results indicate the following relationships between upstream control sites and downstream test sites:

- Analytes that decreased in concentration downstream include:
 - o Aluminium (dissolved)
 - o Arsenic (total – Hughes Creek)
 - o Chromium (dissolved and total)
 - o Cobalt (total – Hughes Creek)
 - o Iron (dissolved)
 - o Manganese (dissolved and total)
 - o Vanadium (dissolved-Hughes and Phillips creeks)
 - o Zinc (total – Hughes Creek)
- Analytes that showed no discernible change between control and test sites include:
 - o EC (Phillips Creek)
 - o Ammonia
 - o Petroleum hydrocarbons (C6-9 and C10-C36)
 - o Arsenic (dissolved)
 - o Boron (dissolved)
 - o Cadmium (dissolved and total)
 - o Cobalt (dissolved)
 - o Copper (dissolved)
 - o Lead (dissolved)
 - o Mercury (dissolved and total)
 - o Molybdenum (dissolved and total)
 - o Nickel (dissolved)
 - o Silver (dissolved and total)
 - o Zinc (dissolved)
- Analytes that were mostly (>85%) below detection or limits of reporting (LOR), include:
 - o Petroleum hydrocarbons (C6-C9 and C10-C36)
 - o Cadmium (dissolved and total)
 - o Cobalt (dissolved)
 - o Lead (dissolved)
 - o Mercury (dissolved and total)
 - o Zinc (dissolved)
- Analytes for which there was insufficient data coverage to make an assessment include:
 - o Dissolved oxygen - indicative data suggests little discernible change after mining. Dissolved oxygen levels were within Queensland guidelines for upland and lowland waters.

-
- o Temperature - indicative readings were within the expected range for warm climate streams.
 - o Total hardness - there are no applicable guidelines for total hardness.
 - Analytes that increased in concentration downstream include those listed below. Median downstream values for all remained within the average or corresponding upstream 80th percentile values, indicating the increase recorded was acceptable for slightly-to-moderately disturbed ecosystems.
 - o EC (Hughes Creek)
 - o pH (Hughes and Phillips creeks)
 - o Total Suspended Solids
 - o Turbidity
 - o Sulfate
 - o Nitrate
 - o Fluoride (Phillips Creek only)
 - o Aluminium (total)
 - o Arsenic (total – Phillips Creek)
 - o Boron (total)
 - o Cobalt (total – One Mile and Phillips)
 - o Copper (total)
 - o Iron (total)
 - o Lead (total)
 - o Nickel (total, and dissolved-Phillips Creek)
 - o Selenium (dissolved)-Hughes and Phillips creeks
 - o Selenium (total)
 - o Uranium (dissolved and total)
 - o Vanadium (total, and dissolved in One Mile Creek)
 - o Zinc (total – One Mile and Phillips creeks)
 - Analytes where the downstream median was greater than the upstream 80th percentile (plus one standard error), but remained below current guidelines include:
 - o EC - One Mile Creek
 - o pH – One Mile Creek
 - o Fluoride - Hughes and One Mile creeks
 - o Arsenic (total) – One Mile Creek
 - o Selenium (total) - One Mile Creek

The One Mile Creek findings require qualification as the upstream sample site may be unrepresentative of the catchment, due to its location in One Mile Dam which receives pipeline raw water at the sample site. As the pipeline water is sourced from Bedford Weir, the water at this background site potentially has different, or better, water quality than what naturally occurs in this stream. To avoid this confounding factor, in May 2012, the mine relocated the site further upstream, to provide a better future guide to the change in water quality in One Mile Creek. Only one result for this new site was available for this report.

- Analytes where the downstream median recorded levels greater than the upstream 80th percentile (plus one standard error), and greater than current guidelines, include:
 - o None



In conclusion, changes in median water quality after mining were within acceptable limits for slightly-to-moderately disturbed systems or remained within applicable guidelines.

Sediment Quality

Five sediment surveys were undertaken by the Central Queensland University (CQU) between December 2011 and June 2013.

Particle Size Analysis

Particle size analysis, done during the 2013 surveys, found stream bed sediments were dominated by sand at all upstream and downstream sites. The fines (clays and silt) content was higher downstream in Hughes, One Mile and Spring creeks, ranging from 7% to 26%, compared to 1% to 2% upstream. This variation in sediment content requires consideration in the interpretation of chemical composition as higher proportions of fines can contribute to increased extractable chemical loadings. The fines content in Phillips Creek was more balanced with both upstream and downstream sites, averaging 3.5%.

Comparison to ISQG Triggers

The ANZECC & ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQG) provides trigger values for a number of metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Ag and Zn). In this study, all metals were below their respective ISQG triggers; and cadmium, mercury and silver were below the limit of reporting at all sites.

Comparison to Background

For metals where no trigger values are provided (Al, B, Co, Fe, Mn, Mo, Se, U and V), the ANZECC & ARMCANZ (2000) guidelines suggest using a value of two times the background concentration as a trigger for further investigation. The data set available was limited to one to five samples per site, restricting meaningful statistical comparison on an individual stream basis. The following general observations were made from comparison of medians upstream and downstream for individual streams and all streams combined:

- Boron and selenium were less than the limit of reporting at all upstream and downstream sites.
- The combined streams basis, all analytes except uranium recorded less than a two-fold increase downstream. Uranium increased by 200% downstream, however this result is qualified as concentrations were close to the limit of reporting (LOR) and 46% of results were below the LOR. The highest uranium levels recorded in the study were at a background site (upstream One Mile Creek); suggesting uranium is slightly enriched in the area. Uranium in sediments are considered low risk as the levels were very low and within the range recorded naturally in the area.
- On a stream by stream basis, all streams except Phillips Creek recorded greater than two-fold increases in some metals downstream. It is notable that Phillips Creek was the only stream evenly represented in terms of fine sediment content at both upstream and downstream sites. Further monitoring is required to confirm the increases in Hughes, One Mile and Spring creeks as the current assessment relies on only 1-2 upstream samples, however the following initial observations were made:
 - Boron and selenium were below detection limits at upstream and downstream sites.

- o Aluminium, cobalt, manganese, molybdenum (Spring Creek), uranium and vanadium (Spring Creek) downstream medians increased by between two and six fold, however the concentrations are considered low risk as similar or higher levels were recorded in some background sites in the study area.
- o Iron (Hughes, One Mile and Spring), molybdenum (One-Mile) and vanadium (Hughes) recorded downstream median increases of between two and seven-fold. The medians were higher than any background site in the area. The increase appears to correlate strongly with the amount of fine sediment collected in the sample rather than wholly the proximity to mining. Upstream and downstream sites containing less fines (clay and silt) recorded lower metal concentrations than downstream samples collected with a higher fines content. Variation was observed in the amount of fine sediment collected at the same site between surveys, resulting in significant variations in the concentration of these metals between surveys. As the results were based on one upstream and two downstream samples per stream, further monitoring is required for confirmation.

According to the ANZECC guidelines' decision tree, the initial data suggests most metals in sediments are "low risk" and require "no action" as downstream concentrations were below trigger values or not increased significantly above background. Iron, molybdenum and vanadium in individual streams require further monitoring (including particle size analysis) to confirm if levels have increased significantly downstream and if the increases are attributed to natural fine sediment levels, or mining and other past and present land use practices.

Bio-indicators

Macroinvertebrate surveys were conducted by the Central Queensland University in six surveys between June 2011 and June 2013 using the methodology prescribed by the Queensland Monitoring and Sampling Manual.

Physical Habitat Conditions:

Nine (9) physical habitat variables were scored at each site during the July 2011 and 2013 surveys and then rated as poor, fair, good or excellent.

Physical habitat conditions suggest the streams in the study area are structurally less than optimal for supporting diverse macroinvertebrate communities. This may contribute to macroinvertebrate indicator scores lower than those expected at reference sites in Queensland. Hughes, One-Mile and Spring creeks, and upstream Phillips Creek, rated generally "fair" overall. Downstream Phillips Creek was the best of the sites assessed, scoring a "good" rating.

Indicators:

Seven (7) macroinvertebrate indicators were measured during the surveys, assessing biodiversity, sensitivity to pollution and comparison with modelled reference conditions:

1. Taxa richness (diversity measured by the number of macroinvertebrate taxa)
2. PET taxa richness (a measure of pollution sensitive taxa present)
3. SIGNAL index (a pollution sensitivity grading)
4. Percentage tolerant taxa (a pollution tolerance rating)
5. Shannon Diversity Index (a diversity measure in terms of species richness and evenness)

6. O/E Families - AUSRIVAS model (ratio of observed to expected taxa families in model)
7. O/E SIGNAL – AUSRIVAS model (ratio of observed to expected pollution sensitive SIGNAL taxa)

The Shannon Diversity Index, O/E Families and O/E SIGNAL indices were not continued into the 2013 surveys.

Due to dry conditions in 2013, only Phillips Creek and downstream One-Mile and Spring creeks were sampled. Sample sizes were limited to 1-2 surveys per site and included only the edge habitat. Prior to 2013, only the pool habitat was sampled, and no results were available for sites upstream in Hughes and Spring creeks, or downstream One-Mile Creek, preventing comparison upstream and downstream of mining in these streams.

As pool and edge habitats at the same site are expected to differ by more than the same habitat at different sites, comparison of data between the 2013 “edge” surveys and previous “pool” surveys is not recommended. Taking these limitations into consideration, this preliminary assessment found the following key initial findings:

- There was high variability in some indicator scores at some sites between surveys, both upstream and downstream; highlighting caution is required when interpreting any individual result.
- Most sites were within or poorer than Queensland guidelines, with occasional scores better than guidelines at times at some sites.
- For Phillips Creek, none of the indicators showed a consistent, discernible deterioration between sites upstream and those downstream.
- In the one edge habitat survey available, downstream One-Mile and Spring creeks were within Queensland guidelines, except for Taxa richness, which scored similarly to upstream and downstream Phillips Creek. There were no upstream site surveys on One-Mile and Spring creeks for comparison.

From the limited data available, the macroinvertebrate indicators did not show changes downstream of mining in Phillips Creek that would warrant immediate investigation, however further monitoring would be required for confirmation and to confidently establish trends for Hughes, Spring and One-Mile creeks.

1. OBJECTIVE & SCOPE

The objective of the Receiving Environment Monitoring Program (REMP) is to provide an assessment of aquatic conditions in local areas potentially affected by mine water release. The data is compared against broader Water Quality Objectives (WQOs) and guidelines, and assists in determining WQOs more applicable to the local environmental values and conditions.

This REMP report is an annual update covering up until 30th June 2013, and has been prepared to meet condition W21 of the Environmental Authority (EA) EPML00862313 (formerly MIN100845908). The aspects covered in this final report covers stream flow, water quality, sediment quality and bio-indicators.

Condition W21 states:

A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions W19 and W20 must be prepared annually and made available on request to the administering authority. This must include an assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.

Condition W19 states:

The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorized mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site.

For the purposes of the REMP, the receiving environment is the waters of the Hughes, One Mile, Spring and Phillips Creeks and connected waterways within five (5) kilometres downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorized mining activity that will potentially be directly affected by an authorized release of mine affected water.

Condition W20 states:

The REMP must:

- a) Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); and*

-
- b) Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; and*
 - c) Include monitoring from background reference sites (e.g. upstream and background) and downstream sites from the release (as a minimum, the locations specified in Table W8); and*
 - d) Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the Queensland Water Quality Guidelines 2006. This should include monitoring during periods of natural flow irrespective of mine or other discharges; and*
 - e) Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in Table 2 and 3; and*
 - f) Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments); and*
 - g) Include, where appropriate, monitoring of macroinvertebrates in accordance with the AusRivas methodology, and*
 - h) Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; and*
 - i) Describe sampling and analysis methods and quality assurance and control; and*
 - j) Incorporate stream flow and hydrological information in the interpretations of water quality and biological data.*

2. DESCRIPTION OF STUDY AREA

2.1 LOCATION & HISTORY

The study area includes creeks traversing Saraji Mine located in Central Queensland near the town of Dysart and 250kms North West of Rockhampton. The study area is located in the Isaac River basin, which forms part of the Fitzroy River basin (Figure 1).

For the purposes of the Queensland Water Quality Guidelines, the creeks (Hughes, One Mile, and Phillips) are in the northern section of the Fitzroy Basin (Basin 130) which is part of the Central Coast Region (QWQG, 2009).

The mine commenced production in 1974. Prior to mining the area was used for agricultural purposes.

The site topography comprises gently undulating country descending to alluvial plains.

Saraji mine shares a portion of the local catchment with Peak Downs mine to the north, and regionally is located downstream of a number of other coal mines in the Isaac River catchment.

2.2 WATER TYPE

The study area is located in the upper to middle reaches of Hughes, One Mile, and Phillips creeks, with monitoring locations at approximately 180 to 360m AHD elevation, placing it into the category of *upland freshwater* stream according to ANZECC (2000). This arbitrary altitude-based definition may not be appropriate for many areas, and the QLD Guidelines (QWQG, 2009) offer a more broadly applicable definition:

Upland freshwaters: Small (first, second and third order) upland streams. Moderate to fast flowing due to steep gradients. Substrate usually cobbles, gravel or sand – rarely mud.

Lowland freshwaters: Larger (third, fourth and fifth order or greater), slow-flowing and meandering streams and rivers. Gradient very slight. Substrates rarely cobble and gravel, more often sand, silt or mud.

The upstream sites in the study area exhibit typical upland characteristics, whereas the downstream sites have characteristics of both. A review of some water quality parameters in the Fitzroy basin found no clear separation between lowland and upland streams (DERM, 2010); therefore guidelines for both water types are considered for discussion in this report.

Figure 1 – Location of Study Area



2.3 WATERWAY DESCRIPTION & LAND USE

The waterways on Saraji Mine, and within 5kms downstream, are completely ephemeral with flow only after significant rainfall and for limited periods each year.

The catchment area upstream of mining is predominately rural grazing land and natural bushland.

Stream substrates are dominated by coarse sand in all creeks across the site.

Table 1 – Saraji Mine Land Uses

Catchment - Hughes, One Mile and Phillips Creeks		
	Primary Industries	Mining
Near Field	Grazing (beef cattle)	Coal
Far Field	Grazing (beef cattle), crops	Coal

2.4 GROUNDWATER INFLUENCE

None of the creeks in the study area have a permanent groundwater base flow that contributes to surface flows.

2.5 COMMUNITIES AND SPECIES OF CONSERVATION CONCERN

There are no protected areas or areas of high conservation significance within or directly adjacent to the study area (FBA, 2010). In a review of communities and species of conservation significance in nearby streams, BMT WBM (2010) found no fish species of conservation significance listed under the Commonwealth (Environment Protection and Biodiversity Conservation (EBPC) Act 1999) or State (Queensland Nature Conservation (NCA) Act 1992) legislation.

2.6 LOCAL CLIMATE

The climate for the area is typical of the region with high daytime summer temperatures, mild winters and low-moderate humidity. Rainfall is highly variable and seasonal with most recorded during the warmer months from December to March (Table 2).

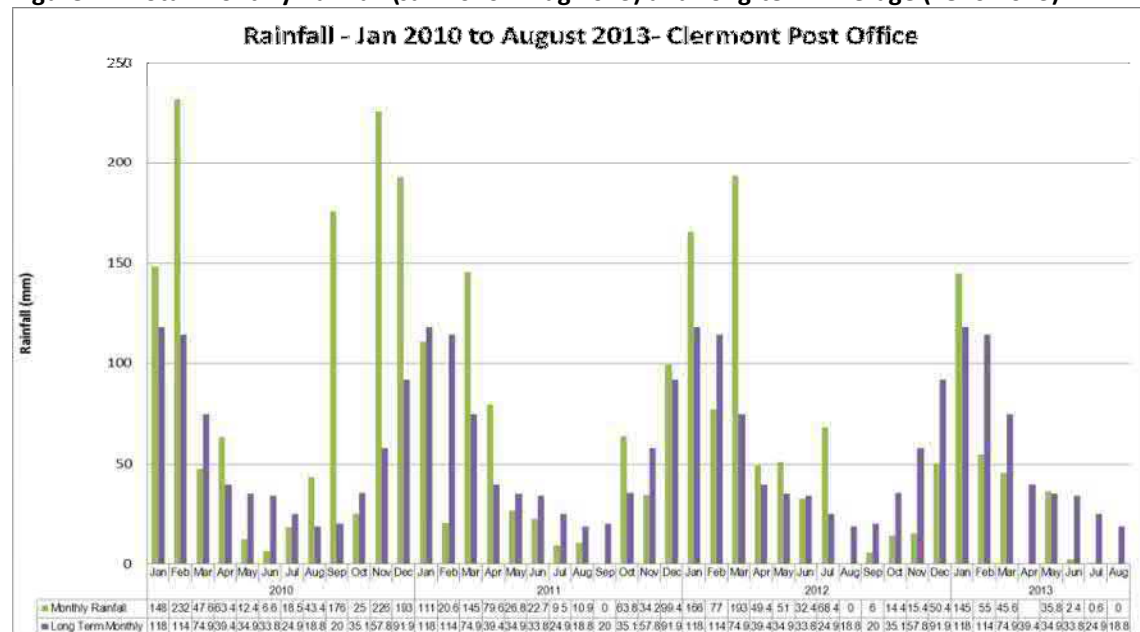
Table 2 – Long Term Climate Statistics (1870 to 2013)

Month	Temperature (°C)		Relative Humidity %		Evaporation* (mm)	Wind (km/hr)	Rainfall (mm)		
	Average Min	Average Max	9am	3pm	Daily	3pm	Mean	Highest Daily	Highest Monthly
	1910-2011	1910-2011	1938-2010	1962-2010	1979-2011	1962-2010	1870-2013	1870-2013	1870-2013
Jan	21.6	34.3	66	42	7.5	10.4	118.1	171.5	516
Feb	21.1	33	71	47	6.8	10.8	114.4	137.7	428
Mar	19.4	32	69	42	6.3	10.8	74.9	148.7	403.4
Apr	15.7	29.5	67	41	5.1	10.6	39.4	113.6	274.2
May	11.4	26.1	68	42	3.7	9.8	34.9	110.8	234.4
Jun	8.1	23.1	69	41	3	9.7	33.8	99.1	307.2
Jul	6.7	23.1	66	37	3.2	9.9	24.9	96.5	192.5
Aug	8.3	25.3	61	33	4.2	10.6	18.8	93.6	171.2
Sep	12.1	28.8	55	29	5.7	11	20.1	97.8	184.9
Oct	16.3	31.9	54	30	7	11.3	35.4	125.4	165.2
Nov	19	33.9	57	34	7.4	10.6	57.8	130.1	263.9
Dec	20.8	34.8	60	38	8.1	10.4	92.3	419.1	670.7

Climate statistics taken from BOM station at Clermont Post Office (ID: 35019).

2.7 RAINFALL DURING REMP STUDY

The REMP study period was wetter than historical averages, although 2012/2013 was drier in most months. Rainfall measured between Jan 2010 and June 2013 at the nearest long term gauging station (Clermont Post Office) was 2822mm; 17% higher than the seasonal long term average of 2408mm (Figure 2).

Figure 2 – Total Monthly Rainfall (Jan 2010 – Aug 2013) and Long-term Average (1870-2013)


Monthly and long term monthly average rainfall statistics taken from BOM station at Clermont Post Office (ID: 35019).

3. ENVIRONMENTAL VALUES

For the purposes of this REMP, the local environmental values are divided into two spatial categories, of which the pertinent environmental values (FBA, 2010; DERM, 2010) are considered in assessing stream water quality are listed in Table 3.

Table 3 – Environmental Values

Environmental Value		Near field (Hughes, One Mile, Phillips Creek)	Far field (Hughes, One Mile, Phillips Creek)
Aquatic Ecosystems	HEV		
	SMD	✓	✓
	HD		
Primary Industries	Irrigation		✓ (Cropping)
	Farm Use		✓
	Stock Watering	✓ (Beef cattle – limited to post rainfall)	✓ (Beef cattle)
	Aquaculture		
Recreation and Aesthetics	Primary Recreation		✓ (swimming, fishing)
	Secondary Recreation		✓
	Visual Appreciation		
Human Consumer	Consuming wild/stocked fish		
Drinking Water	Suitable raw water		✓ (Isaac/Mackenzie/Fitzroy river weirs)
Industrial Use	Mining		
Cultural and Spiritual Values	Indigenous		
	Symbolic		
	Lifestyle		

4. MONITORING PROGRAM DESIGN

4.1 MONITORING ASPECTS

Development of this monitoring program is based on the Monitoring and Sampling Manual (DERM 2009) and the specific requirements of each aspect of the program, which include:

- Stream flow
- Water quality (surface water)
- Sediment quality
- Bio-indicators (macroinvertebrates)

4.2 SAMPLE SITE SELECTION

Sampling sites have been selected to avoid spatially confounding factors. They were selected to best represent the sum of stream influences prior to, and after, the mining operation. Where appropriate, the sites were aligned with historical or regulatory monitoring sites for the purposes of correlation with previous data and EA conditions, and the use of existing infrastructure.

Monitoring sites for various aspects of the REMP at times differed according to the specific site selection requirements of each monitoring aspect. The monitoring sites for each aspect are detailed separately in each section of this report.

Reference, upstream or control sites: In this REMP, reference or control sites are those that are without influence by the mining operation. These sites are referred to as “upstream (U/S)”, “background” or “reference” sites in labels, laboratory reports and survey results. For the purposes of this report, these terms are interchangeable.

Test or downstream sites: In this REMP, test or downstream sites are those that are potentially influenced by the mining operation. These sites are referred to as “test”, “downstream (D/S)” or “putative impact” sites in labels, laboratory reports and survey results. For the purposes of this report these terms are interchangeable.

4.3 TEMPORAL CONSIDERATIONS

The timing of stream monitoring (Table 4) was conducted according to the relevant methodologies of each aspect of the program, the local rainfall and stream flows, and the safety and accessibility of sites.

Table 4 – Temporal Design of Monitoring Program

Aspect	Temporal Program Design
Stream Flow	On-line monitoring provided continuous data
Water Quality	Grab sampling and manual <i>in situ</i> measurements during stream flows at various stages of the hydrograph and during different seasons. The ephemeral streams in the study area required a quick response to obtain grab samples after rain events. The accessibility, safety and staffing available at short notice often dictated the sampling times and locations possible, particularly for highly ephemeral sites. On-line monitoring at some sites provided basic water quality parameters on a continuous



MONITORING PROGRAM DESIGN

Aspect	Temporal Program Design
	basis. Nil or low flow water quality sampling was performed during bio-indicator surveys; however this data was treated separately to the data collected during periods of flow.
Sediments	Sampling occurred during nil or low flow periods (pre or post wet season), often coinciding with macroinvertebrate sampling seasons or surveys.
Bio-indicators	Macroinvertebrate sampling was generally performed according to the Queensland AusRivAS seasonal protocols of Autumn or post-wet season (May-July) and Spring or pre-wet season (Oct-Dec)



5. STREAM FLOW

5.1 PROGRAM DESIGN

Stream flow monitoring was provided by gauging stations on Hughes, One Mile, Phillips and Spring creeks (Table 5 and Figure 3). These stations are located downstream of release points, and will therefore at times include flow inputs from mine water releases.

Table 5 – Description of Flow Monitoring Sites

Site	Parameters	Waterway & Site Descriptor	Easting	Northing
Hughes Creek downstream (HC DS)	Levels (flow)	Hughes Creek, 5.4km downstream from RP2	634543	7525740
One Mile Creek downstream (OMC DS)	Levels (flow)	One Mile Creek, 4.3 km downstream from RP5	636584	7520221
Phillips Creek downstream (PC DS)	Levels (flow)	Phillips Creek, 0.7 km downstream from RP4	639163	7513920
Spring Creek Downstream (SC DS)	Levels (flow)	Spring Creek, downstream from mine	637450	7518574

5.2 METHODOLOGY & QUALITY ASSURANCE

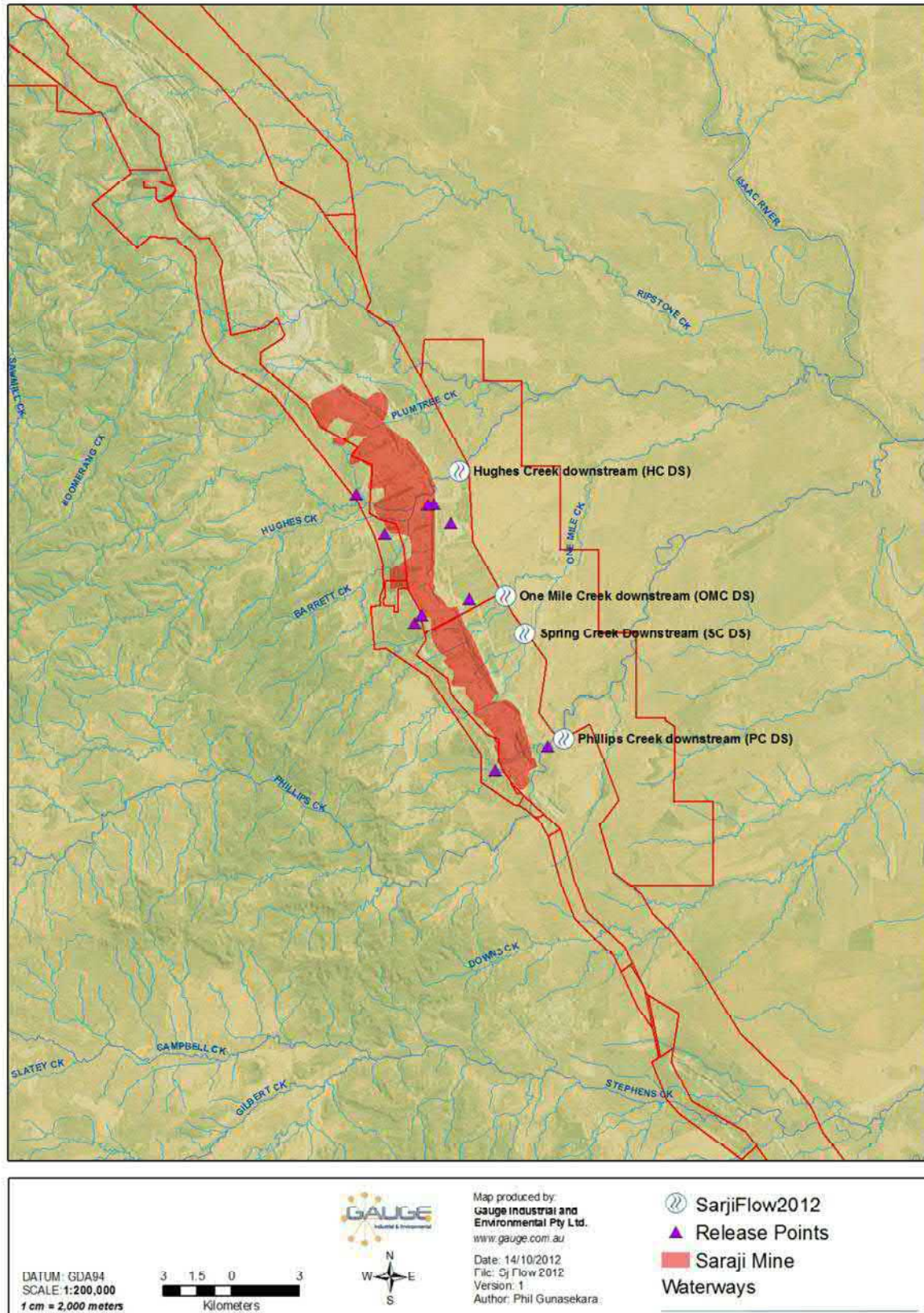
The stage discharge relationship for the Saraji Mine flow sites are developed using standard hydrometric practices. Channel cross section and bed slope survey data is used in slope area calculations to determine the flow volumes throughout the operational range of the monitoring station.

Gauging stations are maintained and operated by specialist contractors Hoban Smith Industries Pty Ltd and data provided on the BMA EnviroSys database. Raw data is routinely reviewed by Hoban Smith Industries Pty Ltd for verification.

The streams around Saraji Mine are ephemeral with mobile sandy beds with most of the monitoring locations lacking a stable control. The stage discharge relationship at the sites will therefore change with each significant flow event as bed levels scour or aggrade. As such, there will be a degree of error related to the discharge figures depending on the date of the last channel cross section survey and subsequent rating table update.

The flows measured at the gauging stations were modified by release patterns from storages.

Figure 3 – Stream Flow Monitoring Sites



5.3 RESULTS & DISCUSSION

The local streams recorded similar ephemeral flow patterns throughout the REMP study, with extended nil flow periods interspersed with sporadic flow events (Figure 5 to Figure 8). Hughes and Phillips creeks experienced major flows during the 2010/2011 wet season and the 2011/2012 and 2012/2013 wet seasons were comparatively drier for all streams, with only a few isolated events including significant flows in March 2012 and January 2013. The flows in One Mile Creek and Spring Creek were similar in pattern, with One Mile Creek experiencing increased flows from March to May 2013 although discharge rates were much smaller for both One Mile and Spring creeks.

The period of flow measured was limited to two or three wet seasons, and as such only indicative flow exceedance estimates are presented (Figure 4). The flow exceedance curves for the REMP study show that streams sustaining a daily average flow greater than one cubic metre per second (cumec) occurred for only 0% to 9.9% of days (Table 6).

Figure 4 – Stream Flow Exceedance Curves for Period 2010-2013

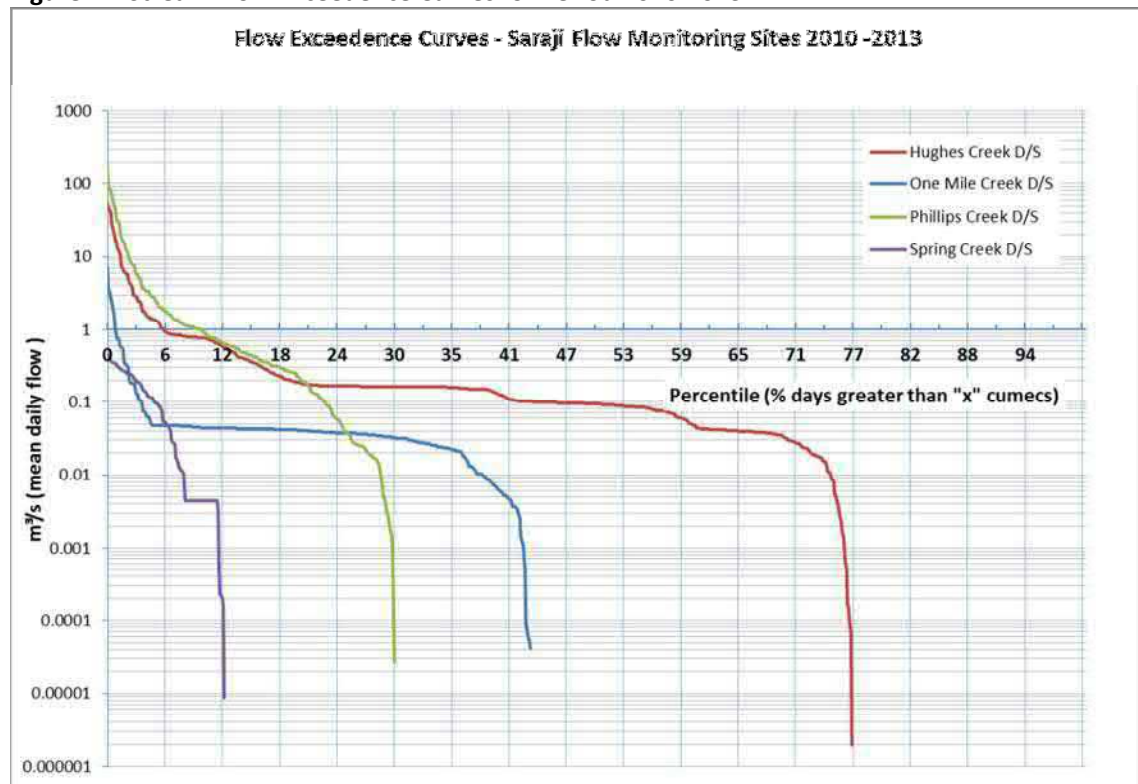


Table 6 – Stream Flow Exceedance Frequencies during REMP Compared to EA Flow Conditions

Stream	Data Period	% of daily averages exceeding flow (cumecs)		
		<1	>=1 and <2	>=2
Hughes Creek	18-11-2010 to 30-6-2013	93.9	2.55	3.55
Phillips Creek	25-9-2010 to 30-6-2013	90.1	4.3	5.6
One Mile Creek	1-8-2010 to 30-6-2013	96.8	2.5	0.7
Spring Creek	1-7-2011 to 30-6-2013	100	0	0

Figure 5 – Hughes Creek Flow – Daily Average – Jan 2010 to Jul 2012

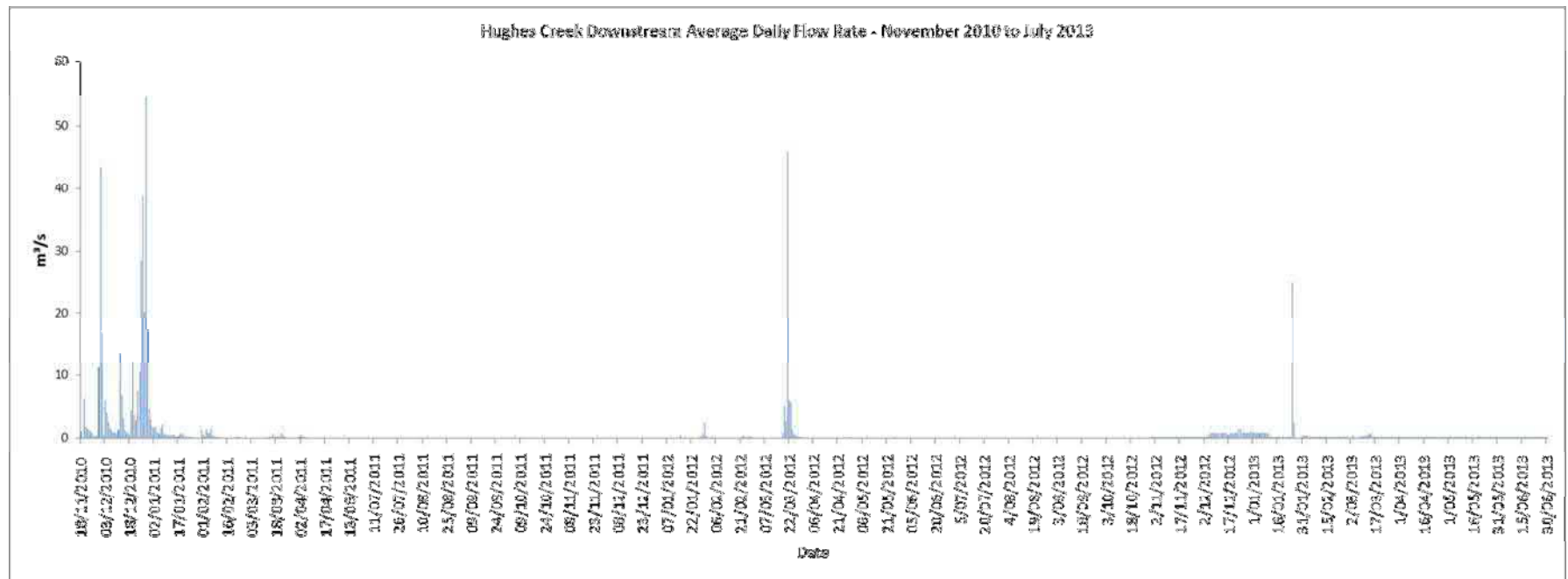


Figure 6 – One Mile Creek Flow – Daily Average – Jan 2010 to Jul 2012

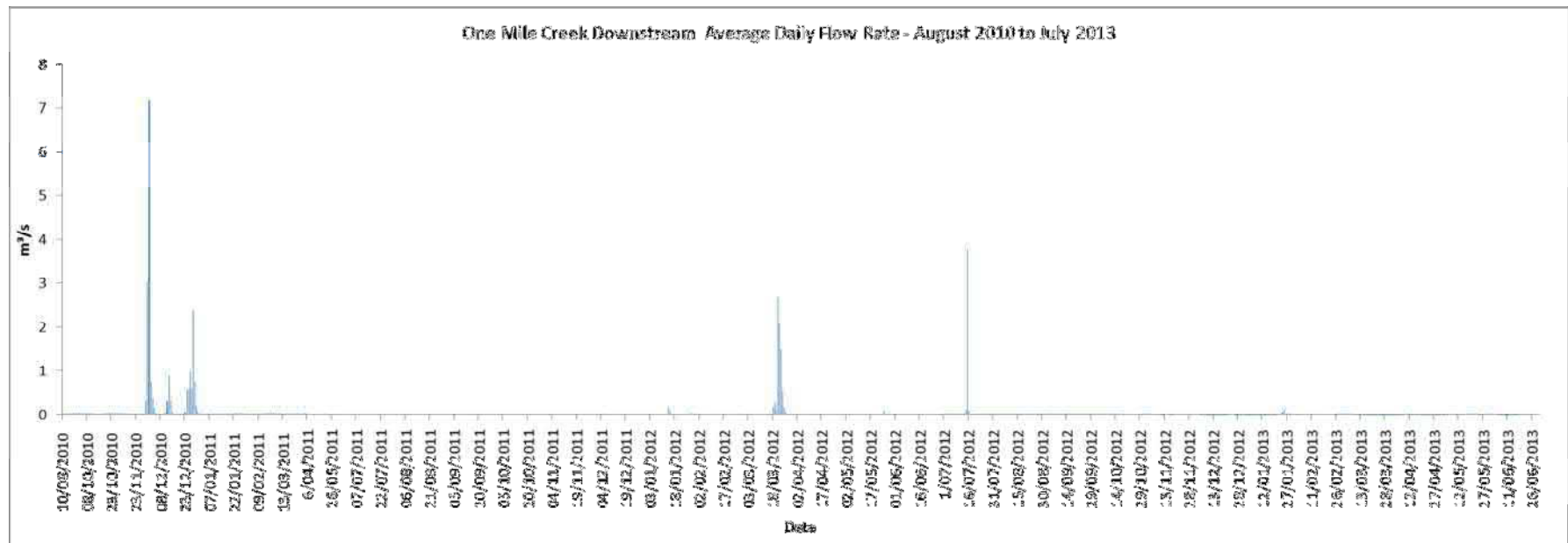


Figure 7 – Phillips Creek Flow – Daily Average – Jan 2010 to Jun 2013

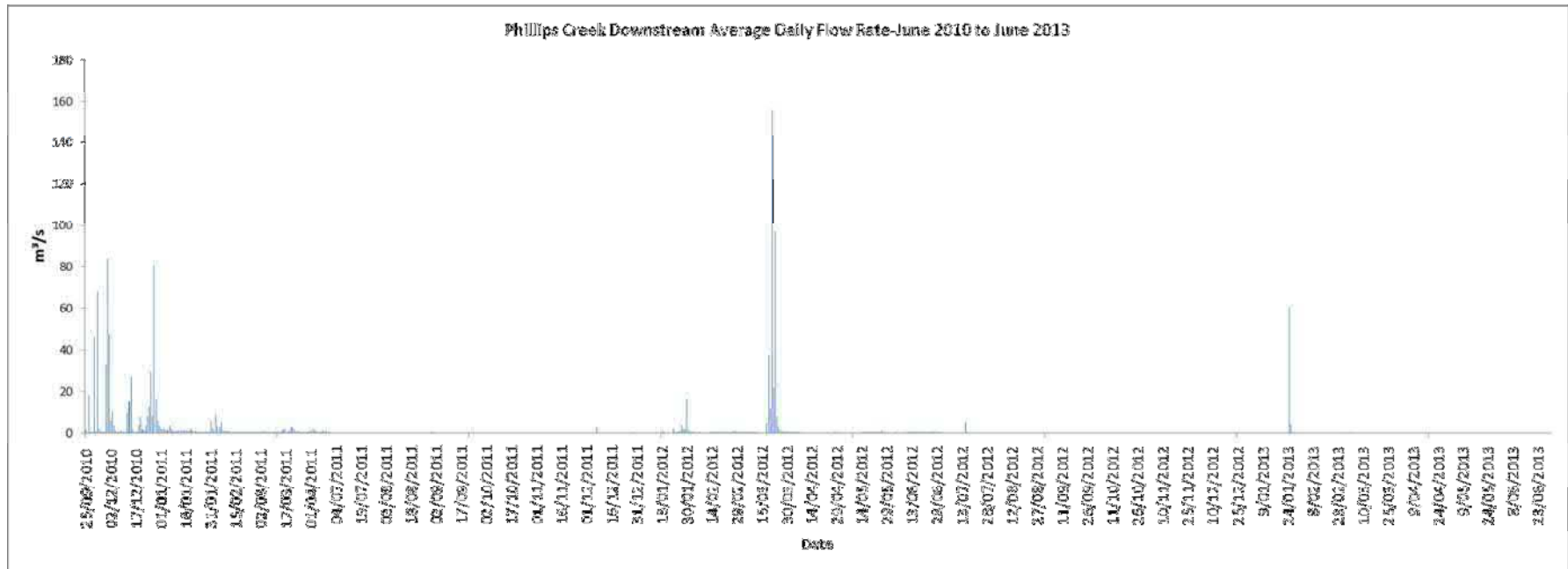
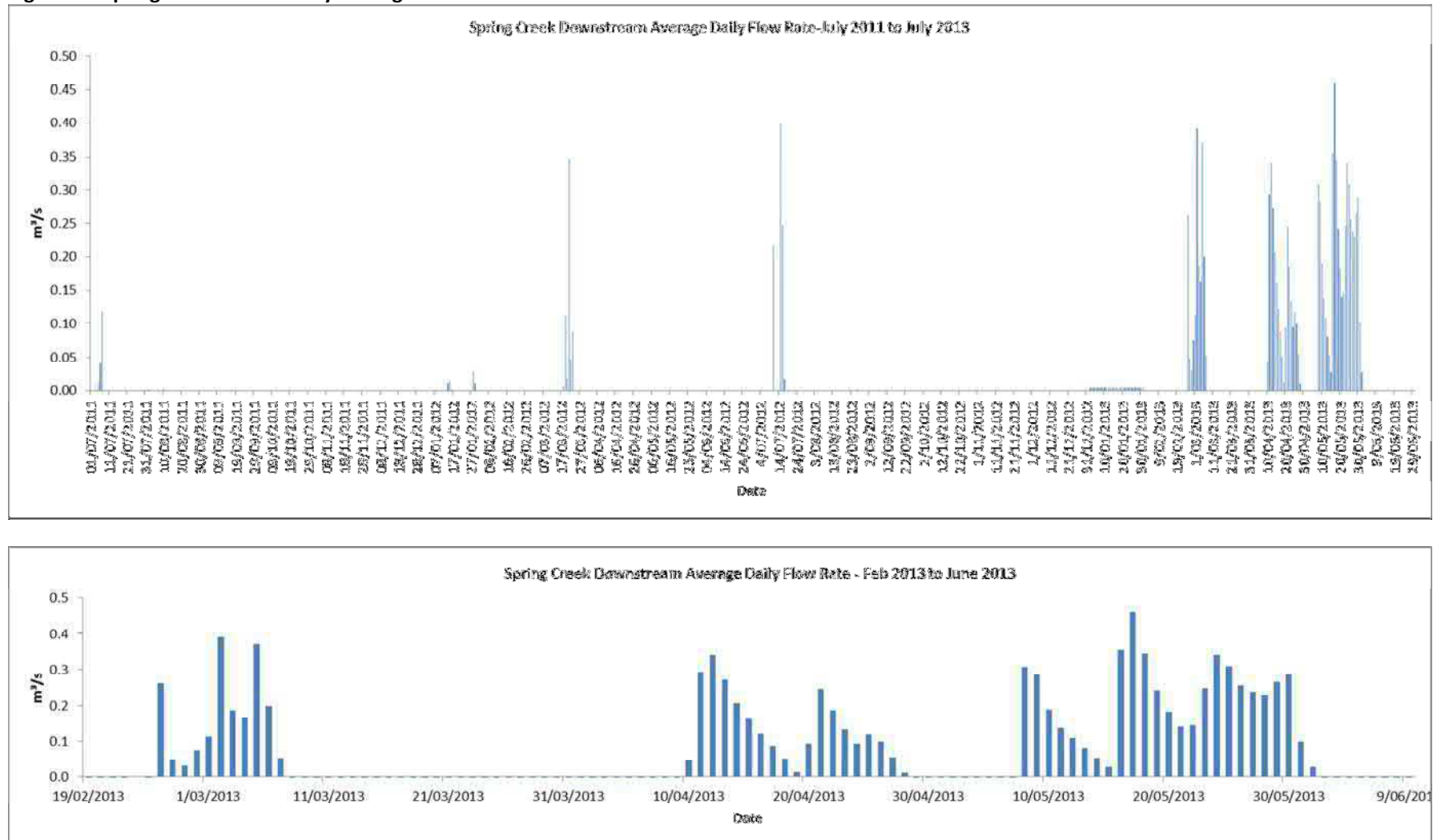


Figure 8 – Spring Creek Flow – Daily Average – Jan 2011 to Jul 2013



6. WATER QUALITY

6.1 SITES

The water quality sites in this study (Table 7 and Figure 9) were selected on the following criteria:

- Representative of upstream or reference conditions.
- Representative of downstream or test conditions.
- Suitable for the parameters being conducted.
- Free of confounding influences at the site.
- Reasonable, legal and safe access during flow periods.
- Preferably, within 5km of mine discharge as specified in EA Condition (W20).

Where possible, site selection aligned with regulatory or historical sites.

The One Mile Creek upstream site was located on the spillway of One Mile Dam, a potentially confounding structure used for storage of raw water piped to the mine site. In alignment with the new EA issued in November 2011, the site was relocated on the 30th May 2012, upstream of One Mile Dam and west of the highway (Dysart Road).

Spring Creek monitoring was limited to sampling on only two days using an auto-sampler and a limited set of analytes. Due to lack of temporal coverage and the absence of verification by manual sampling, the Spring Creek data has not been included in this report for statistical analysis and interpretation.

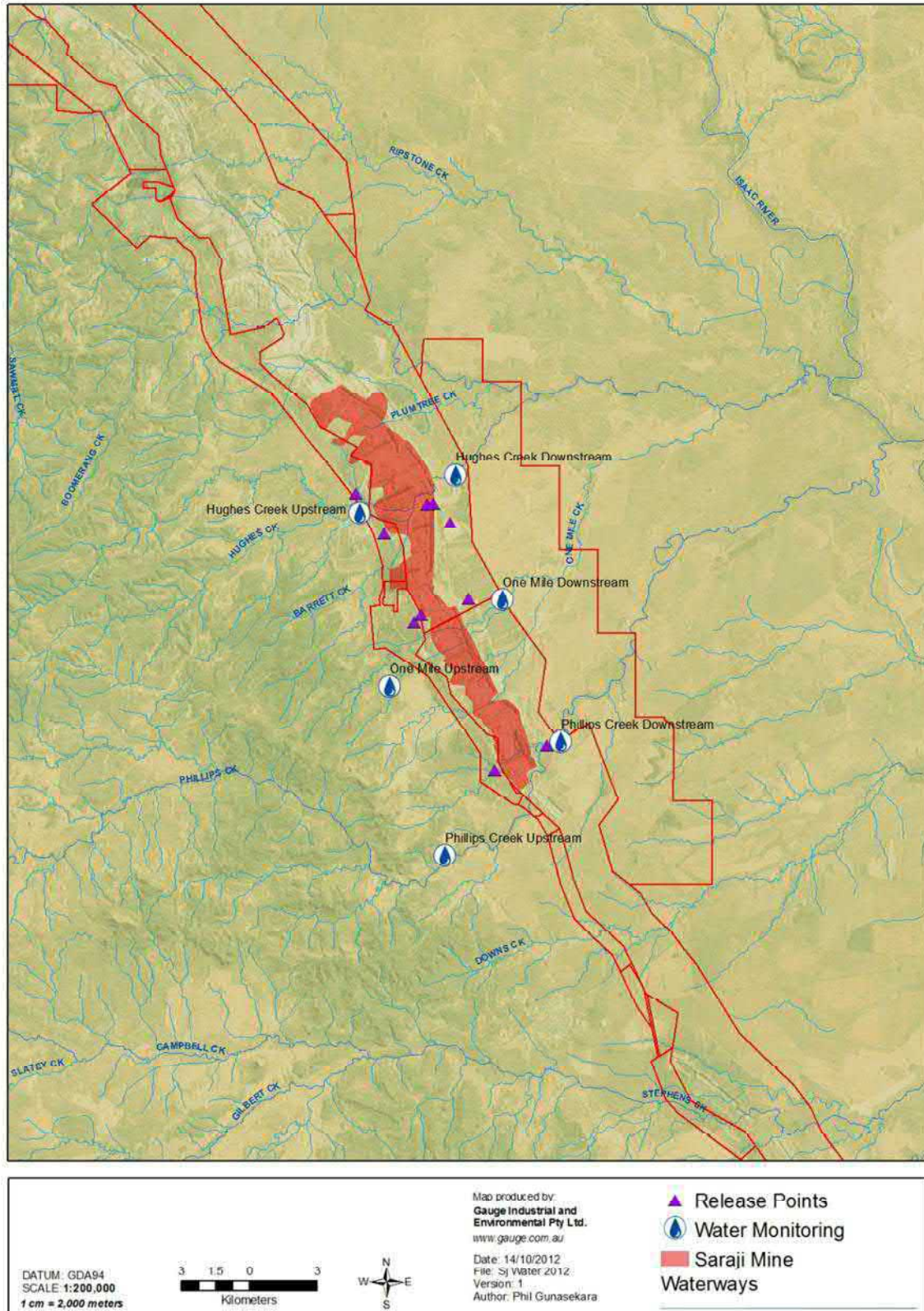
All sites were manual *in situ* testing and sampling locations, with the exception of water quality stations linked to gauging stations which measured electrical conductivity (EC) and temperature.

Some data was provided by automatic samplers on Hughes and Phillips creeks.

Table 7 – Water Quality Monitoring Sites

Site	Type	Easting	Northing
Hughes Creek Upstream	Reference	630293	7524061
One Mile Creek Upstream	Reference	632488	7517976
Phillips Creek Upstream	Reference	634054	7508913
Hughes Creek Downstream	Test	630293	7524061
One Mile Creek Downstream	Test	632488	7517976
Phillips Creek Downstream	Test	634054	7508913

Figure 9 - Water Quality Monitoring Sites



6.2 WATER QUALITY GUIDELINES & OBJECTIVES

The local environmental values and the selected monitoring parameters were matched to currently available water quality guidelines or objectives (Table 8). Where more than one guideline was applicable, the most stringent is listed as “applicable & most stringent”.

The descending order of precedence used in selecting the most appropriate guidelines was:

- Locally derived and validated guidelines.
- State regional or subregional guidelines (QWQG, 2009).
- National guidelines (ANZECC & ARMCANZ, 2000).

In 2010, draft subregional guidelines for the Fitzroy Basin were released for comment (DERM, 2010). The REMP study area is included in the Isaac River sub-region, and the proposed values (Table 9) are considered in this report for discussion.

Table 8 – Water Quality Guidelines Applicable to the Study Area

WATER QUALITY GUIDELINES						
Parameter ¹	Units	Ecosystem (SMD)	Stock watering (beef cattle) & general use	Irrigation (cotton) LTV	General use, Recreational & raw water supply	Applicable & most stringent
pH	pH	6.5-7.5 (upland) 6.5-8.0 (lowland) QWQG	6-9 ANZECC	NA	6.5—8.5 ANZECC	6.5-7.5 (upland) 6.5-8.0 (lowland) QWQG
EC	µS/cm	720 (Fitzroy N) QWQG	5970 ANZECC	3700 ANZECC	NA	720 (Fitzroy N) QWQG
Temperature	°C	20th and 80th percentile range of local	NA	NA	NA	20th and 80th percentile range of local
Turbidity	NTU	25 (upland) 50 (lowland) QWQG	NA	NA	NA	25 (upland) 50 (lowland) QWQG
Dissolved Oxygen	% sat	90-110 (upland) 85-110 (lowland) QWQG	NA	NA	>80 ANZECC	90-110 (upland) 85-110 (lowland) QWQG
Ammonia	µg/L	10 (upland) 20 (lowland) QWQG	NA	NA	10 ANZECC	10 (upland) 20 (lowland) QWQG
Nitrate	µg/L	700 ANZECC	400,000 ANZECC	NA	10,000 ANZECC	700 ANZECC
Total Suspended Solids	mg/L	10 (lowland) QWQG 3 ANZECC	NA	NA	50 ANZECC	10 (lowland) QWQG 3 ANZECC
Sulfate	mg/L	NA	1000 ANZECC	NA	400 ANZECC	400 ANZECC
Fluoride	µg/L	NA	2000 ANZECC	1000 ANZECC	NA	1000 ANZECC
Aluminium	µg/L	55 ANZECC	5000 ANZECC	5000 ANZECC	200 ANZECC	55 ANZECC
Arsenic	µg/L	13 ANZECC	500 ANZECC	100 ANZECC	50 ANZECC	13 ANZECC

WATER QUALITY GUIDELINES						
Parameter ¹	Units	Ecosystem (SMD)	Stock watering (beef cattle) & general use	Irrigation (cotton) LTV	General use, Recreational & raw water supply	Applicable & most stringent
Boron	µg/L	370 ANZECC	5,000 ANZECC	500 ANZECC	1000 ANZECC	370 ANZECC
Cadmium	µg/L	0.2 ANZECC	10 ANZECC	10 ANZECC	5 ANZECC	0.2 ANZECC
Chromium	µg/L	1.0 ANZECC	1000 ANZECC	100 ANZECC	52 ANZECC	1.0 ANZECC
Cobalt	µg/L	NA	1000 ANZECC	50 ANZECC	NA	50 ANZECC
Copper	µg/L	1.4 ANZECC	1000 ANZECC	200 ANZECC	1000 ANZECC	1.4 ANZECC
Iron	µg/L	NA	NA	200 ANZECC	300 ANZECC	200 ANZECC
Lead	µg/L	3.4 ANZECC	100 ANZECC	2000 ANZECC	50 ANZECC	3.4 ANZECC
Manganese	µg/L	1900 ANZECC	NA	200 ANZECC	100 ANZECC	100 ANZECC
Mercury (inorganic)	µg/L	0.06 ANZECC	2 ANZECC	2 ANZECC	1 ANZECC	0.06 ANZECC
Molybdenum	µg/L	NA	150 ANZECC	10 ANZECC	NA	10 ANZECC
Nickel	µg/L	11 ANZECC	1000 ANZECC	200 ANZECC	100 ANZECC	11 ANZECC
Selenium	µg/L	5 ANZECC	20 ANZECC	20 ANZECC	10 ANZECC	5 ANZECC
Silver	µg/L	0.05 ANZECC	NA	NA	50 ANZECC	0.05 ANZECC
Uranium	µg/L	NA	200 ANZECC	10 ANZECC	NA	10 ANZECC
Vanadium	µg/L	NA	NA	100 ANZECC	NA	100 ANZECC
Zinc	µg/L	8 ANZECC	20,000 ANZECC	2000 ANZECC	5000 ANZECC	8 ANZECC
Petroleum Hydrocarbons (C6-C9)	µg/L	NA	NA	NA	NA	None available
Petroleum Hydrocarbons (C10-C36)	µg/L	NA	NA	NA	NA	None available

¹ Metals/metalloids are to be tested for Total and Dissolved. Dissolved metals apply to ecosystem guidelines.

Table 9 – Isaac River Catchment Draft Sub-regional Water Quality Guidelines (Ecosystems)

Parameter	Units	Draft guideline	Comment
pH	pH units	6.5 – 8.5	Broader than QWQG (2009) range of pH 6.5-8.0
EC	µS/cm	835	Higher than QWQG (2009) value of 720
TSS	mg/L	55	Higher than QWQG (2009) value of 10
Sulfate	mg/L	25	No previous QLD ecosystem guideline

6.3 METHODOLOGY & QUALITY ASSURANCE

6.3.1 Sampling and *in situ* Measurements

The water quality monitoring program was conducted according to methodologies in the Queensland Monitoring and Sampling Manual (DERM, 2009). Qualified mine environmental professionals performed sampling and *in situ* measurements for pH, electrical conductivity, dissolved oxygen, temperature and turbidity. Some data was provided by auto-samplers installed at sample sites. Documentation was retained for chains of custody, equipment calibration records and field sheets.

6.3.2 Laboratory Testing

Laboratory testing was performed by ALS Laboratories who are NATA accredited for the analytes and methodologies used in the monitoring program. Laboratory reports containing quality control and quality assurance methodologies were retained for all data.

6.3.3 Data Analysis

6.3.3.1 Processing raw data

Raw data was reviewed prior to statistical analysis and subjected to the following screening (Table 10) to produce a valid data set.

Obvious erroneous data points were removed from the raw data. Due to potentially naturally high variability, a precautionary approach was taken to data considered as outliers. Data was only removed when identified to be several orders of magnitude outside the main data range, and/or illogical in terms of practical possibilities or well below the limit of detection. These types of error are likely to be a result of sampling, testing, or transposition error.

Some data was provided by auto-samplers which obtain multiple samples (e.g. hourly) during a flow event. To prevent bias or over-representation by weight of sample numbers in an auto-sampled event, a daily median of auto-sampled results was calculated and used as a single data point in statistical analysis, providing a result more akin to a single daily manual sample taken during other flow events.

Table 10 – Treatment of Raw Data for Statistical Analysis

Site ID	Date	Comments
Phillips Ck U/S	11/6/2011	Total metals removed – apparent transposition error
Phillips Ck D/S	11/6/2011	Total metals removed – apparent transposition error
One Mile Ck D/S	29/12/2011	Total metals removed – apparent transposition error
Hughes Ck D/S	1/07/2011	TSS result, 10000mg/L, removed as reporting error
Hughes Ck D/S	4/07/2012	TSS result, 6000mg/L, removed as reporting error
One Mile Ck D/S	29/12/2011	Dissolved Hg (3µg/L) & Total Hg (<0.1µg/L) removed as reporting error
Hughes Ck U/S Auto Sampler	22/02/2012	Median result determined for pH, EC, TSS, Sulfate
Hughes Ck U/S Auto Sampler	23/02/2012	Median result determined for pH, EC, TSS, Sulfate
Hughes Ck U/S Auto Sampler	23/04/2012	Median result determined for pH, EC, TSS, Sulfate
Phillips Ck D/S Auto Sampler	13/02/2012	Median result determined for pH, EC, TSS, Sulfate
Phillips Ck D/S Auto Sampler	23/03/2012	TSS (4000mg/L) used in discharge data

Site ID	Date	Comments
Phillips Ck D/S Auto Sampler	23/03/2012	Sulfate median (5µg/L) used in discharge data
Phillips Ck D/S Auto Sampler	23/03/2012	pH, EC & TSS (19,000mg/L) results not included due to overlap
Phillips Ck D/S Auto Sampler	12/06/2012	Median result determined for pH, EC, TSS, Sulfate
Phillips Ck U/S Auto Sampler	18/03/2012	Median result determined for pH, EC, TSS, Sulfate
Spring Ck U/S		Data not included; insufficient data set
Spring Ck D/S		Data not included; insufficient data set

6.3.3.2 Limits of Reporting (LOR)

The statistics presented in this report (particularly the graphs) are based upon applying a *50% LOR rule*, whereby results less than the Limit of Reporting (LOR), or detection limit, are assigned a value of half the LOR. This is one of the options suggested in ANZECC (2000), the other options being using a *0% LOR rule* or using the *100% LOR rule*.

As the proportion of values less than the LOR increases, the significance of this rule in statistical analysis increases. Similarly, when the guideline or trigger value is less than the LOR, the result can appear to exceed the guideline, when in fact it was below detection limits. This issue is complicated because the LOR can change between each sample run, as the laboratory accounts for dilutions needed for differing water characteristics, such as changes in turbidity and salinity.

Where applicable, this report discusses instances where the LOR rule affects the interpretation of results for each analyte, and considers the outcome if the 0% or 100% LOR rule was applied.

6.3.3.3 Statistical analysis and graphical presentation

6.3.3.3.1 “Box and Whisker” Plots

Box & Whisker plots provide a visual representation of the statistical analysis of the data, showing variability within and between sites.

The values represented in these Box & Whisker plots are:

- (1) Median: Middle line in box. The relative position of the median within the box shows the degree of skew in data.
- (2) 25th percentile (or first quartile): lower edge of box.
- (3) 75th percentile (or third quartile): upper edge of box.
- (4) 1.5 times the Interquartile Range (IR): the upper and lower “whisker” lines.
- (5) Outliers: marked as “●”, showing individual values falling outside of 1.5 x IR. These points highlight high variability for data points considered outside of standard data distributions.

6.3.3.3.2 “Comparison with Guidelines” Graphs

The “comparison with guidelines” graph shows local upstream and downstream sites in comparison each other and relevant guidelines and EA triggers.

The key elements of the plots are:

(1) Data set (n)

The data set (n) is the number of tests performed to produce the statistics presented in the graph. The Queensland Water Quality Guidelines recommend 18 or more tests for deriving reliable reference condition values and ANZECC (2000) recommend 24 tests.

(2) 80th (or 20th) percentile for upstream (US) or reference sites.

The 80th percentile of the reference site, typically used for deriving local guidelines (QWQG, 2009; ANZECC, 2000), was applied for all analytes. The 20th percentile was also applicable to pH, temperature and dissolved oxygen.

(3) Average 80th (or 20th) percentile for all upstream (US) sites.

In order to produce a single local reference value from more than one reference site, the QWQG (2009) suggests three alternative approaches for deriving an average reference or upstream value, depending upon the variability between upstream sites.

- Approach 1. Reasonably consistent sites – calculate the average 20/80th percentiles of the reference sites, $\pm$ one standard error around these averages.
- Approach 2. More variable sites – calculate the 20/80th percentiles of the 20/80th percentiles of the reference sites, $\pm$ one standard deviation.
- Approach 3. Highly variable sites – where they have been determined as being naturally highly variable, calculate the average 20/80th percentiles of the reference sites, $\pm$ two standard errors around these averages.

The guidelines are not prescriptive and are open to alternative approaches, particularly for highly variable sites. The intention was for these approaches to be applied to a preferable minimum of three reference sites and 18 or more samples.

Additionally, as variability between sites can differ significantly between different analytes, the application of a single approach for all analytes is difficult. The approach for each analyte would need to be considered and custom applied. For consistency in this report, Approach 1 is applied to the graphs, and then for each analyte the applicability of this approach, and the preferred alternative approach, is discussed.

(4) The Median for Downstream (DS) or Test Sites

For slightly-to-moderately disturbed (SMD) waters, the guideline values should be compared with the median of values at a test site. An acceptable change for SMD systems is one where the downstream median does not exceed the upstream 80th percentile (QWQG, 2009).

(5) The Guideline Most Applicable to the Site

The guideline(s) available for each analyte were selected, and the most applicable guideline was determined according to the following descending order of precedence:

- * Locally derived and validated guidelines.
- * State regional or subregional guidelines (QWQG, 2009).
- * National guidelines (ANZECC & ARMCANZ, 2000).

Draft guidelines, such as the sub-regional guidelines proposed for the Fitzroy basin (DERM, 2010), are also considered in discussion for each analyte, and where appropriate are presented on the graphs.

(6) The Current Environmental Authority (EA) Trigger Value

The current EA trigger was that listed for receiving waters in the mine's Environmental Authority dated 25th November 2013.

6.4 RESULTS & DISCUSSION

6.4.1 General

The results and discussion in this section are presented in a consistent format to visually display statistical data and make comparisons to guidelines. Analytes are reviewed individually in order to understand the unique nature of each in the context of the study area and period, and the variability and robustness of data.

A statistical analysis of results at each site is provided in APPENDIX A– Water Quality Statistical Analysis. The raw data set is provided in APPENDIX B – Water Quality Data.

For statistical analysis, results below the Limit of Detection or Limit of Reporting (LOR) were assigned a value of half the LOR.

Metals were analysed as “Total Metals” and “Dissolved Metals”. The definition of dissolved metals in this report is filtering of samples with a 0.45µm filter prior to analysis.

Section 6.5 provides a summary of conclusions drawn from the results and discussion in terms of the applicability of current limits (triggers and guidelines). This report did not consider whether any particular analyte should or should not be included in the mine’s EA list of triggers, but rather suggests what value may be appropriate should it be included.

The number of samples for each analyte used to derive local reference conditions ranged from between 20 to 125 samples per upstream site or an upstream aggregate of 78 to 358 samples. This surpassing the minimum 18 samples recommended (QWQG, 2009) to provide a robust data set for deriving local guidelines. There was a relatively even spread of data between individual upstream and downstream sites, providing a fair representation of the catchment.

In the “comparison to guidelines” graphs, the upstream 80th percentile values are highlighted in red and the downstream medians are highlighted in blue. Where downstream medians are within upstream 80th percentiles, the change in concentration is considered acceptable for slightly-to-moderated (SMD) ecosystems (QWQG, 2009).

A mine water release to Hughes Creek occurred between the 28th June 2011 and 30th June 2011, during a period of nil natural flow. The released water resulted from a tailings pipeline rupture that discharged into the Hughes Creek diversion. In response, using a levee bank as a containment bund, the mine water was flushed with clean water before being pumped back to the mine’s water storages (see details in Appendix D). Between the 30th June and 8th July, water quality monitoring was conducted on the released water that reached the Hughes Creek downstream site located downstream of the containment bund. Initially a flow was recorded at this site, until the 4th July when flow ceased and water quality monitoring was conducted on drying pools. For completeness, the data from this event has been included in the statistics and analysis in this report. However, the data during this period is not considered representative of the general water quality at this site as (1) the water was mine water, rather than creek water, (2) the testing occurred during an unnatural flow event, and (3) the testing frequency (daily over 8 days) was relatively high for a REMP event, which will skew the data set. To facilitate analysis in light of this event, a separate set of statistics (“Hughes Creek D/S Natural Flows Only”) have been produced for reference (Appendix A) which excludes the data during this period (as highlighted in Appendix B). For analytes where there was a material difference, the results excluding the data from this event are discussed and compared in this report.



The One Mile Creek upstream sample site changed during the REMP study on the 30th May 2012. The original site was located at the spillway of One Mile Dam. This in-stream dam serves as a holding storage for pipeline raw water supplied to the mine from Bedford Weir, and may not be representative of typical water quality for this stream. The new sampling site is located upstream of the dam, and is considered a better background representation of the catchment. In this report, data from the old and new site was used in the statistical analysis as data sets for the new site was limited to one sample. In light of the limitations of the old site, interpretation of the One Mile Creek results requires qualification when comparing upstream and downstream data.

6.4.2 Electrical Conductivity

Electrical Conductivity (EC) generally increased as Hughes and One Mile creeks progress through the mine lease while Phillips Creek remained relatively static (Figure 10).

The average upstream 80th percentile (478µS/cm) is below the current EA trigger (2,000µS/cm) and QLD guidelines for the Fitzroy North region (720µS/cm) (Figure 11).

The downstream median for Hughes (439µS/cm) and Phillips creeks (436µS/cm) were below the average upstream 80th percentile (478µS/cm), whereas One Mile Creek (569µS/cm) was moderately higher. The One Mile Creek downstream median was also higher than its upstream 80th percentile (235µS/cm); indicating salinity in this stream may have been altered beyond acceptable limits for slightly-to-moderately disturbed systems. This finding requires qualification in that the upstream site may be unrepresentative of the catchment due to the addition of pipeline water from Bedford Weir at the sample site. The new upstream site, implemented in May 2012, will provide a better future guide to the change in water quality in One Mile Creek, as only one sample was available post May 2012. The downstream median results in all three streams were below the current EA trigger value (2,000µS/cm) and the QLD guidelines for the Fitzroy North region (720µS/cm) (Figure 11).

Downstream in Hughes Creek, the mine water release monitoring that occurred without natural flow (30-6-11 to 7-7-11) accounted for the values greater than 1,873µS/cm. The exception of 6,130µS/cm occurred on the 20th March 2013 during a non-flow event caused by a previously reported pipeline rupture (pers.comm. BMA, 2014). During natural flow events, the downstream median (419µS/cm) was below the upstream 80th percentile (510µS/cm).

The current guideline value of 720µS/cm is appropriate for ecosystem protection, although at times it will be naturally exceeded in Hughes and Phillips creeks (Figure 10). The current EA trigger of 2,000µS/cm accommodates natural, variable levels in each stream, whilst aligning with recent ecotoxicology studies (Prasad, *et al.*, 2012) that found salinity levels up to 2,000µS/cm-2,500µS/cm provide 95% protection (acceptable for SMD systems) for aquatic species in the Fitzroy Basin.

Figure 10 – Electrical Conductivity Box & Whisker Plot

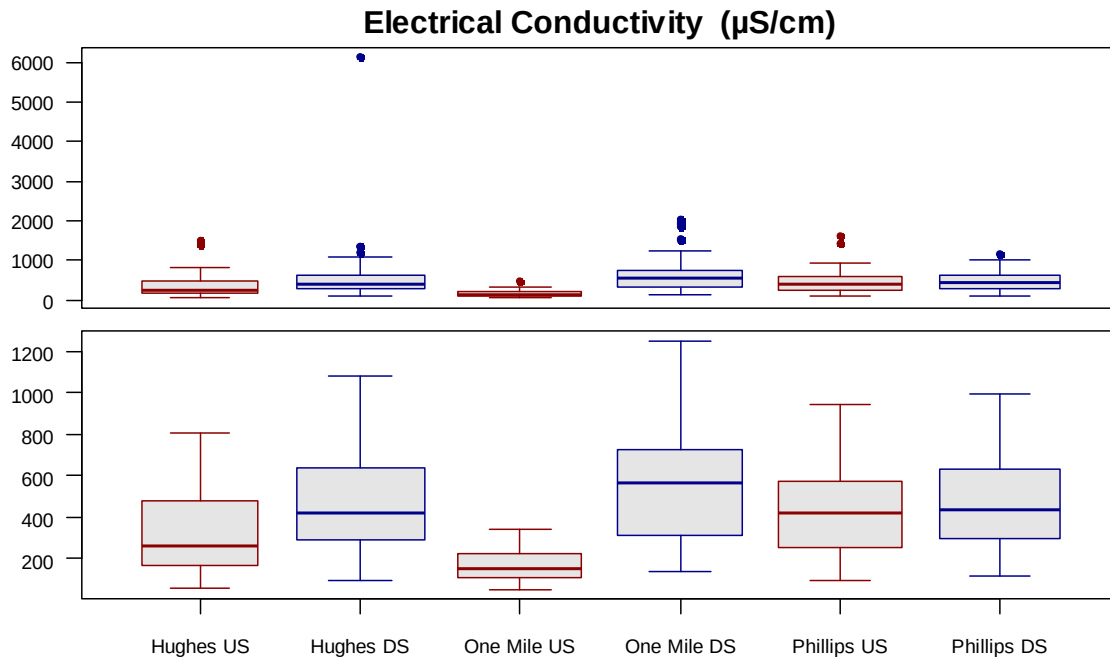
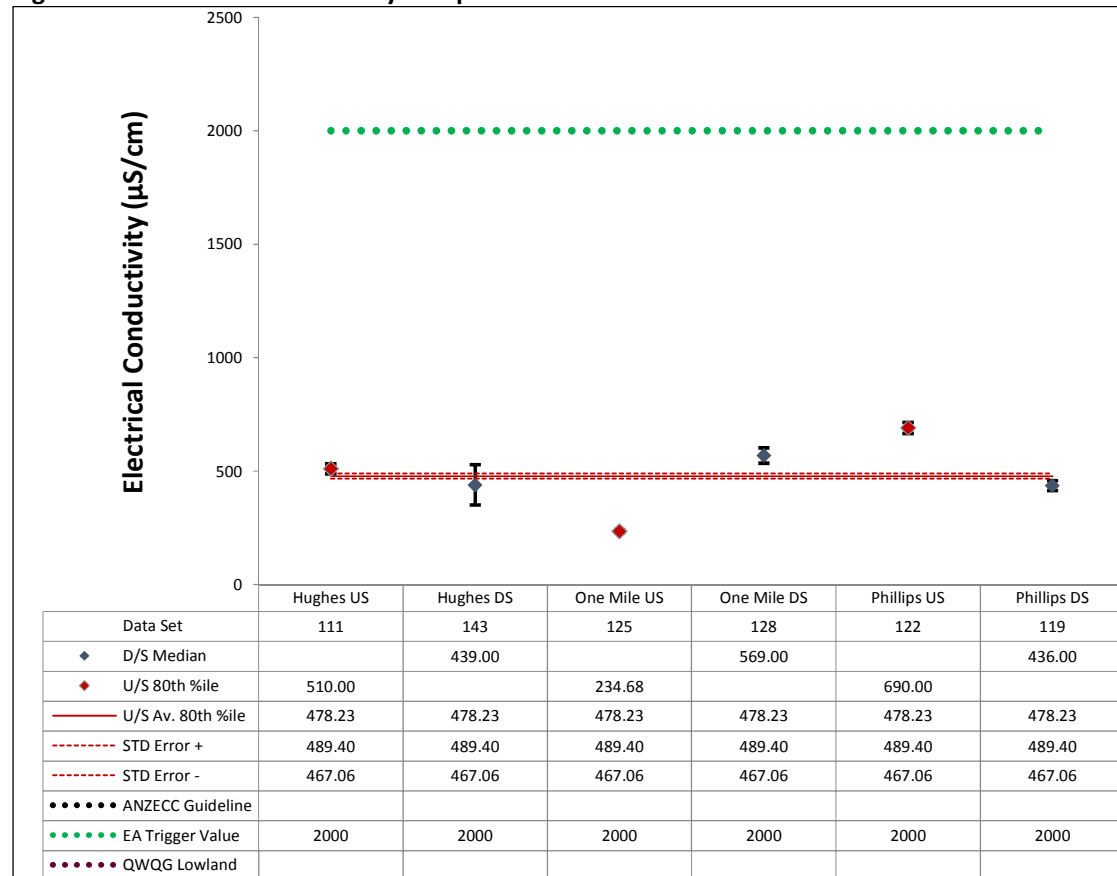


Figure 11 – Electrical Conductivity Comparison to Guidelines



6.4.3 pH

The pH in Hughes, One Mile, and Phillips creeks are generally neutral, and slightly increase as they progress through the mine lease. The median upstream range of pH 7.3 – 8.0 increased downstream to pH 7.9 – 8.1 (Figure 12).

In terms of ecosystem protection, the Queensland Water Quality Guidelines (2009) stipulate a pH range of pH 6.5-7.5 for upland rivers, pH 6.5-8.0 for lowland rivers, pH 5.5-9.0 during flood or nil flow, and pH 3.6-6.0 in wallum areas. Draft guidelines for the Fitzroy basin propose adopting a pH range of 6.5-8.5 for the Isaac River catchment (DERM, 2010). This pH range accommodates ANZECC guidelines for stock protection, irrigation, primary recreation and drinking water.

The average upstream 80th percentile (pH 7.9) and 20th percentile (pH 7.4) were within the draft Fitzroy sub-regional guideline (pH 6.5-8.5) and the current QLD guideline for lowland waters (pH 6.5-8.0), but slightly higher than the guideline for upland waters (pH 6.5-7.5) (QWQG, 2009) (Figure 13).

The downstream medians were within one standard error of the average upstream 20th/80th percentiles. On an individual stream basis, downstream Phillips and Hughes creeks were within their respective upstream 80th percentiles and the draft Fitzroy sub-regional guideline (pH 6.5-8.5). The One Mile Creek downstream median (pH 7.9) was above its upstream 80th percentile (pH 7.5), however, this finding requires qualification in that the upstream site may be unrepresentative of the catchment due to the addition of pipeline water from Bedford Weir at the sample site. The new upstream site will provide a better future guide to the change in water quality in One Mile Creek. The downstream median for One Mile Creek was within the Queensland lowland and the draft Fitzroy sub-regional guidelines.

The current EA trigger range of pH 6.5-9.0 adequately covers the range encountered in local streams, although occasional outliers below pH 6.5 are expected.

Figure 12 – pH Box & Whisker Plot

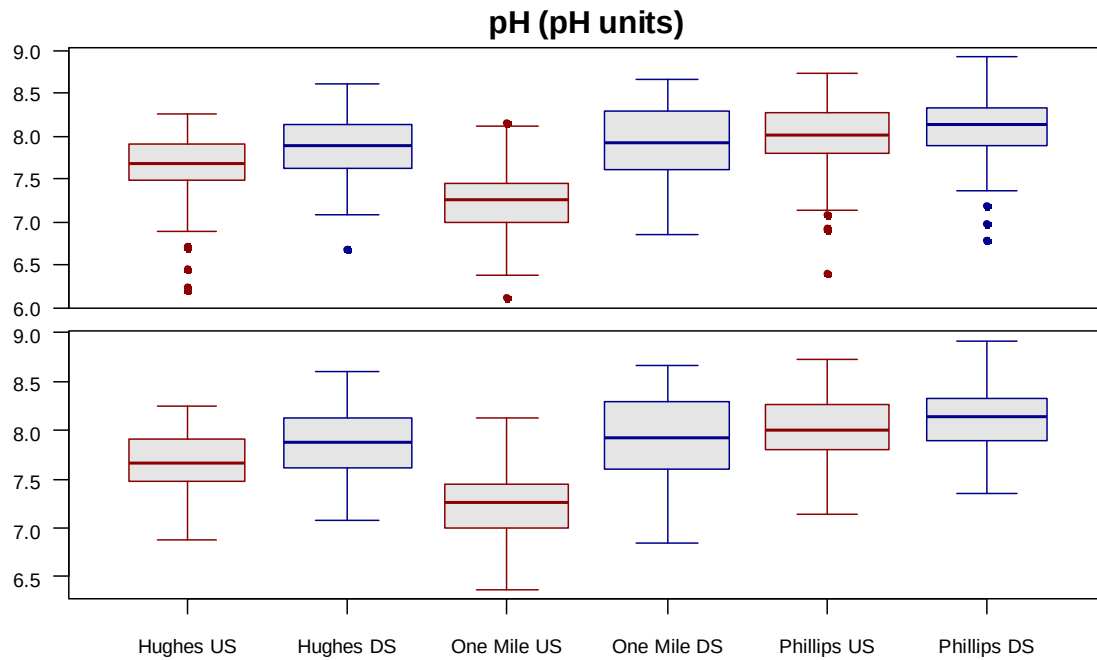
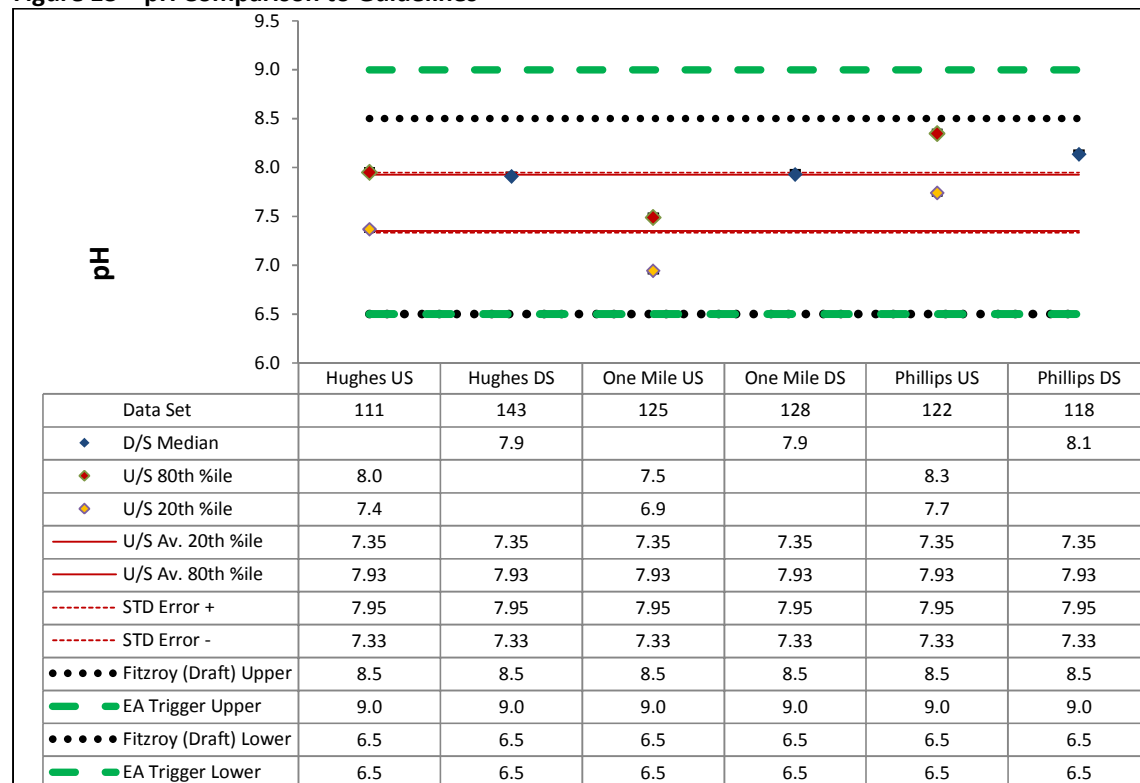


Figure 13 – pH Comparison to Guidelines



6.4.4 Temperature

Water temperature slightly decreased as One Mile, and Phillips creeks progress through the mine lease, while Hughes Creek slightly increased downstream (Figure 14).

The average 80th and 20th percentile upstream temperatures were 30.6°C and 25.6°C respectively (Figure 15).

The median downstream results were within the upstream 20th/80th percentile range (Figure 15).

Temperature varies diurnally and seasonally and is highly dependent upon the location. The QWQG (2009) recommend calculating the 20th & 80th percentiles based on the ecosystem temperature distribution approach in ANZECC (2000). The temperatures recorded downstream of the mining operation are within the seasonal extremes (12-33°C) naturally occurring in Hughes, One Mile and Phillips creeks. Developing a seasonal temperature distribution would be difficult in ephemeral upstream sites that rarely flow during winter. If qualification of this parameter is necessary, further monitoring is required to establish a background ecosystem temperature distribution.

Figure 14 – Temperature Box & Whisker Plot

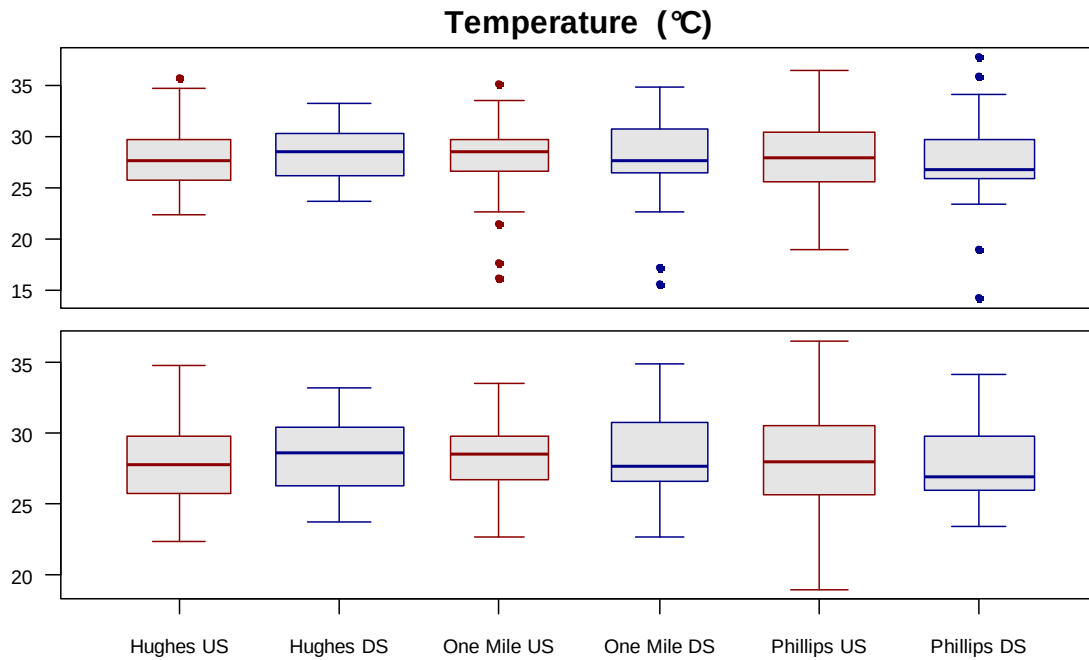
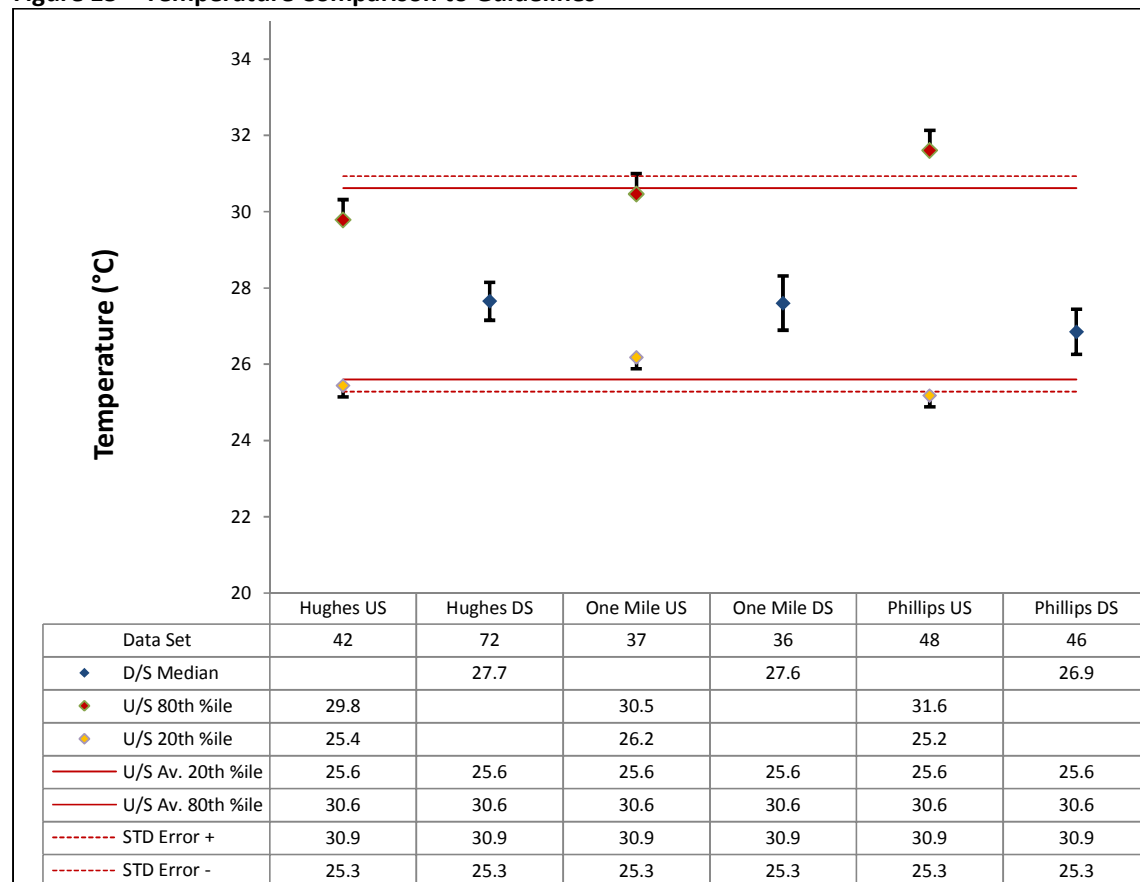


Figure 15 – Temperature Comparison to Guidelines



6.4.5 Dissolved Oxygen

Dissolved oxygen was relatively stable as Hughes, One Mile and Phillips creeks progressed through the mine lease (Figure 16). Dissolved oxygen medians ranged between 7.1mg/L and 7.8mg/L, which equated to 90-98% saturation at the median water temperature of 28°C.

Low dissolved oxygen levels are of concern for the environment, with impacts on warm water biota expected at levels below 5-6mg/L (ANZECC, 2000), or 63-76% saturation at 28°C.

Downstream medians (7.6-7.7mg/L or 96-97% saturation) were better than the upstream 20th percentile (6.7-7.5mg/L) and appear unaffected by mining activity (Figure 16).

The dissolved oxygen levels were within the Queensland guideline values of 90-110% for upland waters and 85-110% for lowland waters.

The data set was limited to 7-13 samples per upstream site and not sufficient in terms of quantity or temporal coverage to consider deriving local guideline values. If qualification of this parameter is necessary, further monitoring is required, with measurements in % saturation units to enable comparison with Queensland guidelines.

Figure 16 – Dissolved Oxygen Box & Whisker Plot

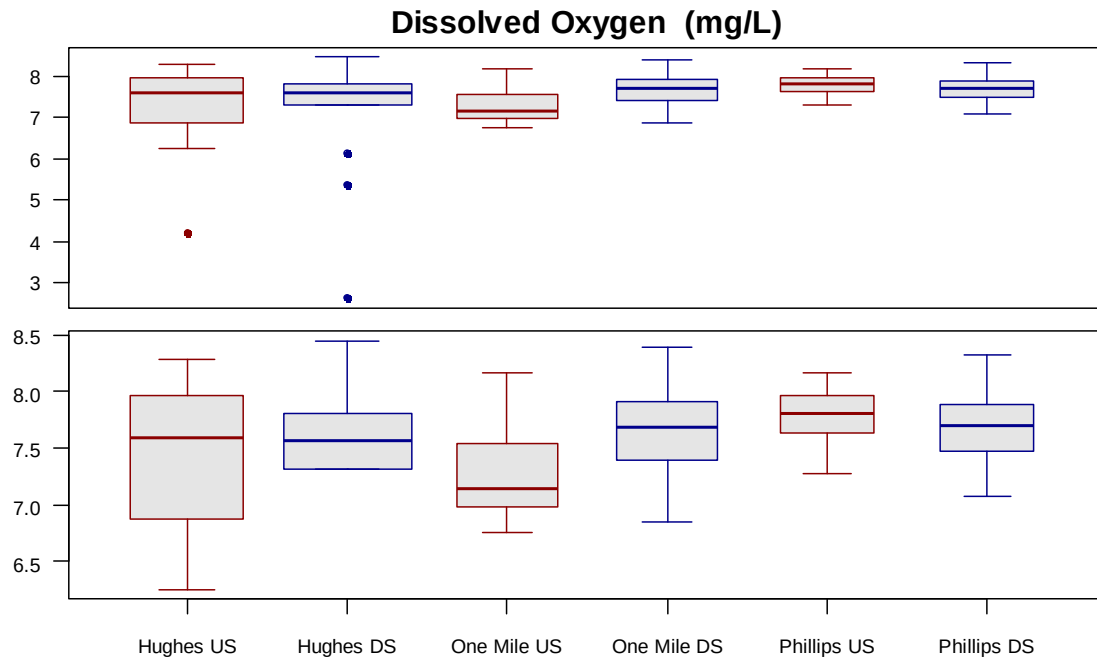
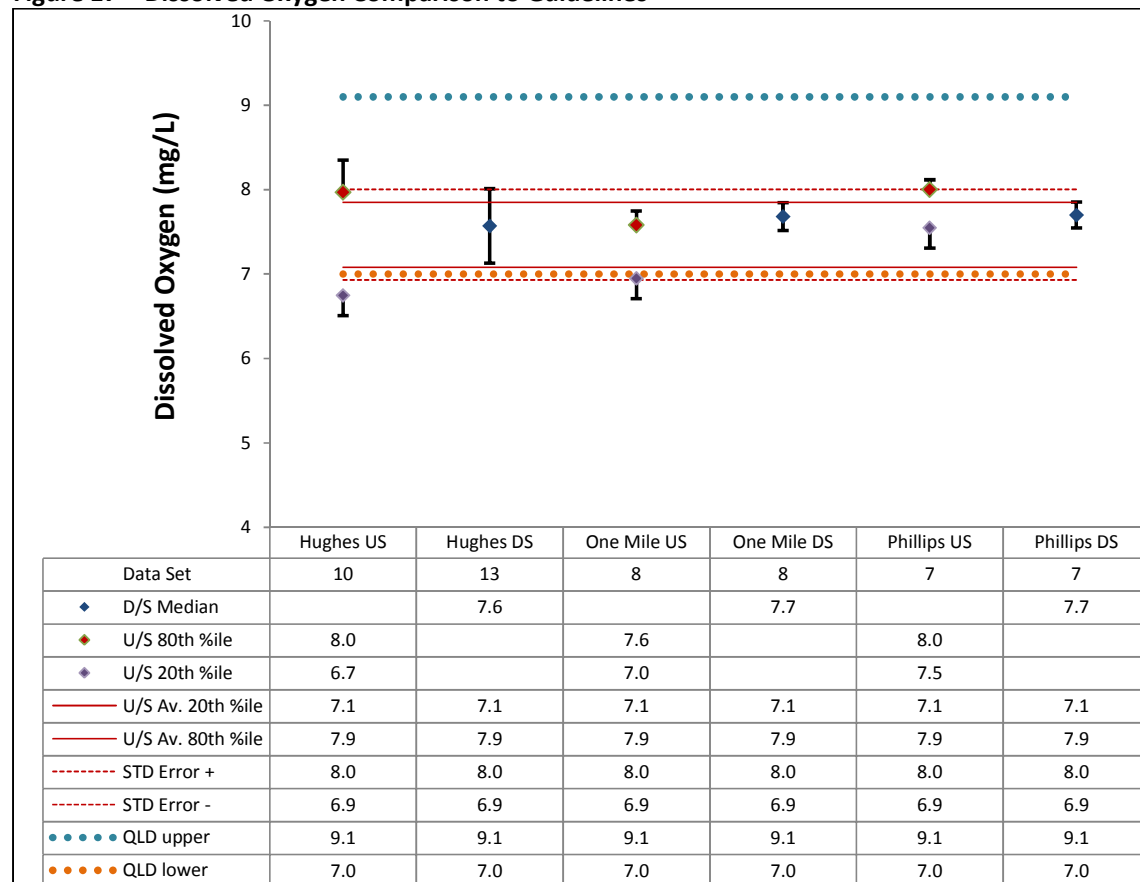


Figure 17 – Dissolved Oxygen Comparison to Guidelines



6.4.6 Turbidity

Turbidity increased slightly as One Mile and Phillips creeks progress through the mine lease whereas, Hughes Creek decreased moderately. The range of turbidity values varies significantly within individual sites (Figure 18).

The median downstream turbidity was below the upstream 80th percentiles, which indicates the change in turbidity is within acceptable levels for SMD ecosystems.

The average upstream 80th percentile (387NTU) is well above the Queensland guideline for upland waters (25 NTU) (Figure 19), indicating a new or interim guideline may be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were greater than the highly variable category, that is reference sites differed by greater than two standard errors, and an individual stream assessment approach is suggested. As Hughes and One Mile creeks 80th percentiles were within one standard error of their average 80th percentiles, a combined interim guideline of 294NTU (average 80th percentile) is suggested for these streams. For Phillips Creek, an individual interim guideline would be 573NTU (based on the 80th percentile). However, for these ephemeral streams, it would be more practical to compare simultaneous upstream and downstream turbidity data at any point in time, to mitigate the confounding hydrograph effects and the large variability of data (spanning several orders of magnitude).

Figure 18 – Turbidity Box & Whisker Plot

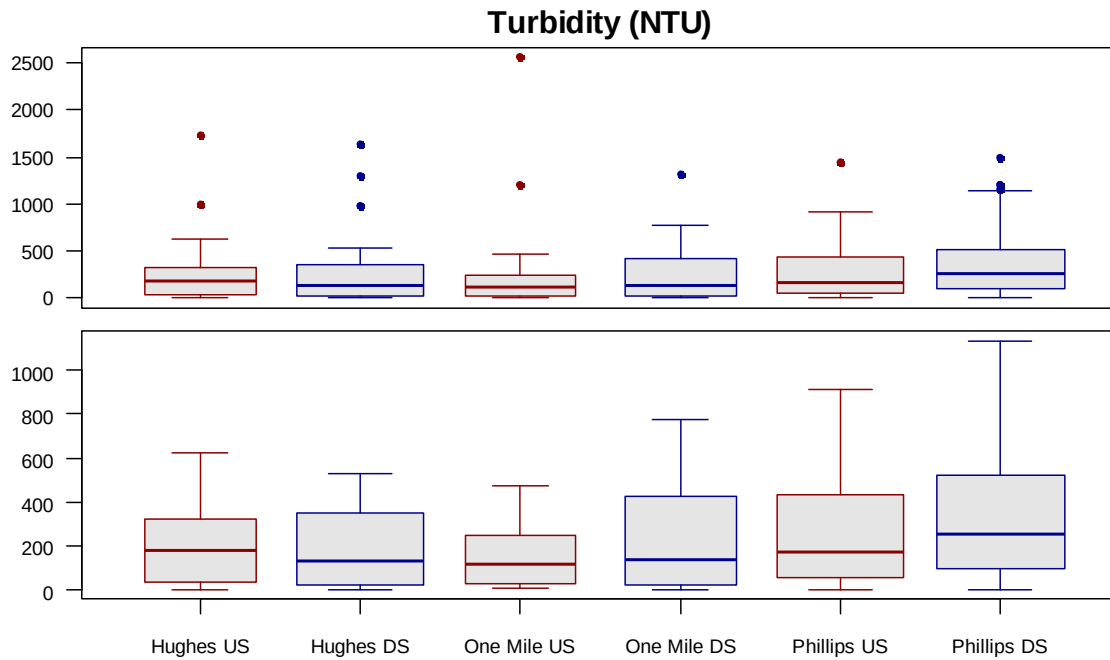
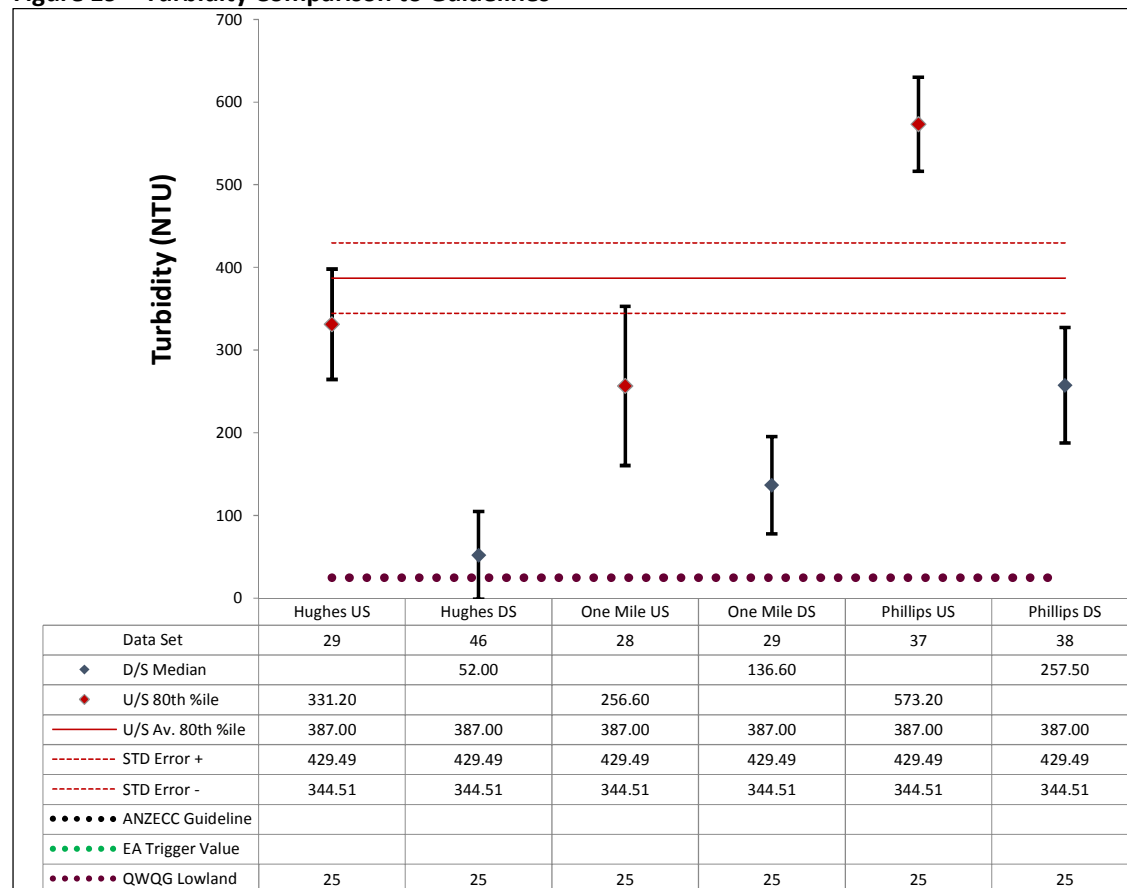


Figure 19 – Turbidity Comparison to Guidelines



6.4.7 Total Suspended Solids

Total suspended solids (TSS) generally increase as Hughes, One Mile, and Phillips creeks progress through the mine lease. The upstream average median (55mg/L) increased downstream to 121mg/L (Figure 21). The range of TSS values varies significantly within individual sites (Figure 20). Both upstream and downstream sites at times recorded similarly extreme values (ranging between 2.5mg/L and 5,020mg/L).

The median downstream TSS values were below the average 80th percentile upstream level, suggesting mining is not impacting above acceptable limits for slightly too moderately disturbed systems. In contrast, the One Mile Creek downstream median (134mg/L) was significantly higher than the corresponding upstream 80th percentile (36mg/L). This anomaly is attributed to the One Mile Creek upstream site being located on a large dam just before the spillway which acts as a sedimentation basin, removing suspended matter prior to the monitoring site.

The average upstream 80th percentile (280mg/L), and the downstream medians, were well above QLD guideline for lowland streams (10mg/L) (Figure 21). This indicates a new or interim guideline may be suggested (QWQG 2009). There is no QLD guideline value for upland streams and no current EA trigger.

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were greater than the “highly variable” category, that is, the reference sites’ 80th percentiles differed by more than two standard errors. Additionally TSS levels vary significantly according to variations in flow rates and stages. However, for these ephemeral streams, it would be more practical to compare simultaneous upstream and downstream TSS data at any point in time, to mitigate the confounding hydrograph effects and the large variability of data (spanning several orders of magnitude).

Figure 20 – Total Suspended Solids Box & Whisker Plot

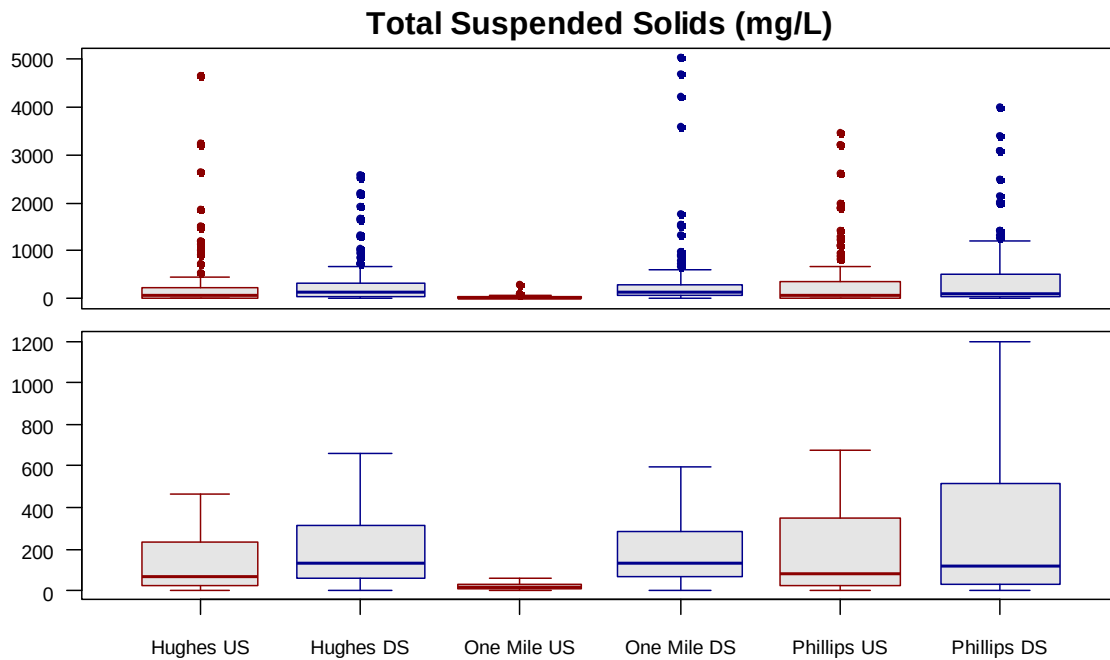
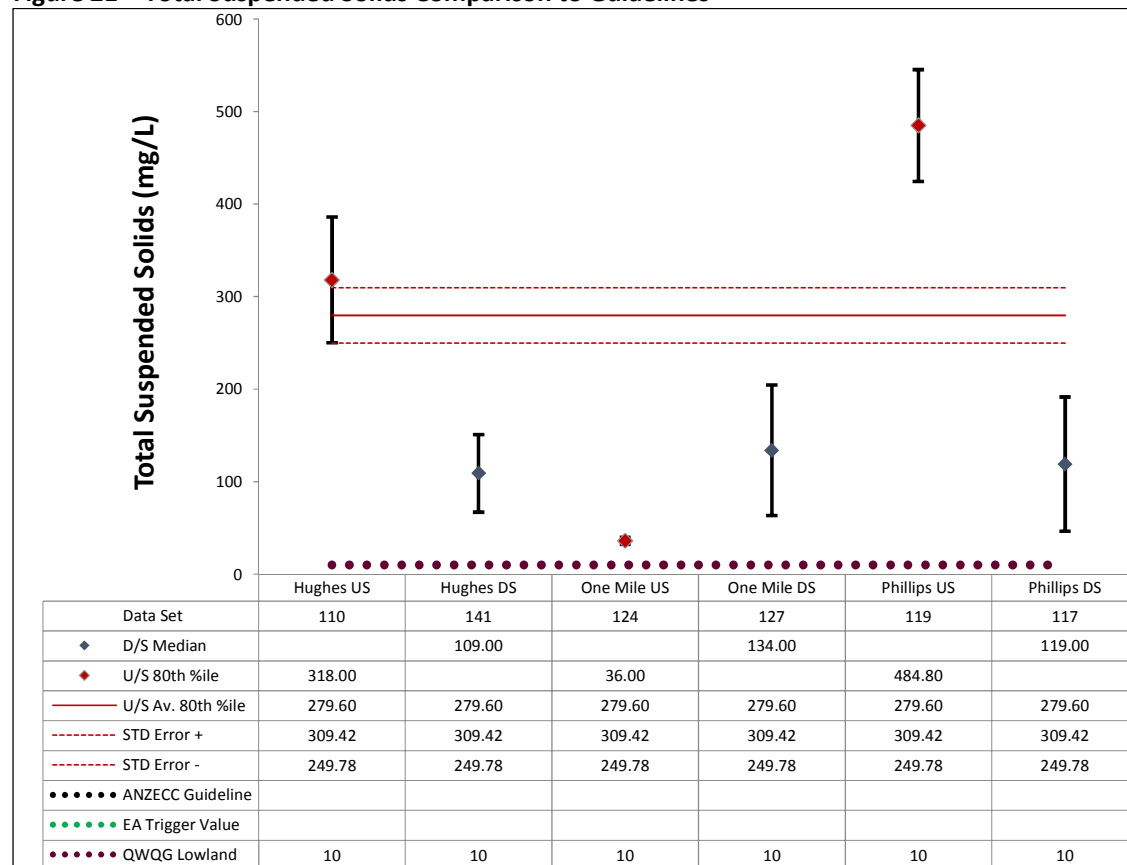


Figure 21 – Total Suspended Solids Comparison to Guidelines



6.4.8 Sulfate

Sulfate levels increased slightly as Hughes, One Mile and Phillips creeks progressed through the mine lease (Figure 22).

The downstream medians for Hughes and One Mile creeks (43mg/L and 42mg/L respectively) were above the average upstream 80th percentile (20mg/L), although Hughes Creek was within one standard error of its individual upstream 80th percentile. All downstream sites remained well below the ANZECC guidelines for stock watering (1,000mg/L) and recreation (400mg/L), the Isaac River Catchment Draft Sub-regional (25mg/L) guidelines and the EA trigger value (Figure 23).

The average upstream 80th percentile (20mg/L) was well below the current ANZECC guidelines.

The current EA trigger and the ANZECC guideline (1000mg/L) adequately accommodates natural levels of sulfate in the system, whilst protecting the main local stream use (stock watering).

Figure 22 – Sulfate Box & Whisker Plot

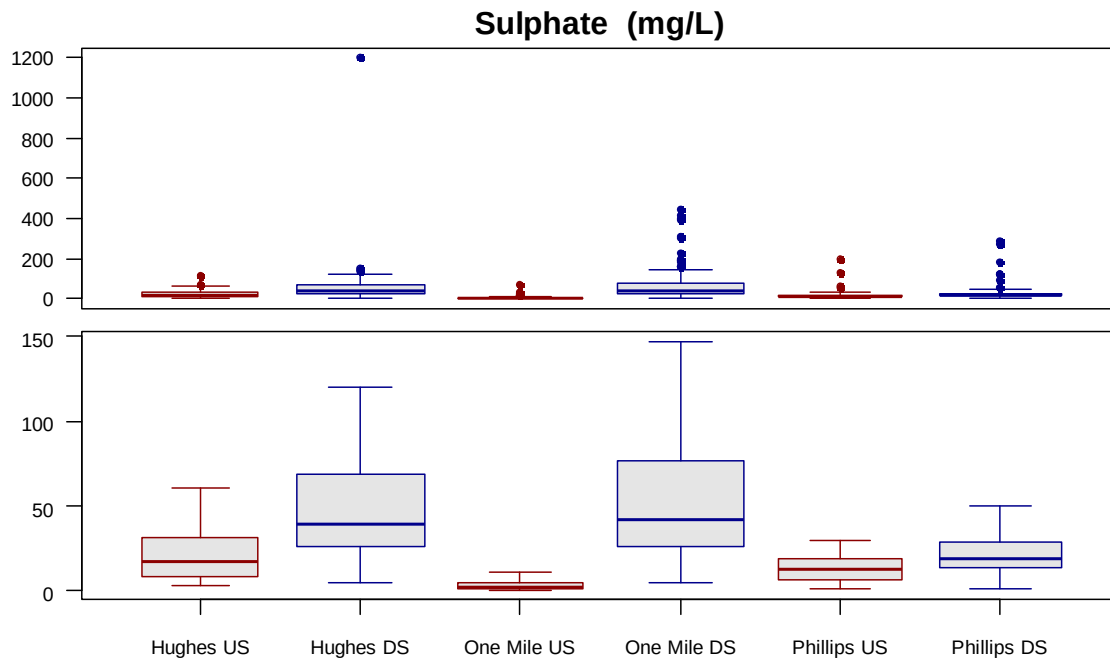
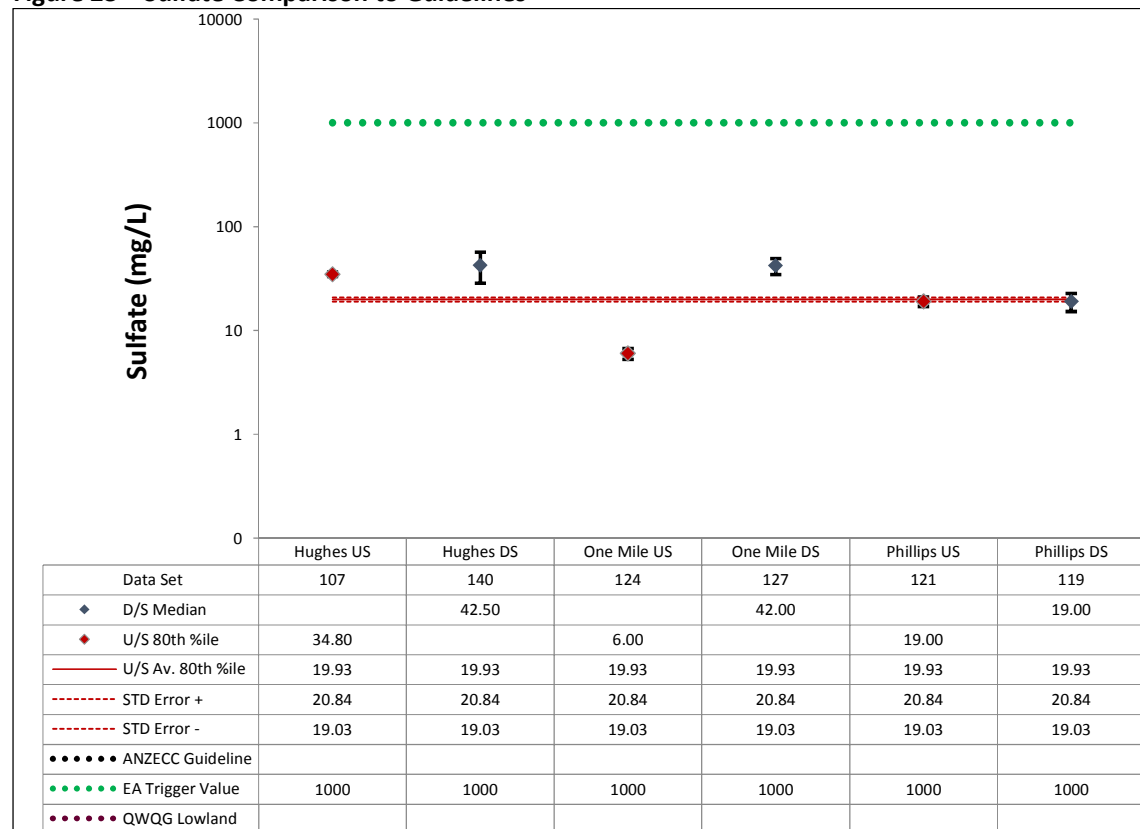


Figure 23 – Sulfate Comparison to Guidelines



6.4.9 Ammonia

Ammonia levels were generally static as Hughes, One Mile, and Phillips creeks progressed through the mine lease. The upstream median range of 20µg/L to 30µg/L was similar to downstream medians (20 - 30µg/L) (Figure 18).

The average upstream 80th percentile (43µg/L) was above the QLD Guideline of 10µg/L (upland) and 20µg/L (lowland) (Figure 18), indicating a new or interim guideline may be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were within the “reasonably consistent” category, that is, the reference sites’ 80th percentiles are within one standard error. Therefore the average upstream 80th percentile of 43µg/L is suggested as a local guideline (all sites have greater than 18 samples) for Hughes, One Mile and Phillips creeks.

The median downstream ammonia levels were below the average upstream 80th percentile levels, suggesting mining is not impacting above acceptable limits for SMD systems.

The current QWQG values are overly stringent, and a more appropriate local guideline value is 43µg/L; based on the 80% percentile upstream.

Figure 24 – Ammonia Box & Whisker Plot

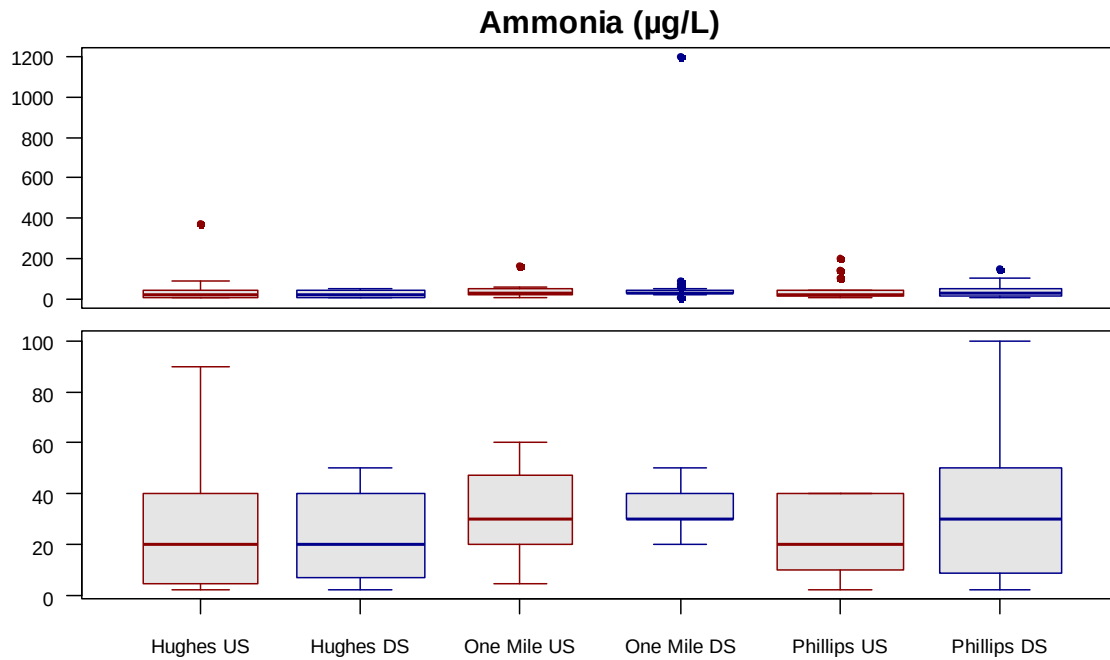
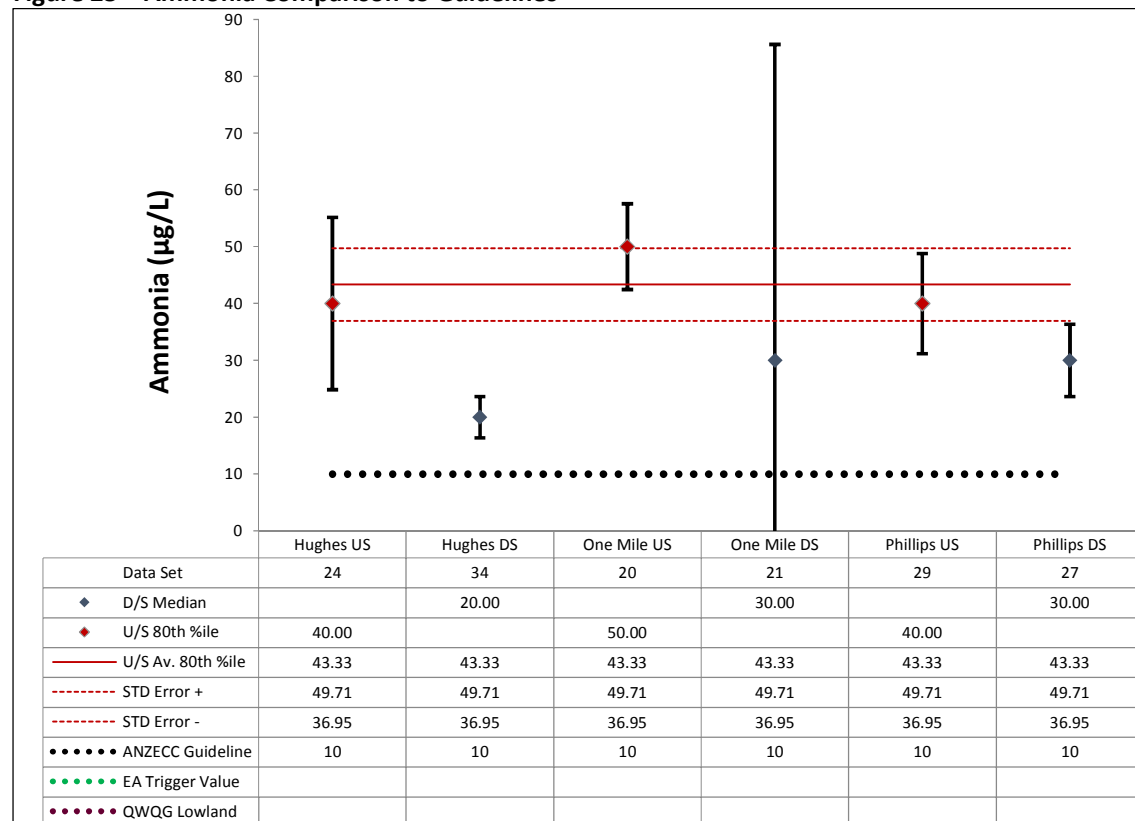


Figure 25 – Ammonia Comparison to Guidelines



6.4.10 Nitrate

Nitrate levels slightly increased as Hughes, One Mile, and Phillips creeks progressed through the mine lease (Figure 26). The upstream medians ranged from 25µg/L to 70µg/L and increased downstream from 40µg/L to 100µg/L (Figure 27).

Downstream medians remained well below guidelines and the average upstream 80th percentile, indicating concentrations are not being increased beyond levels acceptable for slightly-to-moderately disturbed (SMD) ecosystems.

The average upstream 80th percentile (123µg/L) is well below the ANZECC guideline (700µg/L) (Figure 27).

The ANZECC guideline of 700µg/L adequately accommodates local background levels.

Figure 26 – Nitrate Box & Whisker Plot

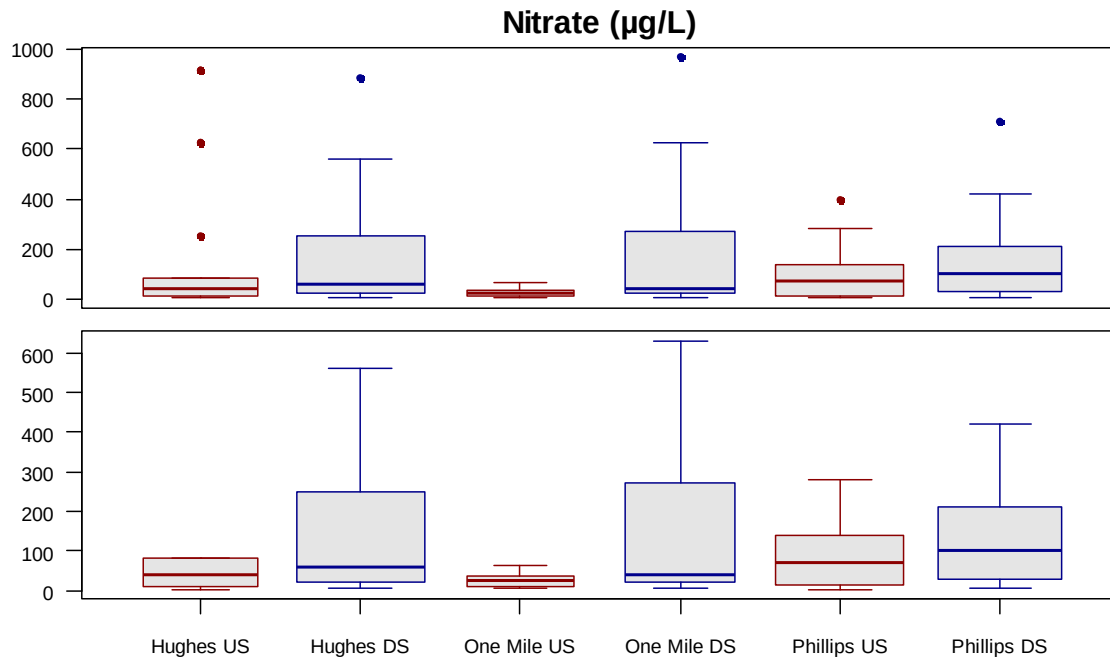
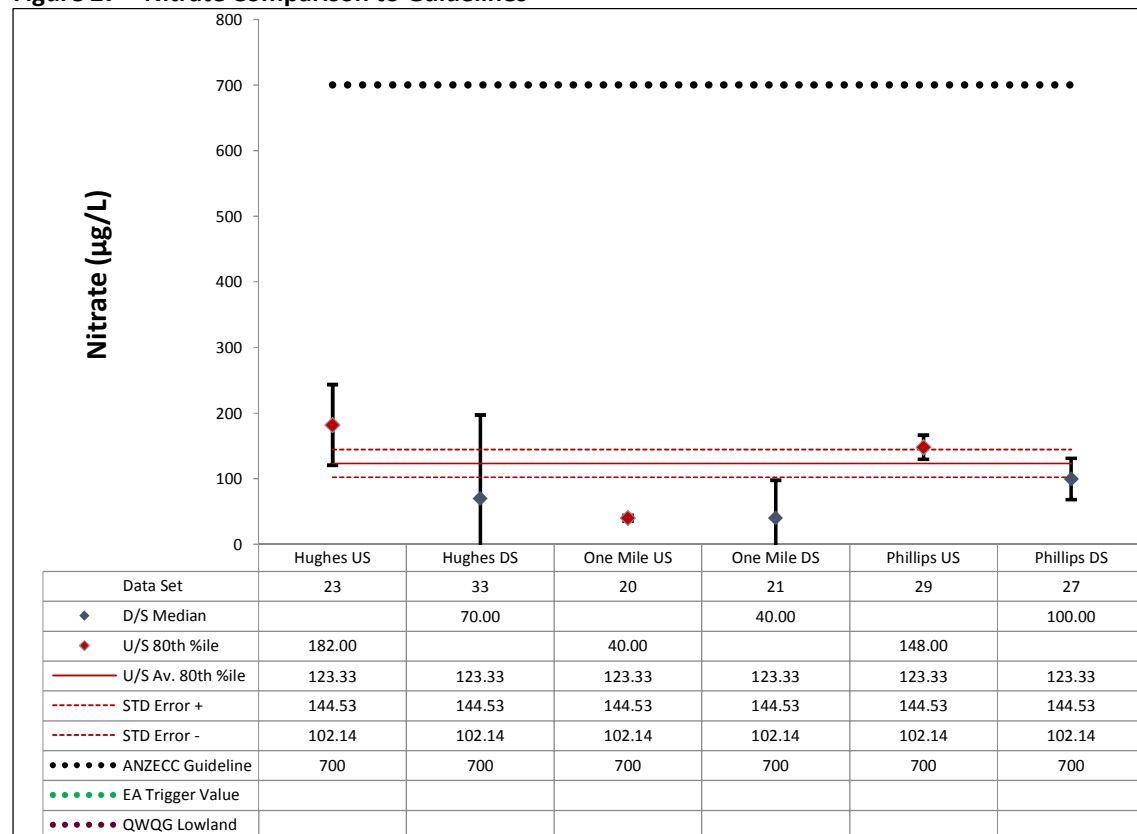


Figure 27 – Nitrate Comparison to Guidelines



6.4.11 Petroleum Hydrocarbons

All petroleum hydrocarbons in the C6-C9 fraction were below limits of detection (Figure 28).

Petroleum hydrocarbons in the C10-C36 fraction were below limits of detection, with the exception of 5 outliers (Figure 30).

Two of these outliers occurred on the same day (14/10/2010) on upstream (490µg/L) and downstream (500µg/L) Hughes Creek and suggests potential background influences or sample contamination. Another two of the outliers also occurred on the same day (29/01/2012) on upstream (1,680µg/L) and downstream (1,140µg/L) Phillips Creek and suggests potential background influences or sample contamination. The other outlier occurred on Phillips Creek upstream (60µg/L) with the result just above the LOR of 50µg/L.

Upstream and downstream sites were equivalent for C6-C9 fractions (Figure 29).

Downstream median for C10-C36 fractions were well below the EA trigger value, and below the average upstream 80th percentile (Figure 31).

There are no appropriate guideline values for petroleum hydrocarbons in water. The data indicates the mining operation is not increasing petroleum hydrocarbons above background levels.

Figure 28 – C6-C9 Petroleum Hydrocarbons Box & Whisker Plot

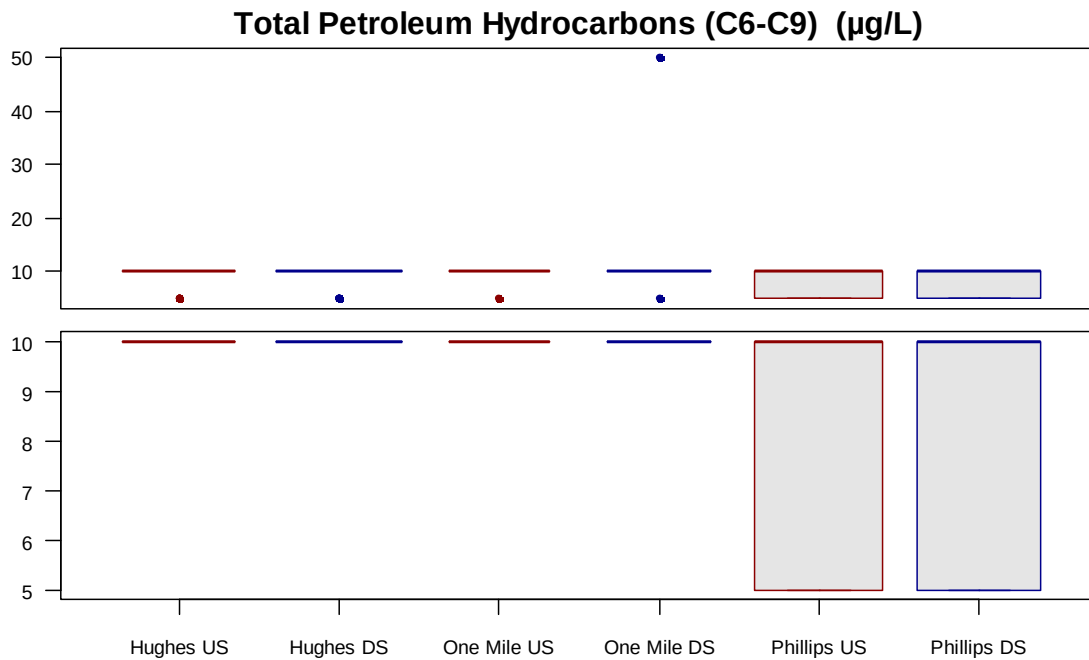


Figure 29 – C6-C9 Petroleum Hydrocarbons Comparison to Guidelines

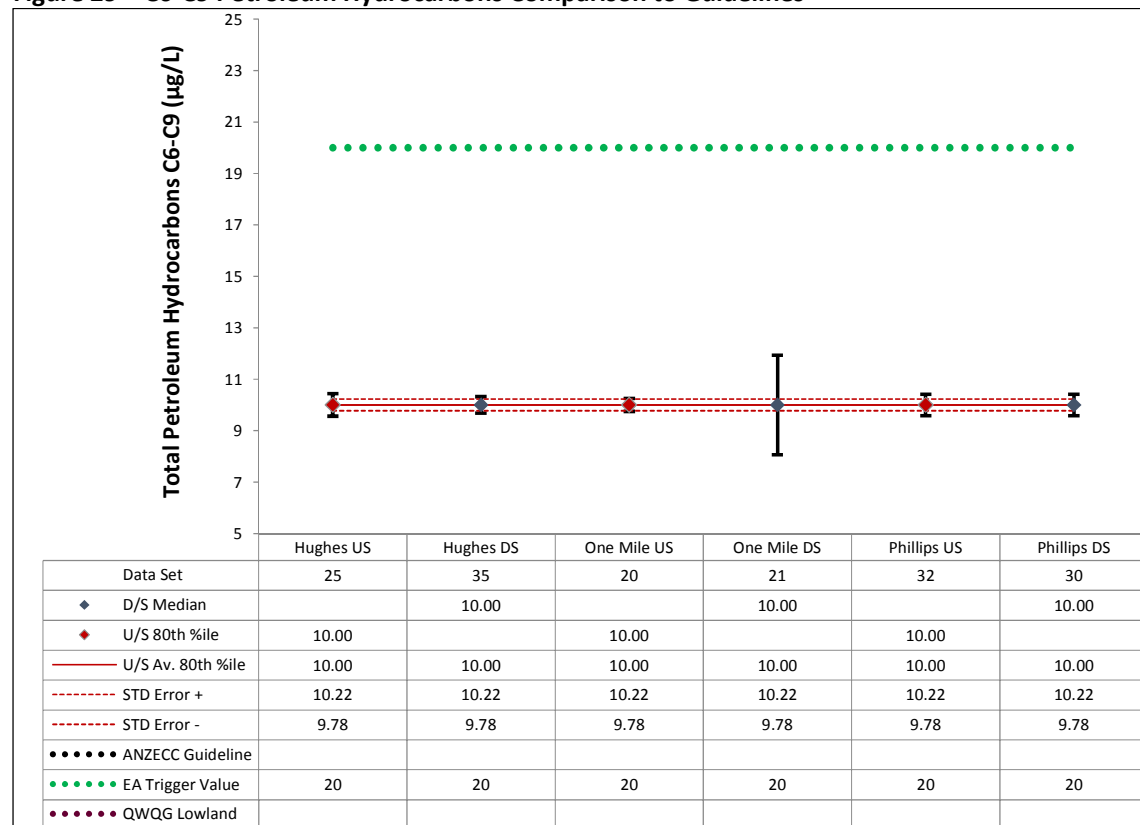


Figure 30 – C10-C36 Petroleum Hydrocarbons Box & Whisker Plot

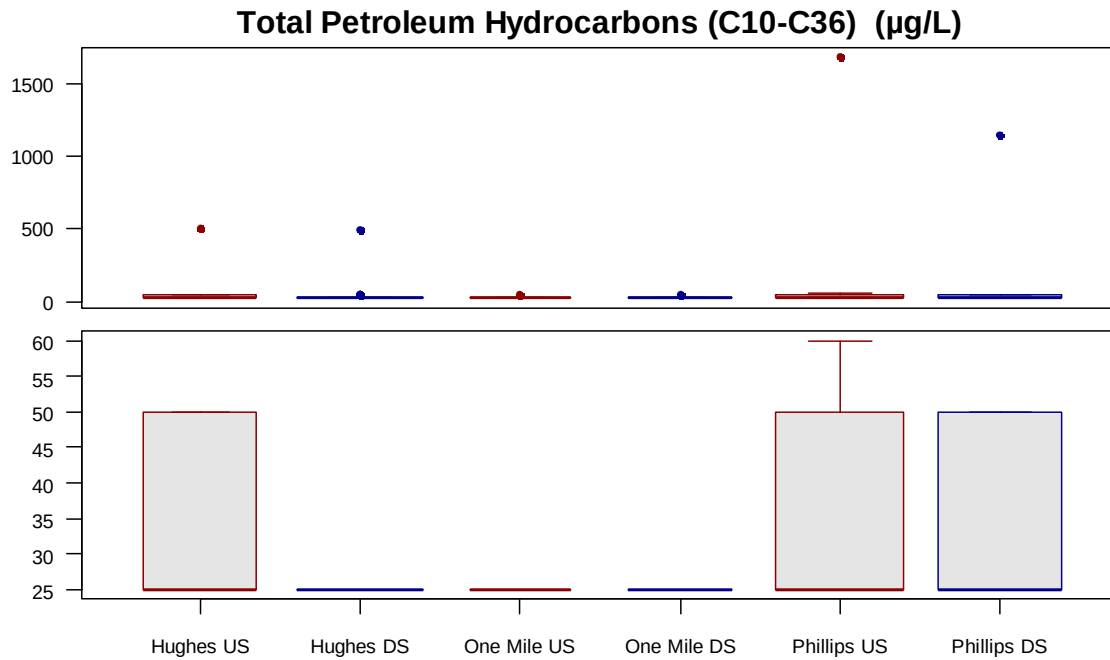
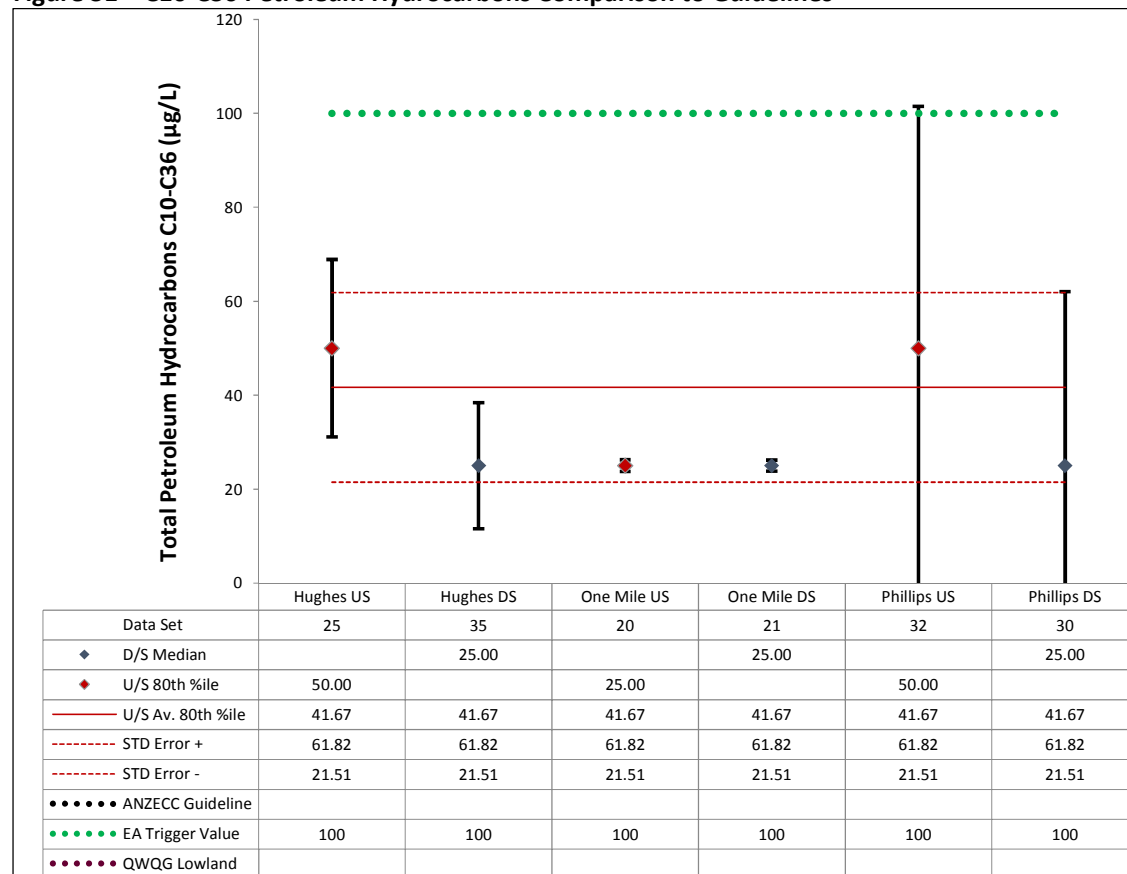


Figure 31 – C10-C36 Petroleum Hydrocarbons Comparison to Guidelines



6.4.12 Fluoride

Fluoride levels increase as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 32). The upstream median range 50µg/L to 100µg/L increased downstream to a range of 100µg/L to 200µg/L (Figure 27).

The downstream median in Hughes (200µg/L) and One Mile (200µg/L) creeks were slightly higher than the average upstream 80th percentile (161µg/L), and the Phillips Creek downstream median was lower. The One Mile Creek finding requires qualification in that the upstream site may be unrepresentative of the catchment due to the addition of pipeline water from Bedford Weir at the sample site. The new upstream site, implemented in May 2012, will provide a better future guide to the change in water quality in One Mile Creek.

All downstream medians were well below ANZECC stock guideline (Figure 33); indicating fluoride is below levels of concern.

The ANZECC guideline of 2,000µg/L adequately accommodates local background levels.

Figure 32 – Fluoride Box & Whisker Plot

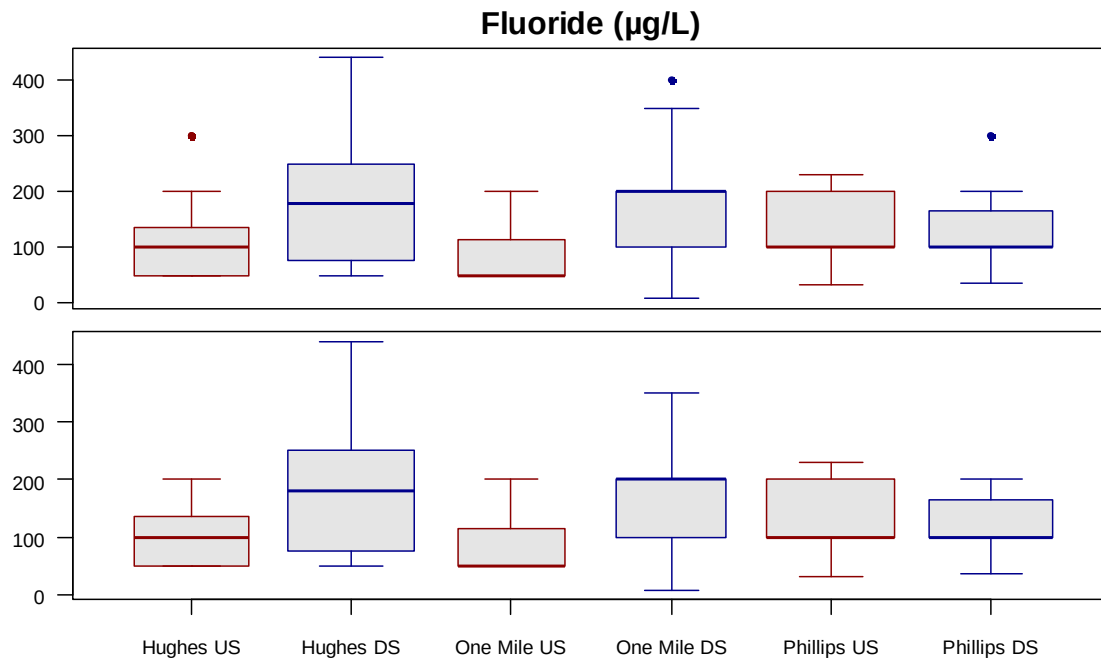
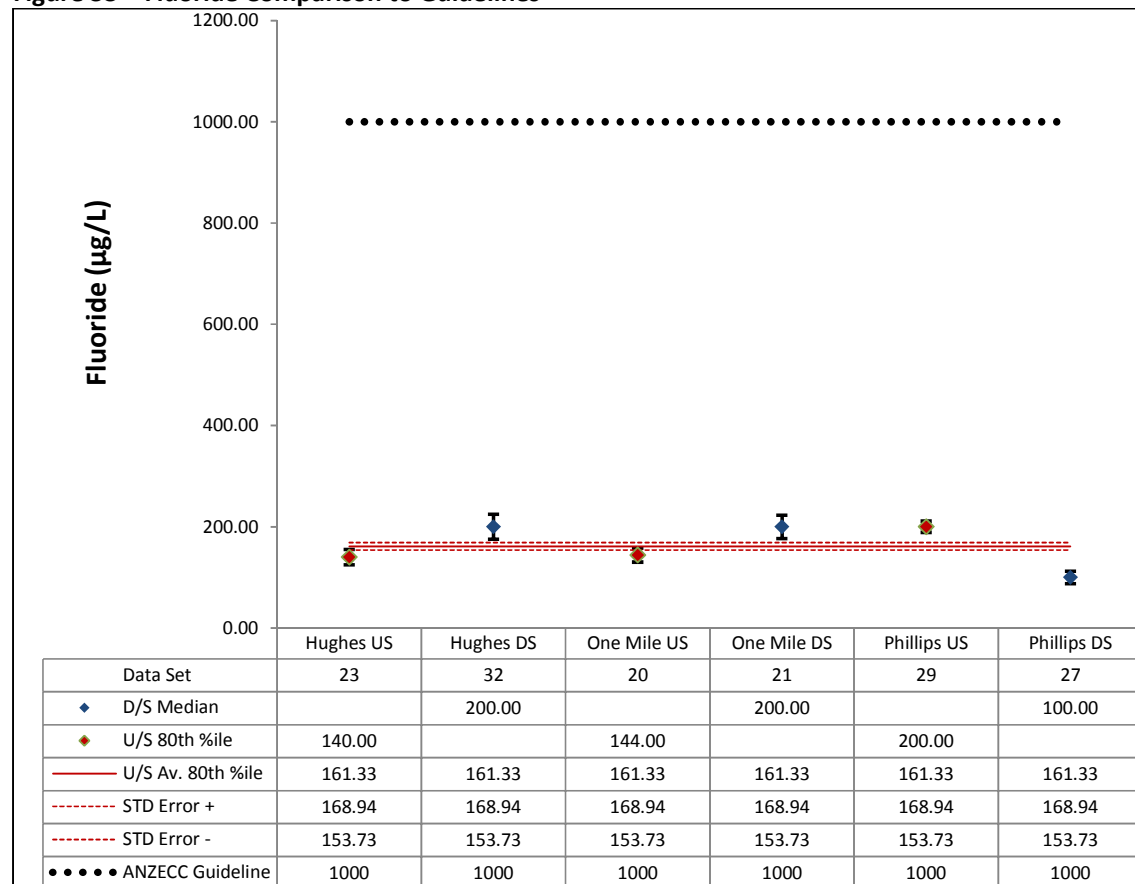


Figure 33 – Fluoride Comparison to Guidelines



6.4.13 Total Hardness

Total hardness appears to increase downstream, however this is based on a limited number of upstream data points (1 to 11 samples) and downstream points (2 to 15 samples). Further monitoring is required to better establish trends.

Hardness values are presented here for reference when considering hardness modified trigger values for heavy metals. No guidelines or EA triggers apply.

Figure 34 – Total Hardness Box & Whisker Plot

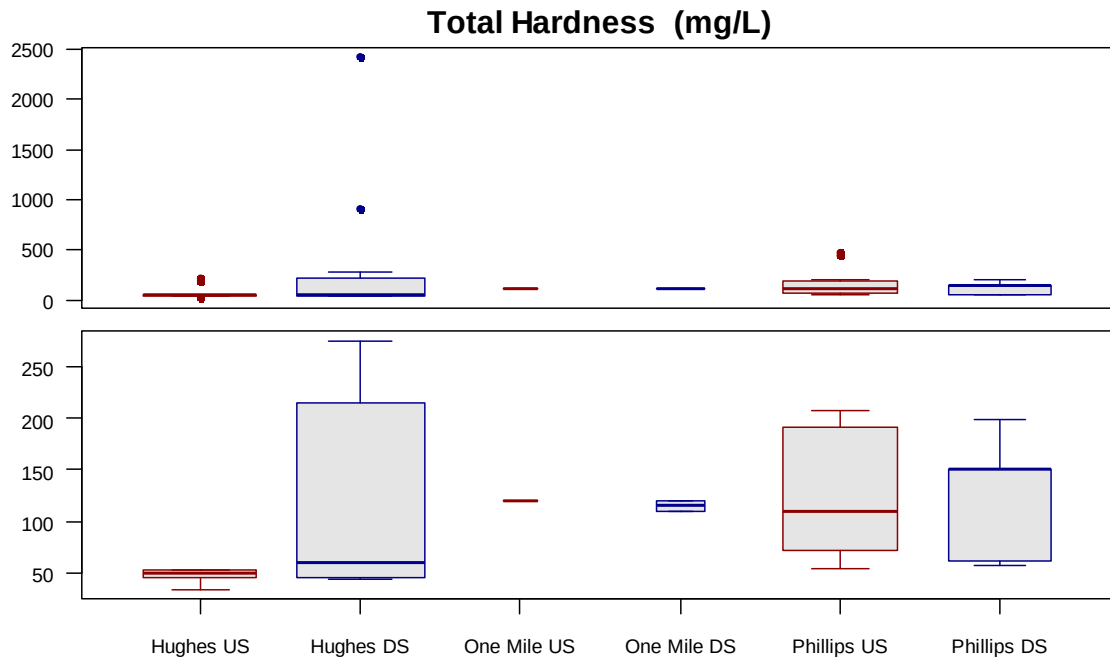
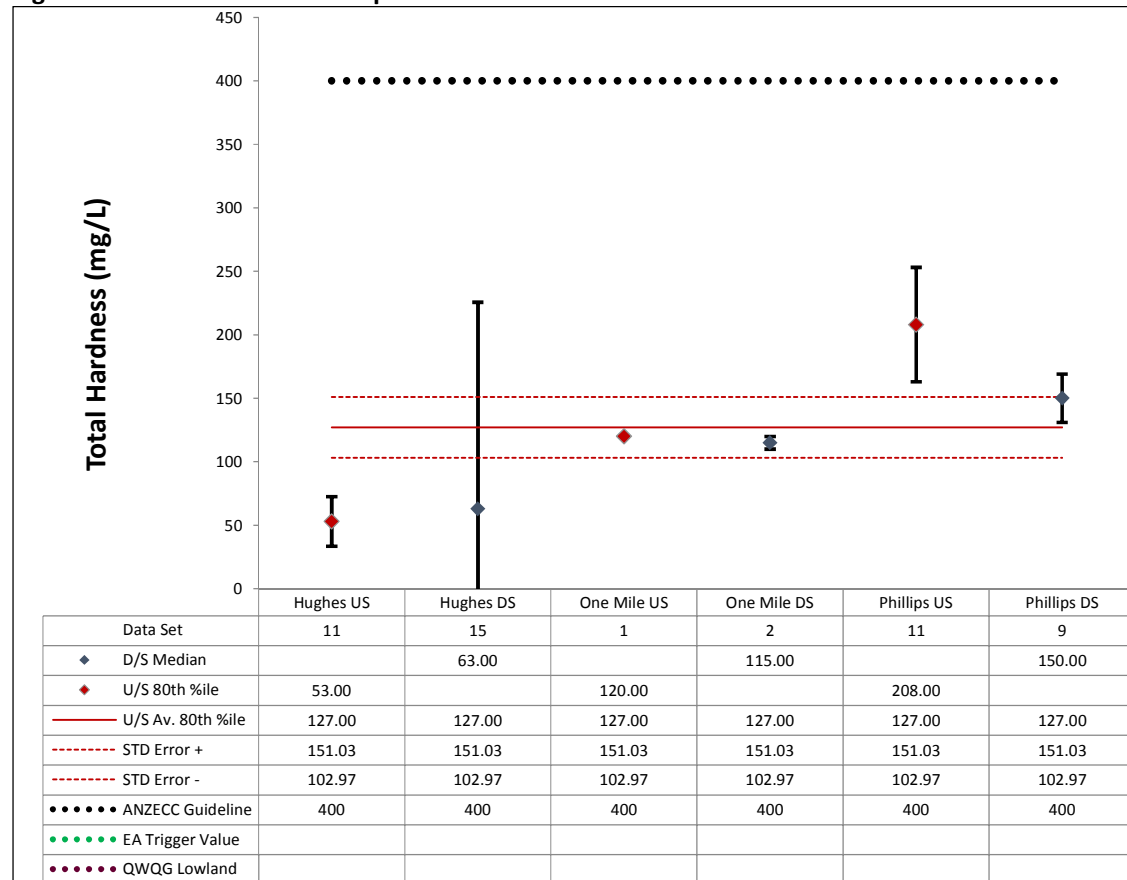


Figure 35 – Total Hardness Comparison to Guidelines



6.4.14 Aluminium

6.4.14.1 Dissolved Aluminium

Dissolved aluminium levels slightly decreased as Hughes, One Mile, and Phillips creeks progressed through the mine lease (Figure 36). The upstream site medians ranged from 95-230µg/L and downstream medians ranged from 75µg/L to 195µg/L. At times, significant outliers were recorded at most upstream and downstream sites.

The downstream medians were below the upstream 80th percentile and the EA trigger, indicating levels are not being increased above acceptable locals for SMD ecosystems.

The average upstream 80th percentile (499µg/L) was well above the ANZECC ecosystem guideline (55µg/L) (Figure 37), indicating a new or interim guideline may be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were greater than the 'highly variable' category as reference sites were greater than two standard errors of the average 80th percentile. Accordingly this warrants individual stream guidelines based on 80th percentiles. For simplicity, since the sites were very close to close to the "highly variable" category (with the Hughes Creek 80th percentile (760µg/L) just exceeding the average 80th percentile plus two standard errors (721µg/L), an interim guideline of 721µg/L based on the "highly variable" approach (QWQG, 2009) could provide a practical local guideline. This guideline is an interim value, as defined by the assessment approach for the 'highly variable' category, and would require reassessment when more data is available.

The current EA trigger (416µg/L) appropriate in being within one standard error of the average upstream 80th percentile (499 ± 111µg/L), however it will be overly stringent for Hughes Creek. Adoption of the proposed site wide guideline (721µg/L) is suggested as a more practical trigger value.

6.4.14.2 Total Aluminium

Total aluminium levels increased as One Mile and Phillips creeks progress through the mine lease, while Hughes Creek decreased (Figure 38).

The average upstream 80th percentile (10,316µg/L) was above the ANZECC guidelines for stock and irrigation (5,000µg/L), and recreation (200µg/L) (Figure 39).

Downstream medians (± one standard error) were below the corresponding upstream 80th percentiles and the ANZECC stock watering and irrigation guidelines.

Total aluminium levels in Hughes, One Mile, and Phillips creeks are not being increased above acceptable levels for SMD ecosystems.

Figure 36 – Dissolved Aluminium Box & Whisker Plot

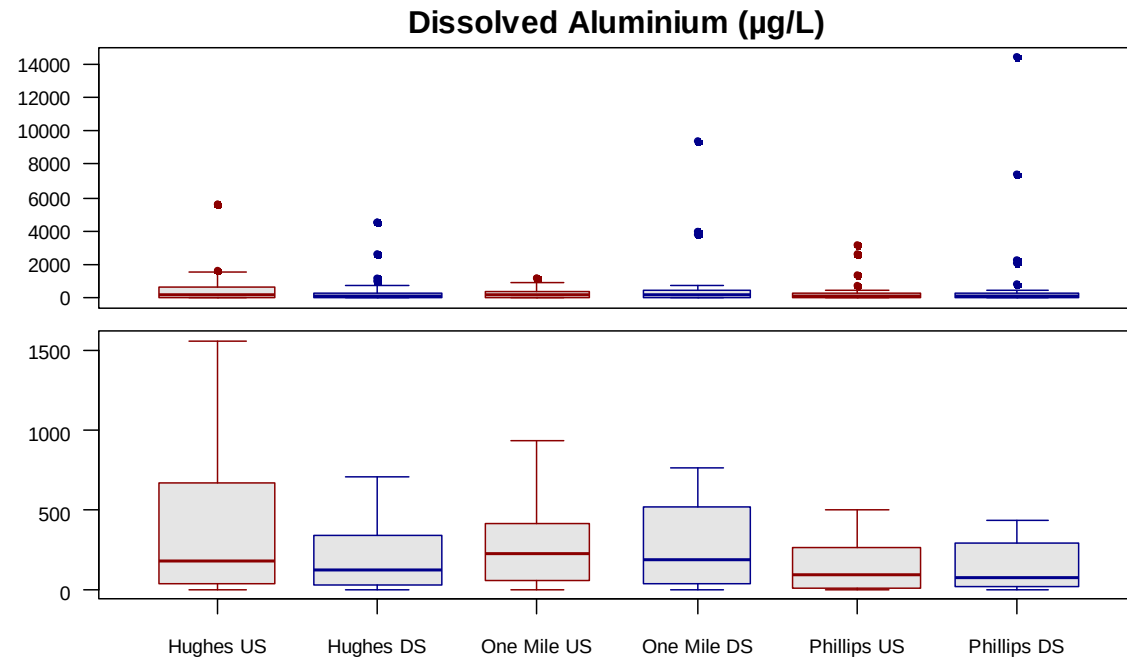


Figure 37 – Dissolved Aluminium Comparison to Guidelines

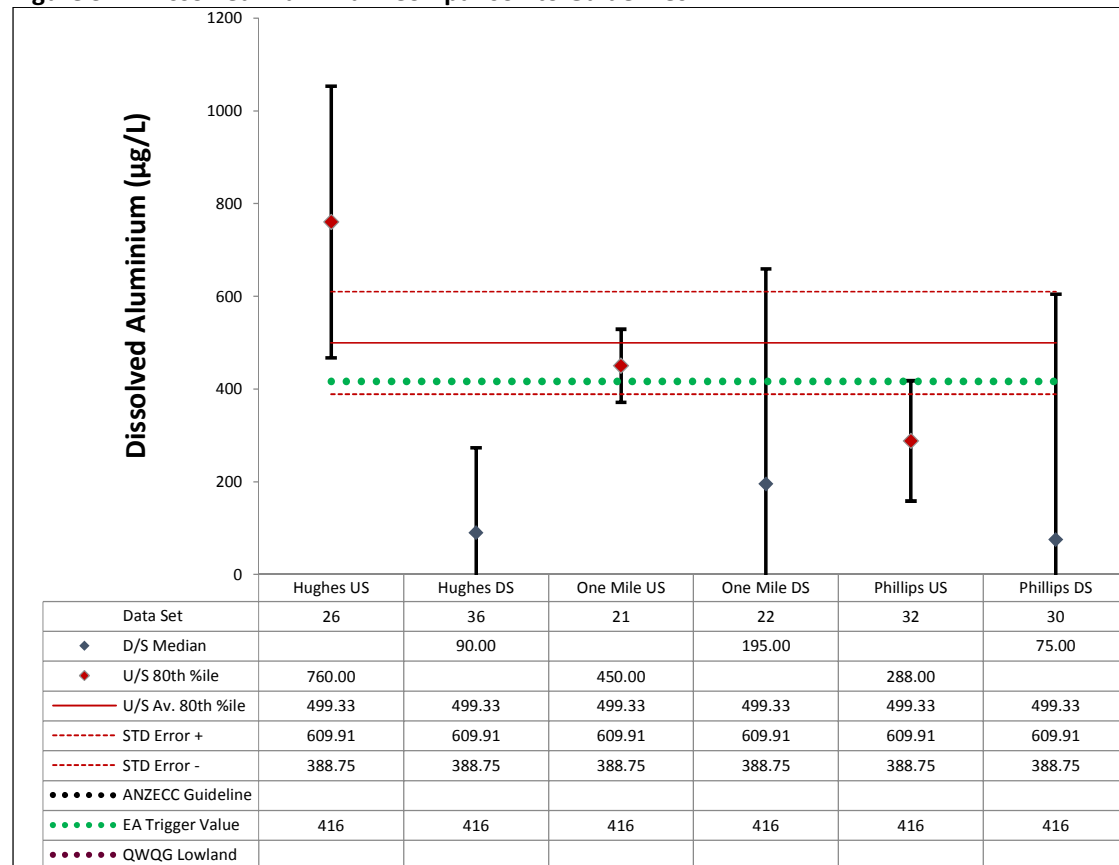


Figure 38 – Total Aluminium Box & Whisker Plot

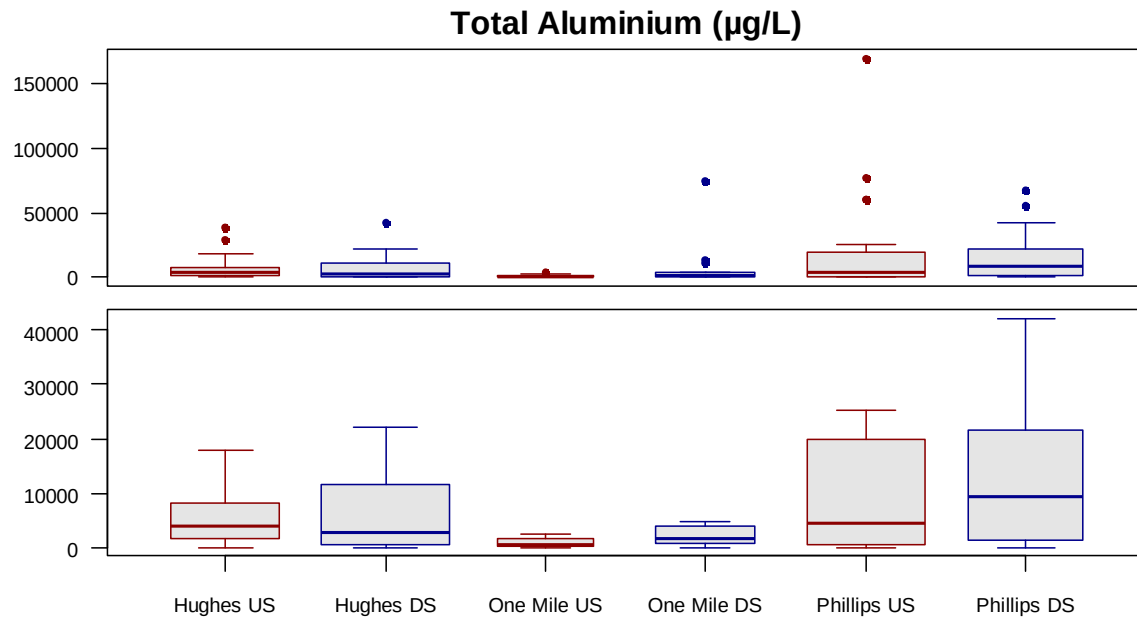
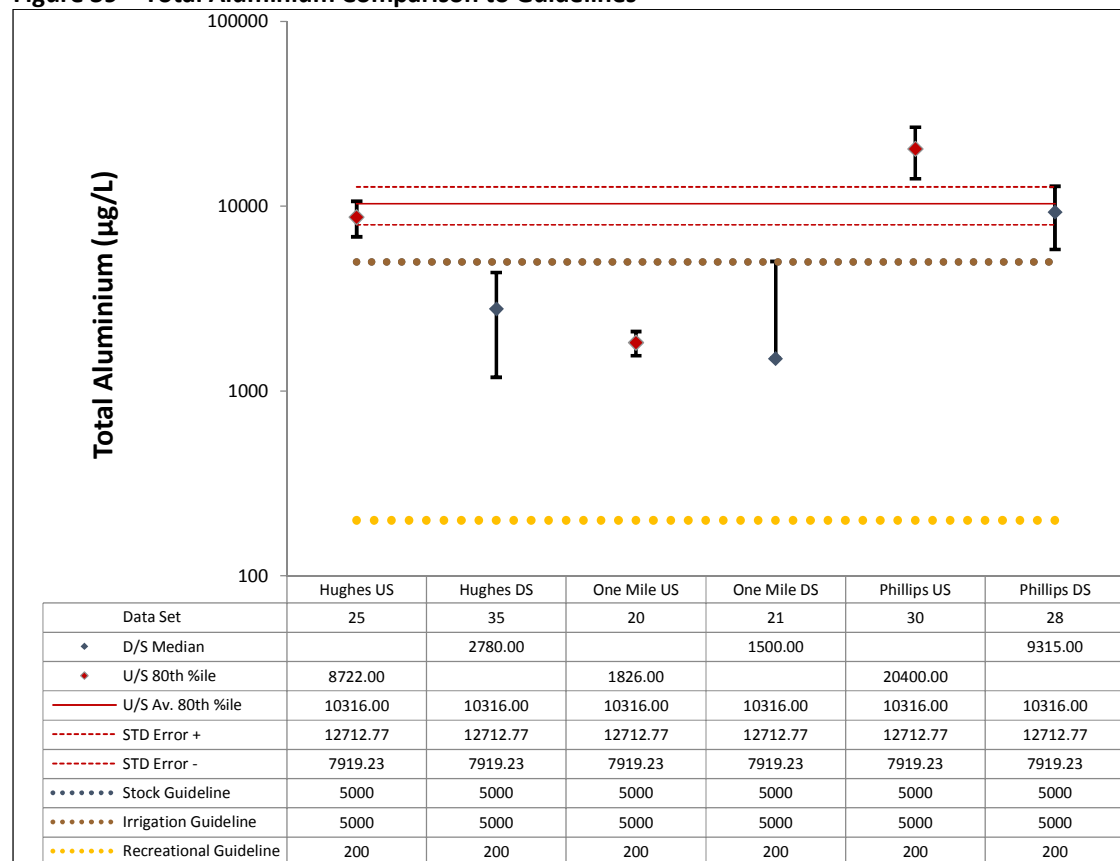


Figure 39 – Total Aluminium Comparison to Guidelines



6.4.15 Arsenic

6.4.15.1 Dissolved Arsenic

Dissolved arsenic levels remained relatively steady as Hughes, One Mile, and Phillips creeks progressed through the mine lease. The upstream One Mile Creek median ($0.5\mu\text{g/L}$) increased downstream to $1\mu\text{g/L}$ (Figure 40); however this result was solely a function of the limits of reporting (LOR).

Most results were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be $0\mu\text{g/L}$.

The average upstream 80th percentile ($0.83\mu\text{g/L}$) was well below the ANZECC ecosystem (SMD) guideline of $13\mu\text{g/L}$ (Figure 41).

The downstream medians were within one standard error of the upstream 80th percentile levels, and below the ANZECC guidelines.

The results indicate dissolved arsenic levels are below the level of concern for the local environment and not being altered by mining activity. Should this analyte be used as a trigger, the ANZECC guideline ($13\mu\text{g/L}$) would be appropriate.

6.4.15.2 Total Arsenic

Total arsenic levels slightly increased as One Mile Creek progressed through the mine lease. Median levels in Phillips and Hughes creeks were static or decreased downstream (Figure 42 and Figure 43)

The average upstream 80th percentile ($2.4\mu\text{g/L}$) was well below the ANZECC guidelines for stock ($500\mu\text{g/L}$), irrigation ($100\mu\text{g/L}$) and recreational ($50\mu\text{g/L}$) (Figure 43).

Downstream median levels were below the upstream 80th percentiles, except for One Mile Creek. The One Mile Creek finding requires qualification in that the upstream site may be unrepresentative of the catchment due to the addition of pipeline water from Bedford Weir at the sample site. The new upstream site, implemented in May 2012, will provide a better future guide to the change in water quality in One Mile Creek. All downstream medians were well below the ANZECC guidelines.

Total arsenic levels in Hughes, One Mile, and Phillips creeks are below the level of concern for the local environment and not being significantly altered by mining activity.

Figure 40 – Dissolved Arsenic Box & Whisker Plot

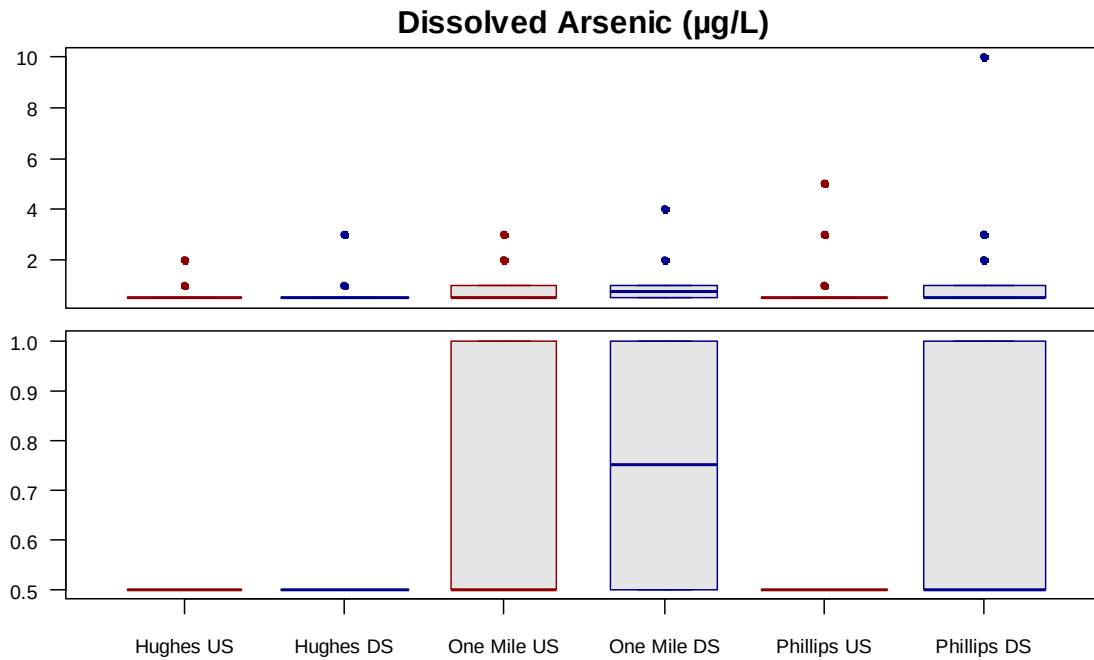


Figure 41 – Dissolved Arsenic Comparison to Guidelines

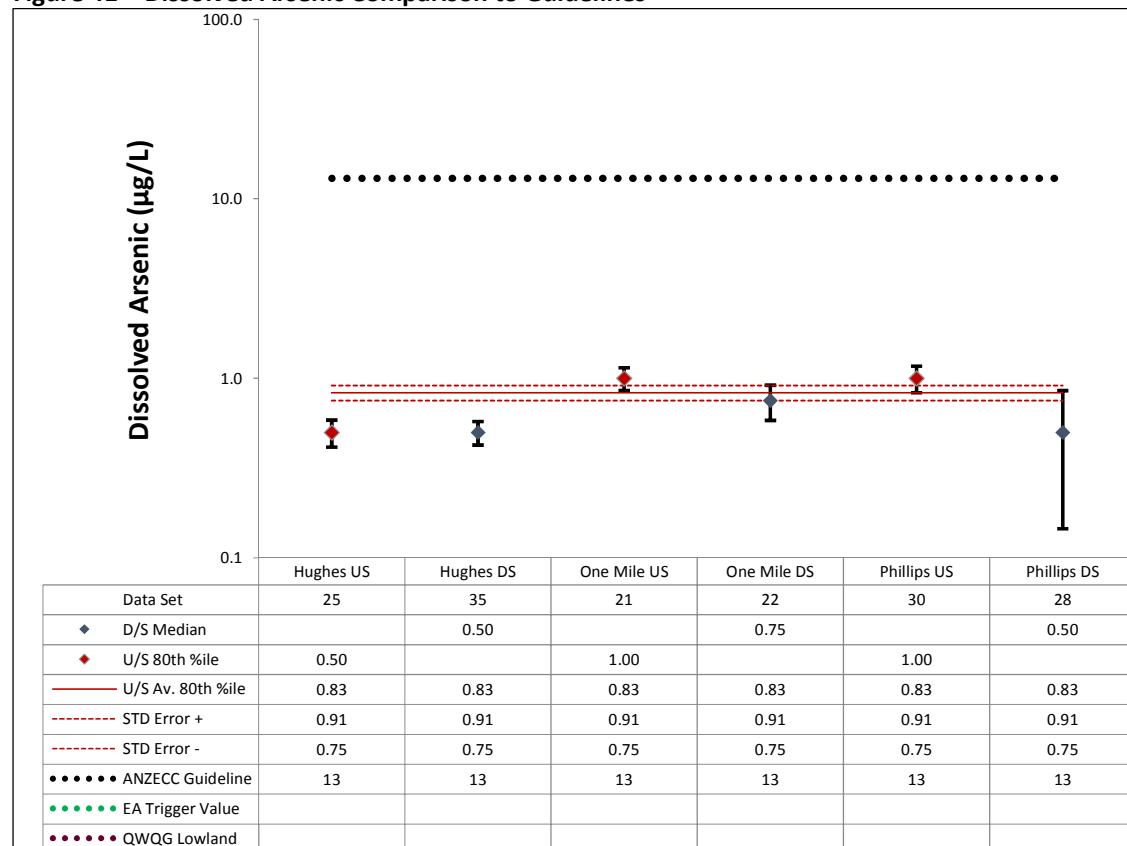


Figure 42 – Total Arsenic Box & Whisker Plot

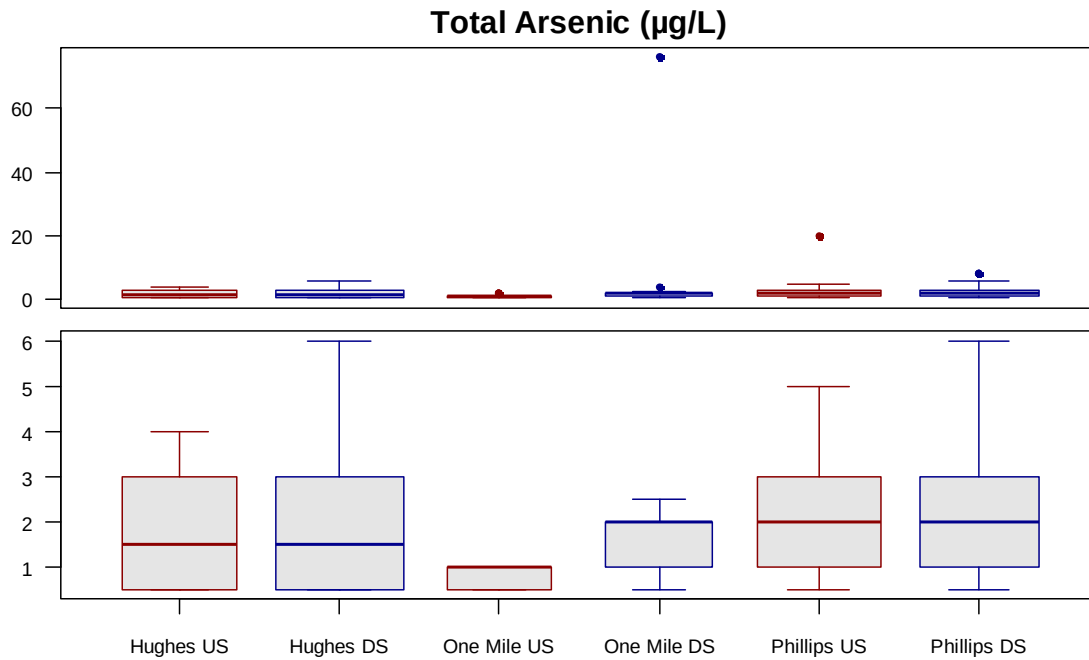
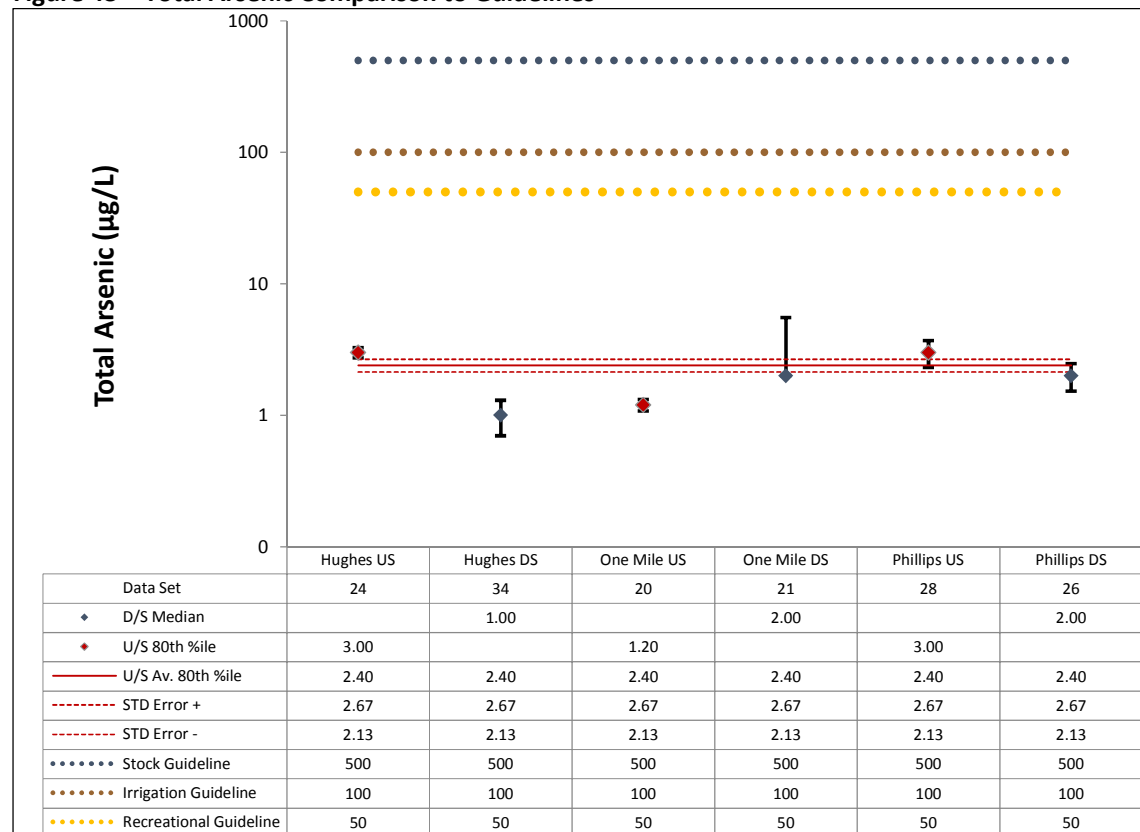


Figure 43 – Total Arsenic Comparison to Guidelines



6.4.16 Boron

6.4.16.1 Dissolved Boron

Dissolved boron levels remained relatively static as Hughes, One Mile, and Phillips creeks progressed through the mine lease (Figure 44 & Figure 45).

The downstream medians were within one standard error of the average or individual upstream 80th percentiles (Figure 45).

The results indicate dissolved boron remained below levels of concern and within acceptable limits for SMD ecosystems. Should this analyte be used as a trigger, the ANZECC guideline (370µg/L) adequately accommodates local background levels.

6.4.16.2 Total Boron

Total boron levels slightly increase as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 46 and Figure 47). However, downstream medians were below the upstream 80th percentiles (plus one standard error) for individual streams.

The average upstream 80th percentile (72µg/L) was below the ANZECC guidelines for stock (5,000µg/L), irrigation (500µg/L) and recreational (1,000µg/L) (Figure 47).

Downstream median were also well below the ANZECC guidelines.

Total boron levels increase slightly through the mining lease but remain within acceptable levels of change for SMD systems and well below levels of concern.

Figure 44 – Dissolved Boron Box & Whisker Plot

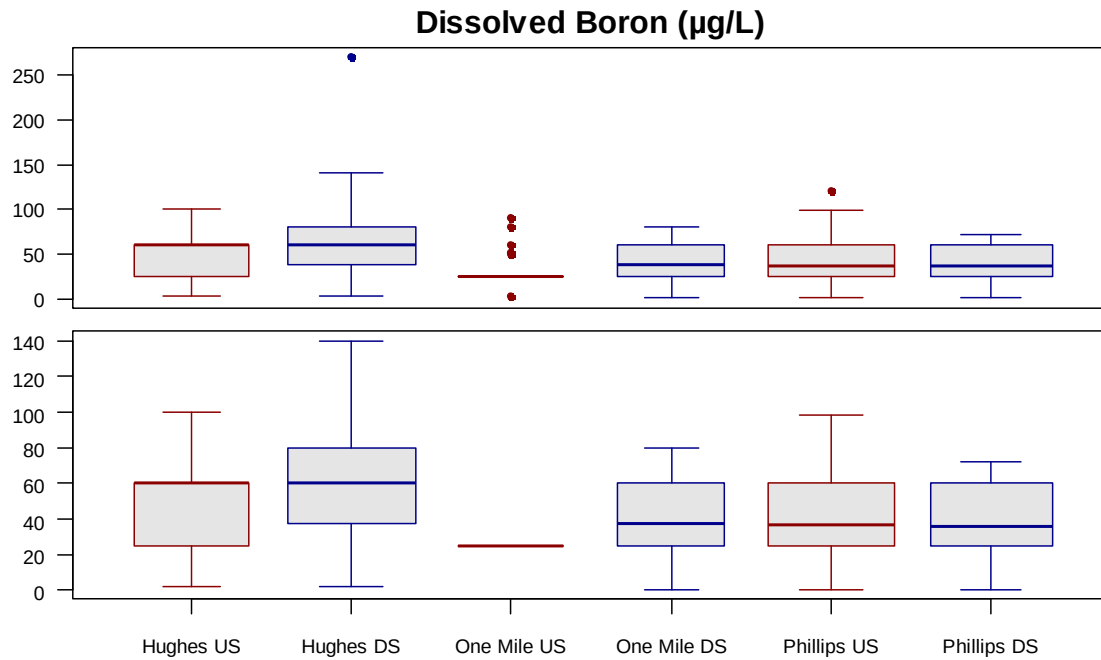


Figure 45 – Dissolved Boron Comparison to Guidelines

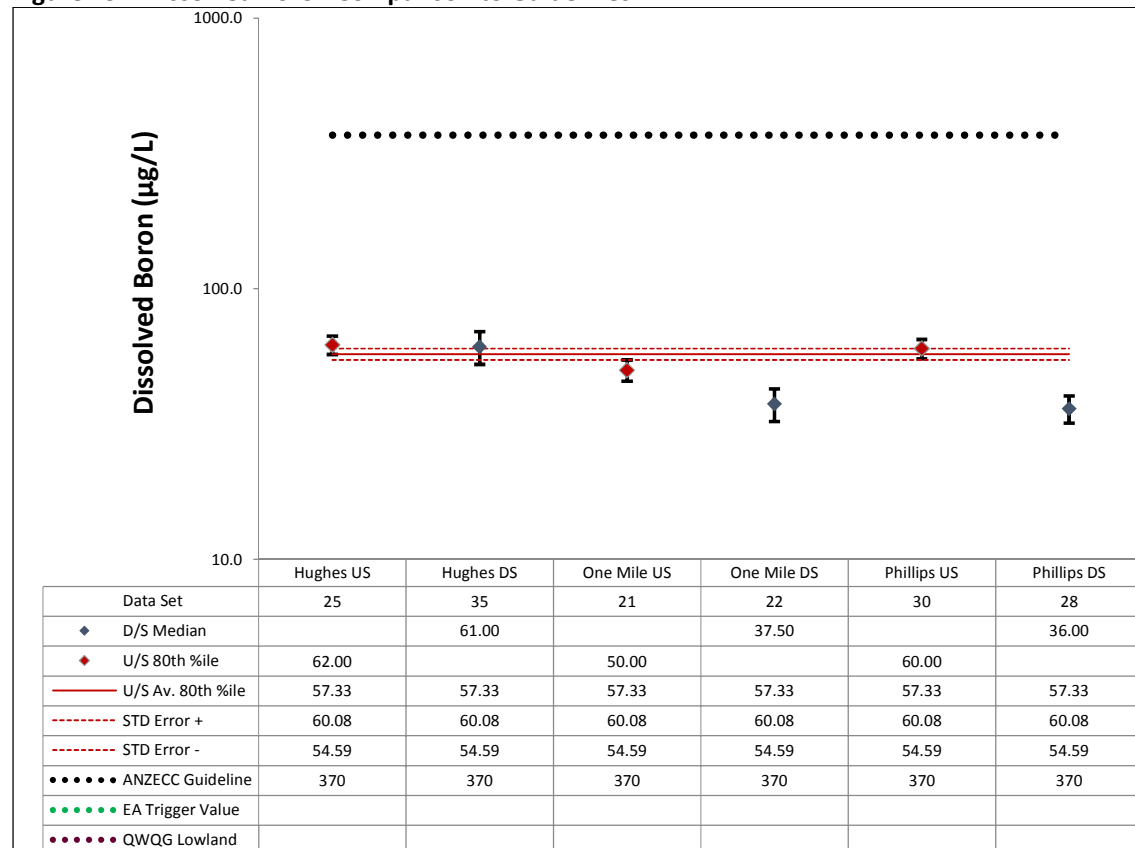


Figure 46 – Total Boron Box & Whisker Plot

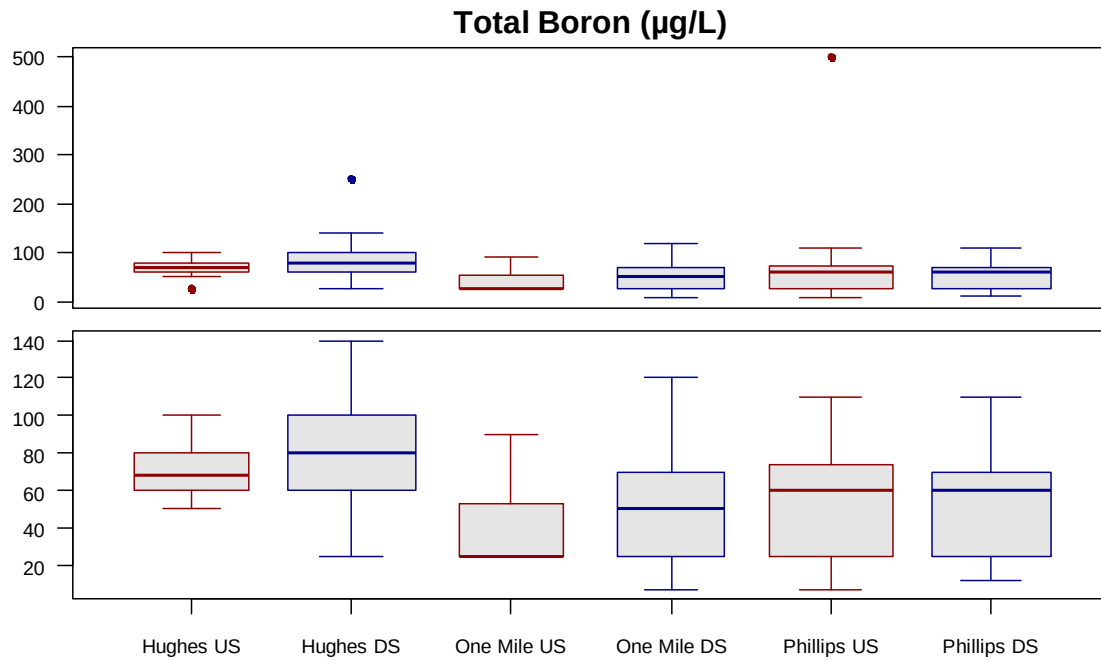
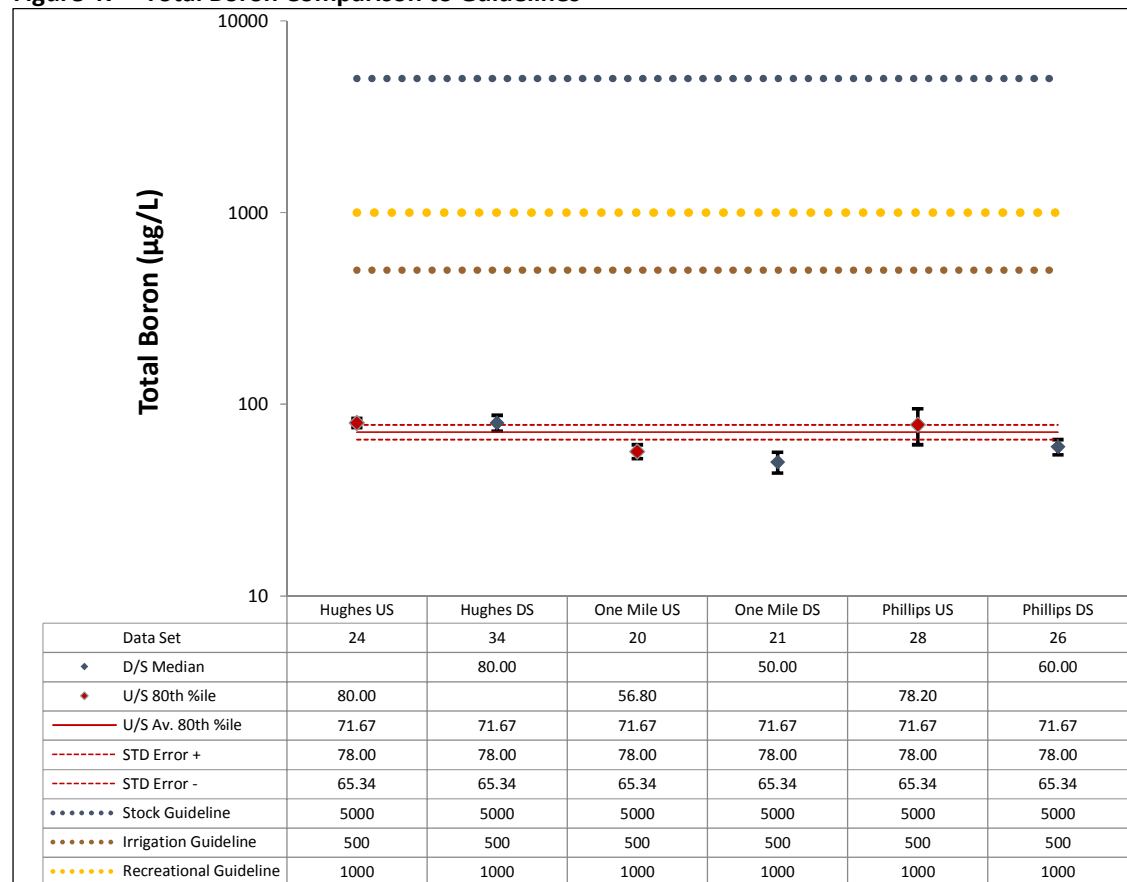


Figure 47 – Total Boron Comparison to Guidelines



6.4.17 Cadmium

6.4.17.1 Dissolved Cadmium

Dissolved cadmium levels remain steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 48 & Figure 49).

Most (>95%) of all results for upstream and downstream samples were below detection, and medians were skewed according to the 50% LOR rule. If applying the 0% LOR rule, the median for all upstream and downstream sites would be 0µg/L.

The average upstream 80th percentile (0.04µg/L) was below the ANZECC ecosystem (SMD) guideline of 0.2µg/L, and above the downstream median values.

The results indicate dissolved cadmium is below levels of concern and not being altered by mining activity. Should this analyte be used as a trigger, the ANZECC guideline (0.2µg/L) accommodates the local conditions.

6.4.17.2 Total Cadmium

Total cadmium levels remain steady as Hughes, One Mile, and Phillips creeks progress through the mine lease, with most results below the limit of reporting and the occasional outlier recorded (Figure 50).

Most (>85%) results for upstream and downstream samples were below detection limits, and medians were skewed according to the 50% LOR rule. If applying the 0% LOR rule, the median for all upstream and downstream sites would be 0µg/L. The higher value for upstream creeks was a function of the LOR variability rather than stream variability.

The average 80th percentile upstream (0.04µg/L) was below the ANZECC guidelines for stock (10µg/L), irrigation (10µg/L) and recreational (5µg/L).

Downstream median levels were below the average upstream 80th percentile and below the guidelines.

Total cadmium levels in Hughes, One Mile, and Phillips creeks are below the level of concern for the local environment and do not appear to be altered by mining activity.

Figure 48 - Dissolved Cadmium Box & Whisker Plot

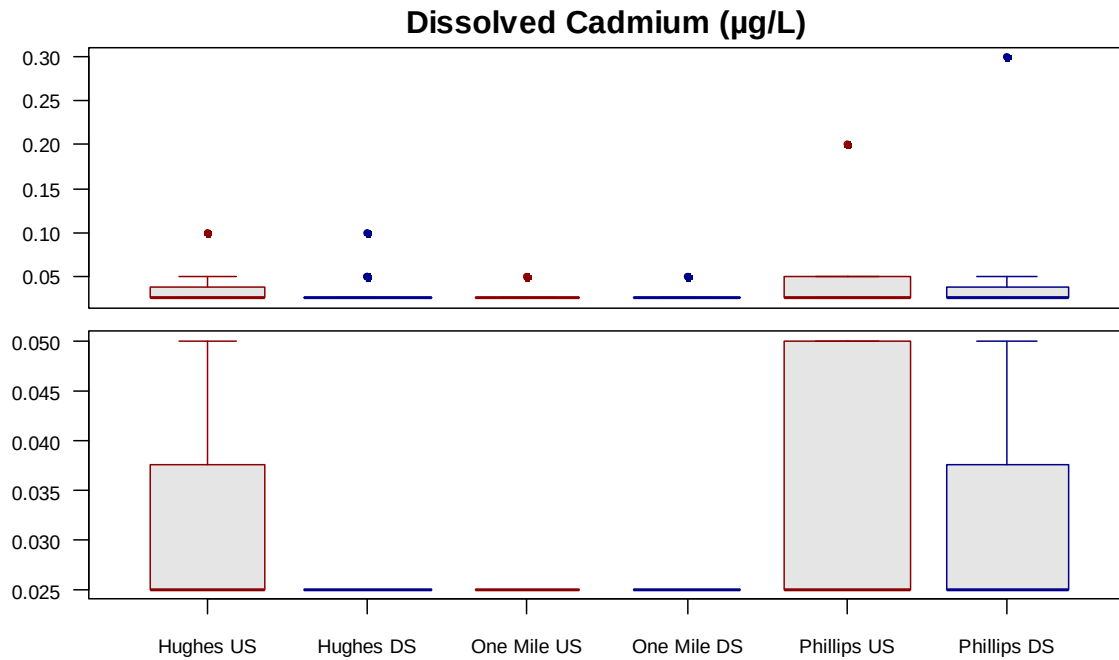


Figure 49 – Dissolved Cadmium Comparison to Guidelines

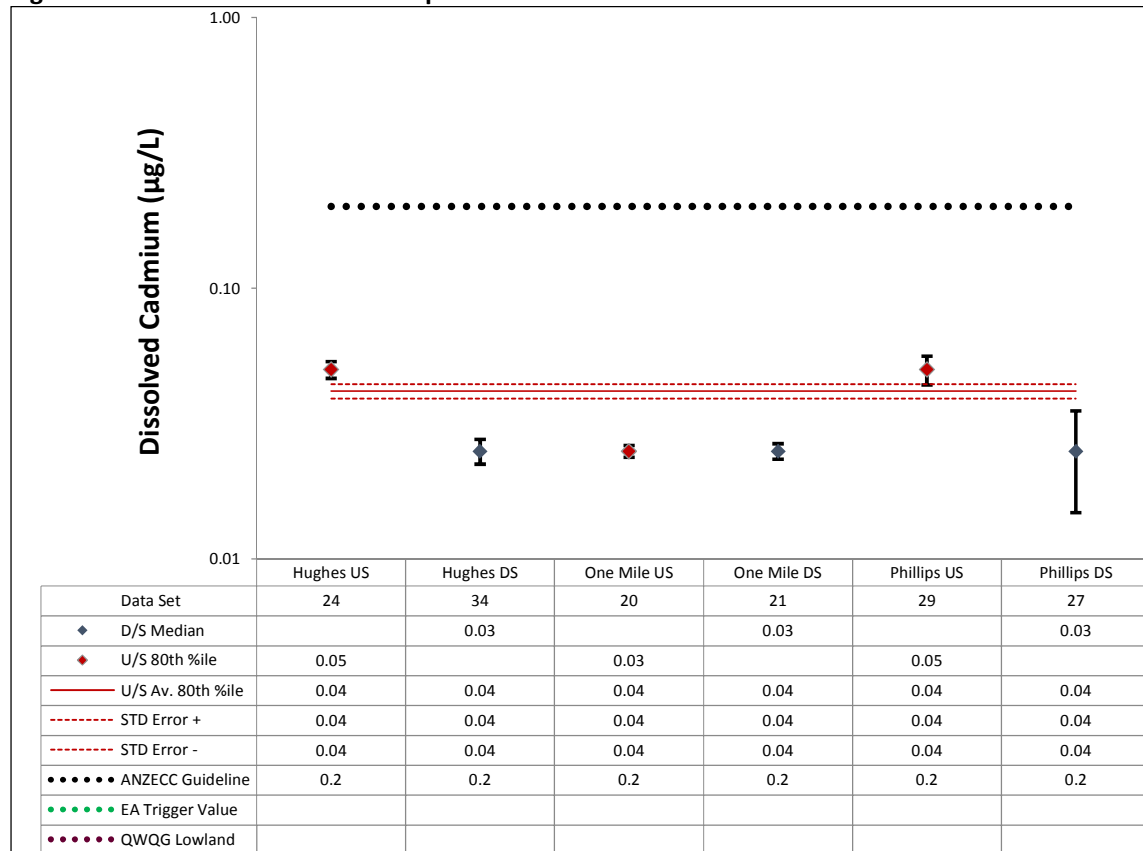


Figure 50 – Total Cadmium Box & Whisker Plot

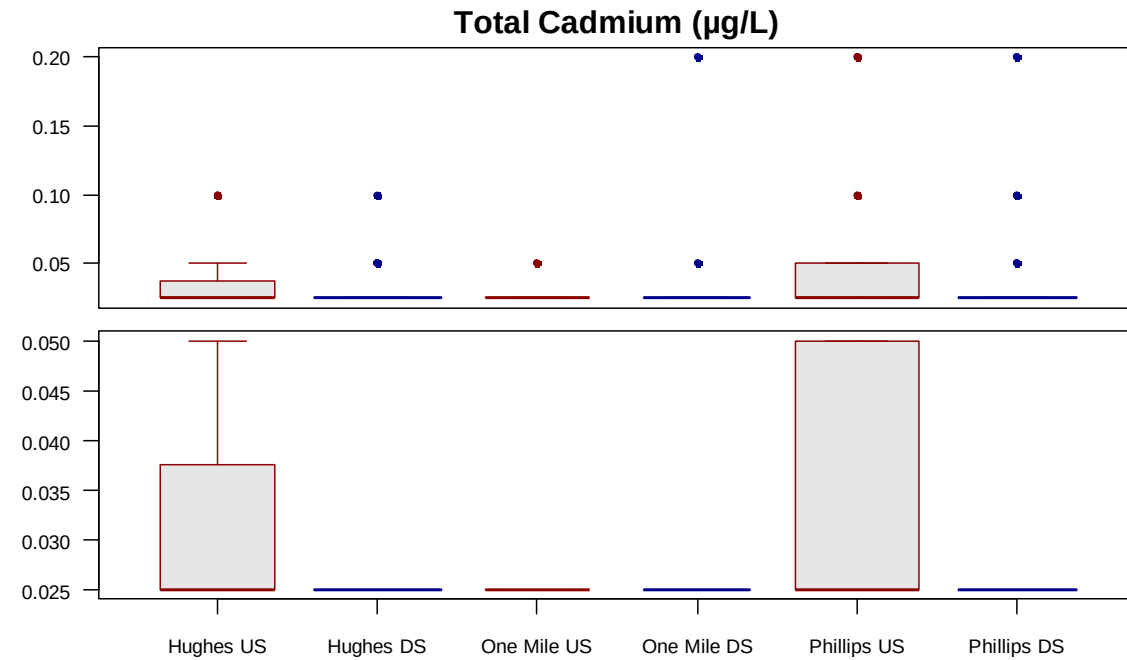
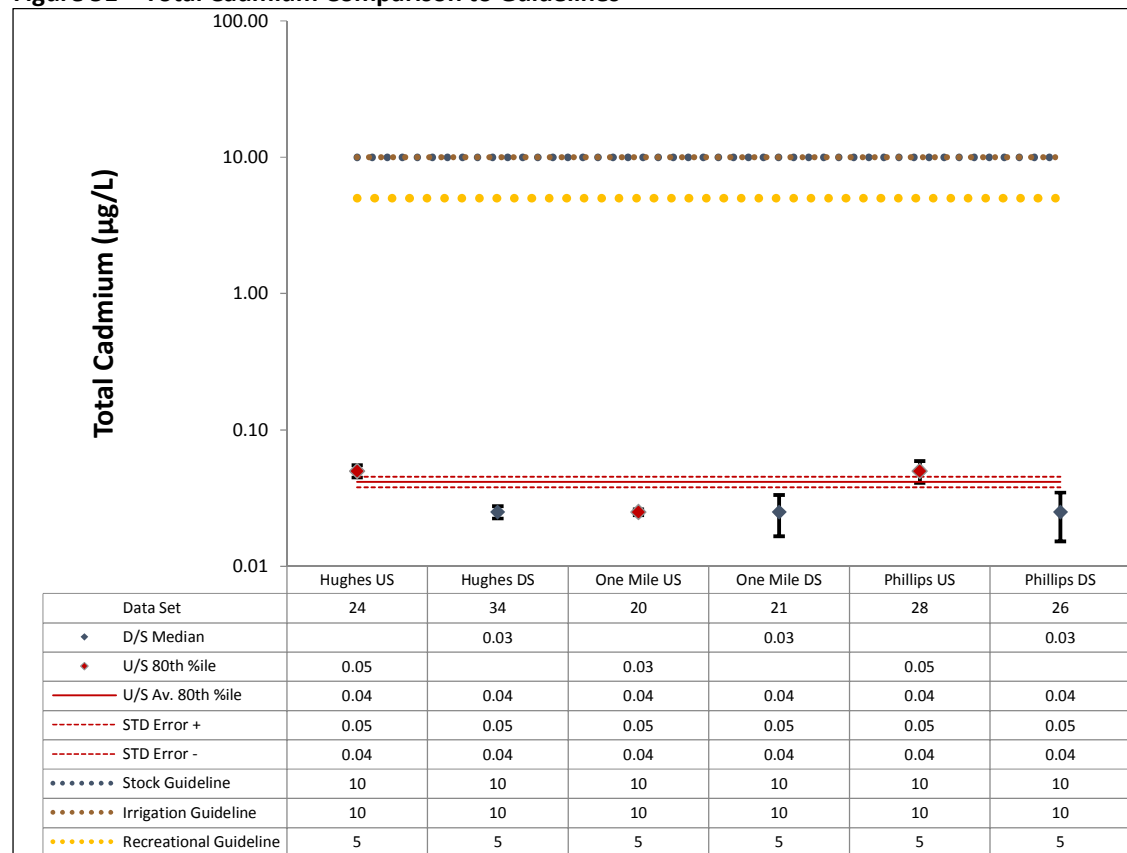


Figure 51 – Total Cadmium Comparison to Guidelines



6.4.18 Chromium

6.4.18.1 Dissolved Chromium

Dissolved chromium levels slightly decrease as Hughes, One Mile, and Phillips creeks progress through the mine lease. The upstream median range of 0.5µg/L to 0.7µg/L decreased downstream, ranging from 0.3µg/L to 0.4µg/L (Figure 52).

The downstream medians were below the upstream 80th percentiles (Figure 53).

The average upstream 80th percentile (0.87µg/L) was below the EA trigger and ANZECC ecosystem (SMD) guideline of 1.0µg/L. However, the One Mile Creek upstream 80th percentile (1.2µg/L) suggests the current guideline value is overly stringent for local conditions in this stream. This indicates a new or interim guideline may be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were greater than the highly variable category; that is, reference sites differed by greater than two standard errors and an individual stream assessment approach is merited. Hughes and Phillips creeks are within the current guideline trigger of 1µg/L which remains appropriate. For One Mile Creek an individual guideline value 1.2µg/L is suggested based on the 80th percentile.

The results indicate dissolved chromium is not being increased by mining activity.

6.4.18.2 Total Chromium

Total chromium levels decrease as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 54).

The average upstream 80th percentile (9.1µg/L) was below the ANZECC guidelines for stock (1,000µg/L), irrigation (100µg/L) and recreational (52µg/L) (Figure 55).

Downstream median levels are below the average upstream 80th percentile and the ANZECC guidelines.

Total chromium levels in Hughes, One Mile, and Phillips creeks are below levels of concern and do not appear to be increased by mining activity.

Figure 52 – Dissolved Chromium Box & Whisker Plot

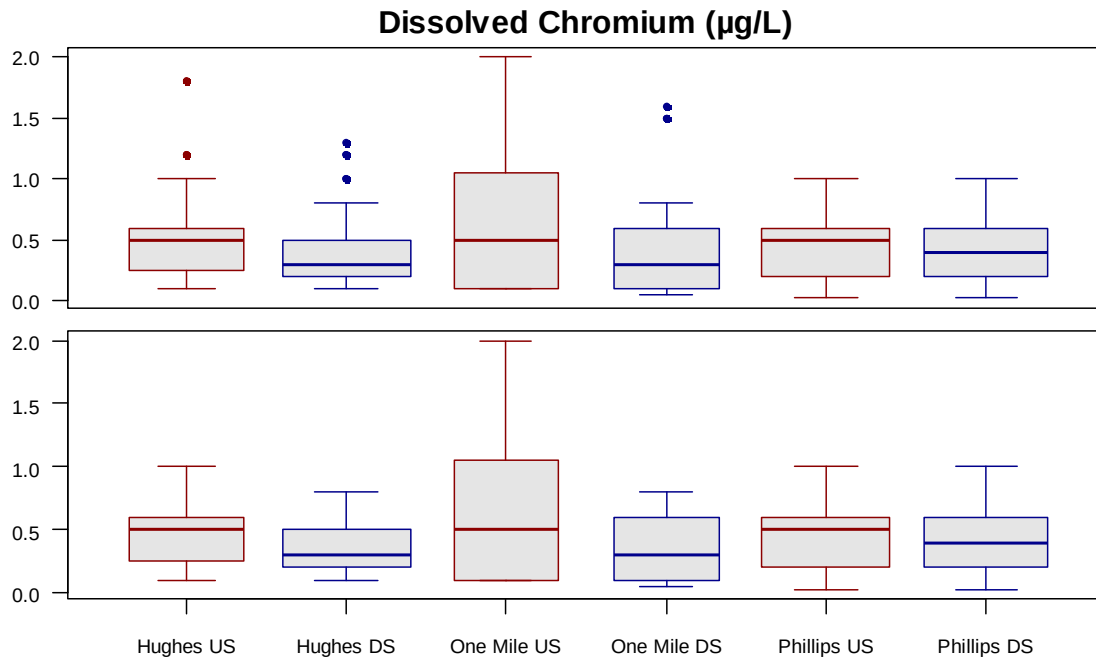


Figure 53 – Dissolved Chromium Comparison to Guidelines

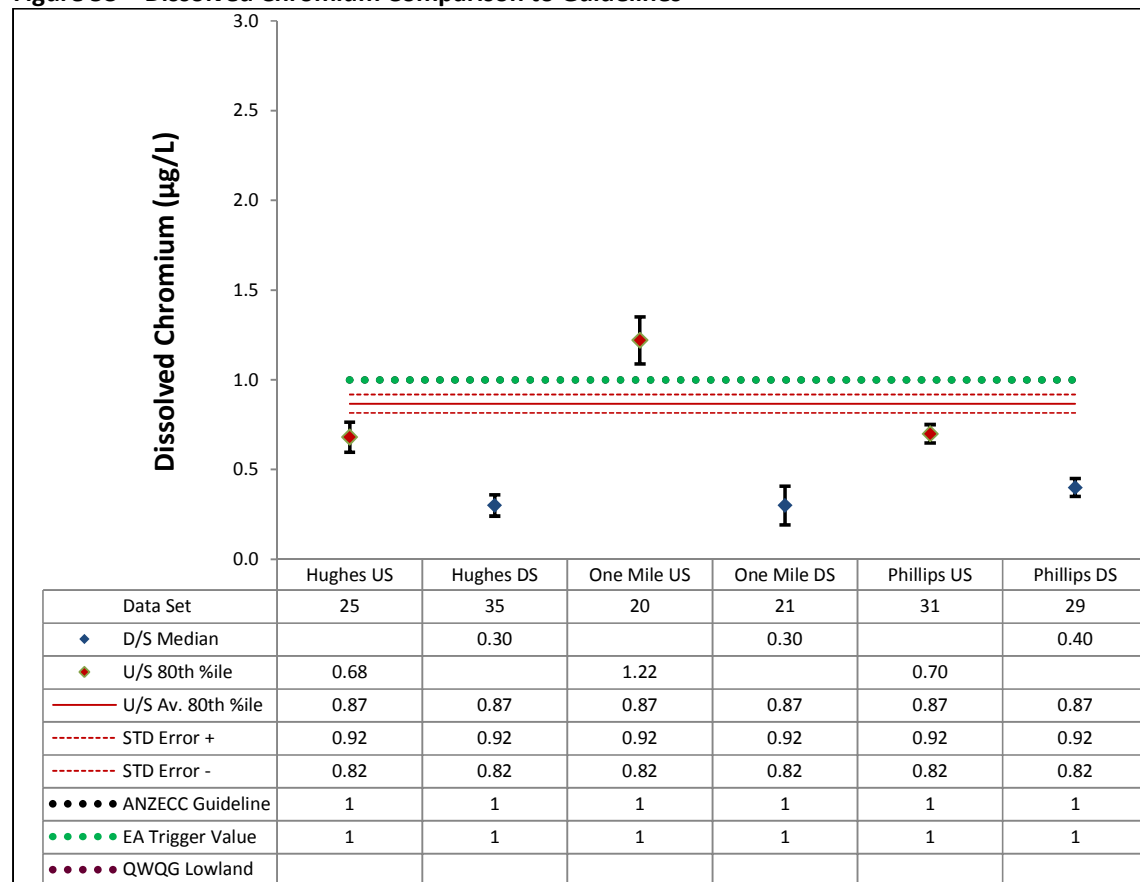


Figure 54 - Total Chromium Box & Whisker Plots

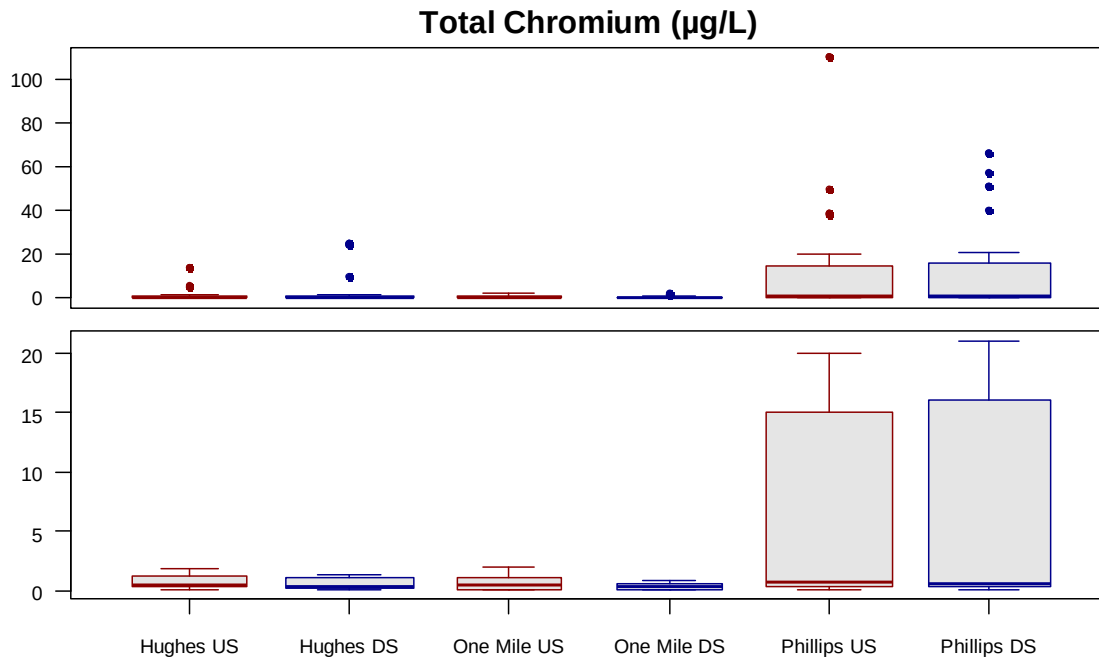
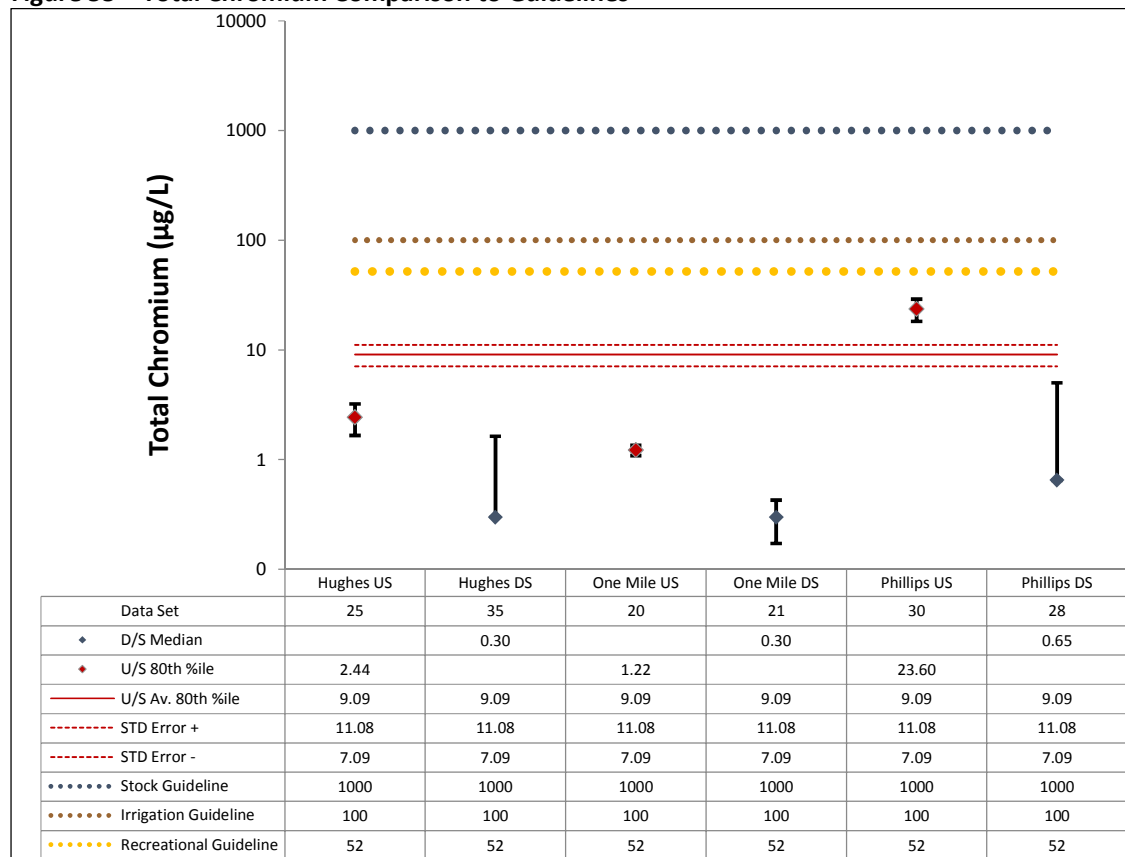


Figure 55 – Total Chromium Comparison to Guidelines



6.4.19 Cobalt

6.4.19.1 Dissolved Cobalt

Dissolved cobalt levels remained steady as Hughes, One Mile, and Phillips creeks progressed through the mine lease. The medians upstream (0.5µg/L) were the same as downstream 0.5µg/L (Figure 56); however this result was solely a function of the limits of reporting (LOR).

Most (>85%) upstream and downstream results were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L.

The downstream median values were below the average upstream 80th percentile (0.53µg/L) (Figure 57). A total of 18 outliers for all sites (highest value 43µg/L) indicating a significant level of variation.

There are no applicable guidelines for dissolved cobalt.

The results indicate dissolved cobalt is below levels of concern and does not appear to be increased by mining activity. Proximity of results to the LOR has skewed the data set and would make setting a local guideline inappropriate.

6.4.19.2 Total Cobalt

Total cobalt levels slightly increased as Hughes and Phillip creeks progress through the mine lease whereas Phillips creek decreased slightly (Figure 58). However, downstream medians are below the average upstream 80th percentile, and within one standard error of corresponding individual 80th percentiles, and below the ANZECC guidelines.

The average upstream 80th percentile (9.1µg/L) was below the ANZECC guidelines for stock watering (1,000µg/L), and irrigation (50µg/L) (Figure 54).

Total cobalt levels in Hughes, One Mile, and Phillip creeks are below levels of concern and do not appear to be increased unacceptably by mining activity.

Figure 56 – Dissolved Cobalt Box & Whisker Plot

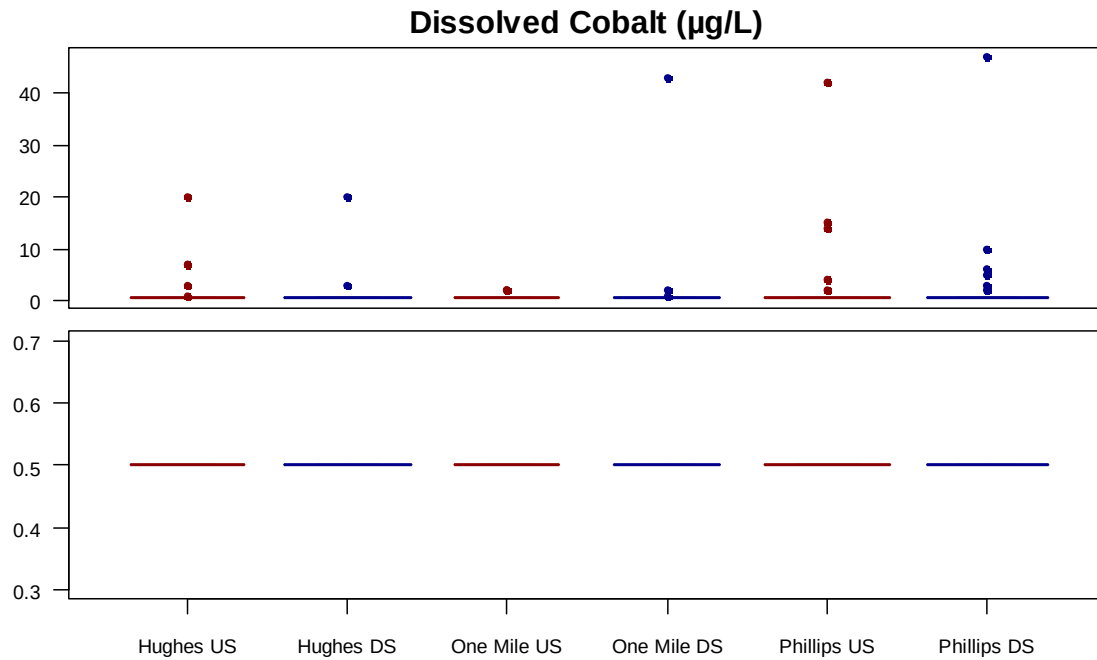


Figure 57 – Dissolved Cobalt Comparison to Guidelines

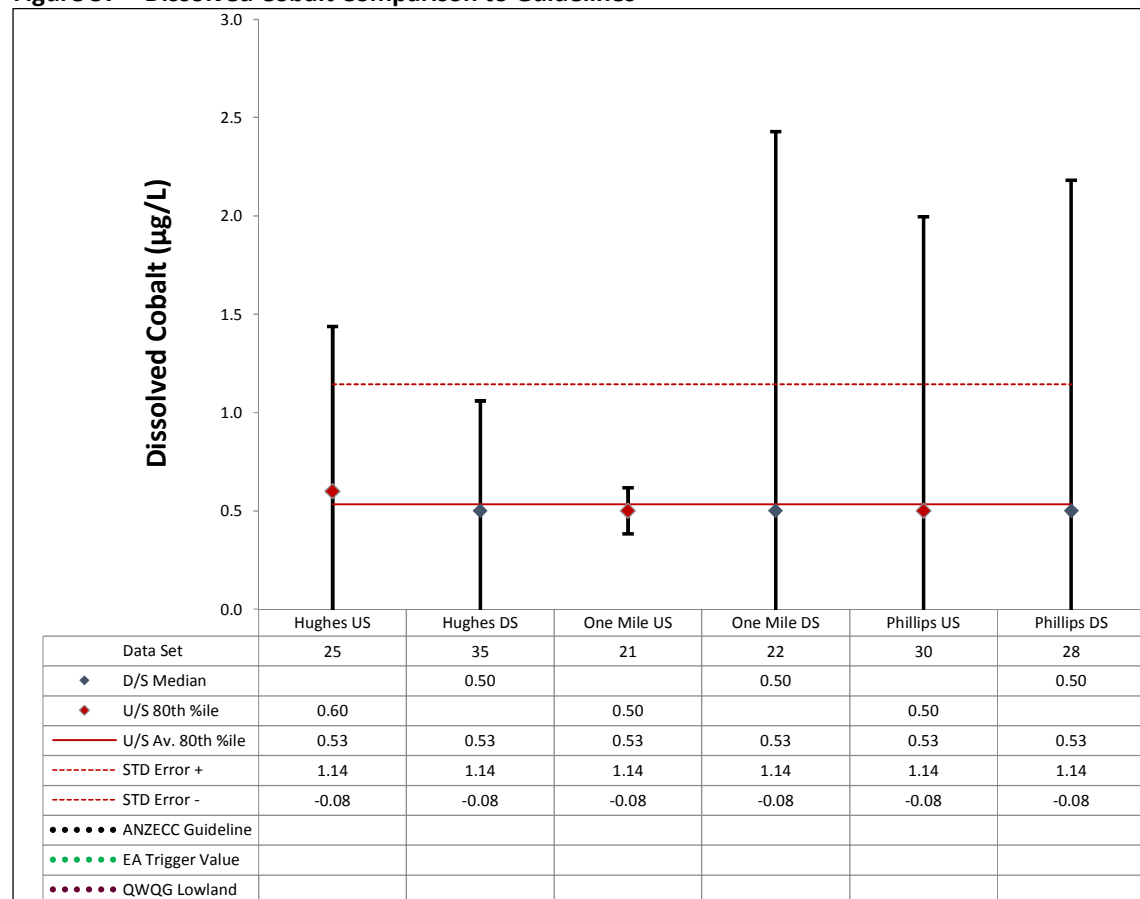


Figure 58 – Total Cobalt Box & Whisker Plot

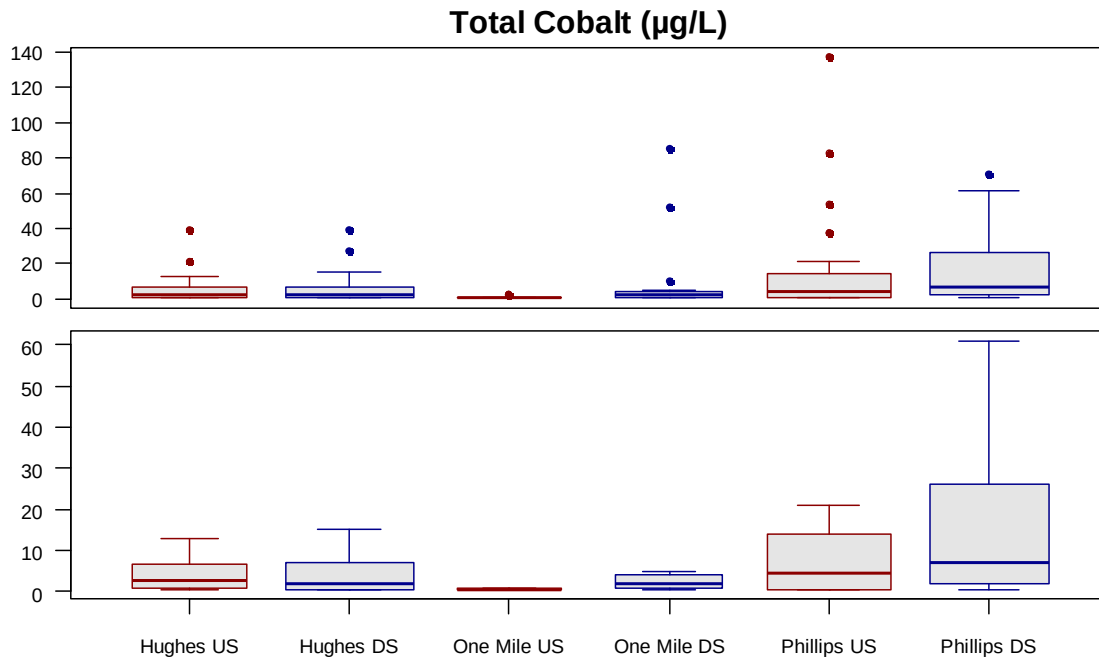
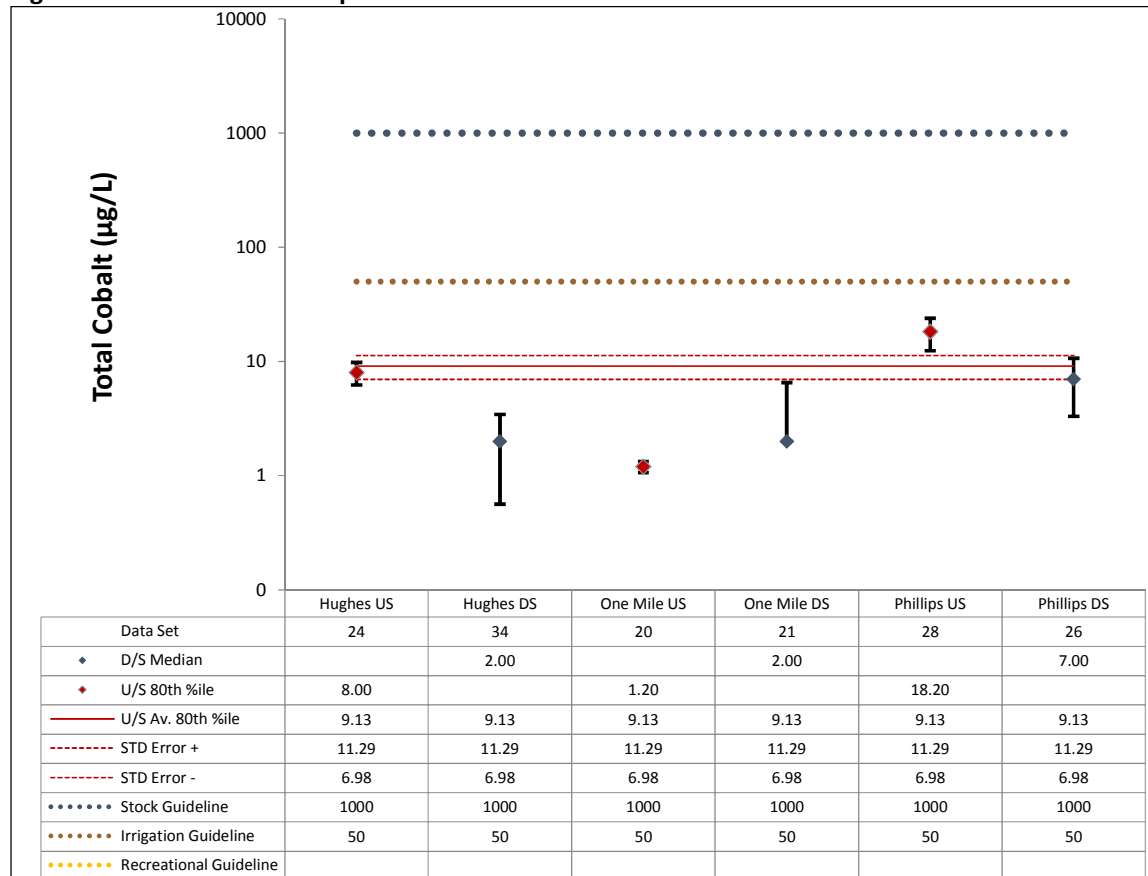


Figure 59 – Total Cobalt Comparison to Guidelines



6.4.20 Copper

6.4.20.1 Dissolved Copper

Dissolved copper levels remain steady as Hughes, One Mile, and Phillip creeks progress through the mine lease. The median for upstream One Mile Creek ($0.5\mu\text{g/L}$) increased downstream to $1\mu\text{g/L}$ (Figure 60).

The downstream medians were below, or equal to, the average upstream 80th percentile, indicating concentrations are not being altered beyond acceptable levels for SMD ecosystems.

The average upstream 80th percentile ($2\mu\text{g/L}$) was above the ANZECC ecosystem (SMD) guideline of $1.4\mu\text{g/L}$ (Figure 61). This indicates a new or interim guideline may be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were within the 'reasonably consistent' category, indicating reference sites were within one standard error (of the average 80th percentile). Therefore, a local guideline of $2\mu\text{g/L}$ (average 80th percentile) is suggested, which is the same as the current EA trigger value.

6.4.20.2 Total Copper

Total copper levels slightly increased as Hughes, One Mile, and Phillips creeks progressed through the mine lease (Figure 62). However, downstream medians were below the average upstream 80th percentile (plus one standard error) and the ANZECC guidelines.

The average upstream 80th percentile ($9.9\mu\text{g/L}$) was well below the ANZECC guidelines for stock watering ($1,000\mu\text{g/L}$), and irrigation ($200\mu\text{g/L}$) (Figure 63).

Total copper levels in Hughes, One Mile, and Phillips creeks are below levels of concern for the local environment and do not appear to be unacceptably altered by mining activity.

Figure 60 – Dissolved Copper Box & Whisker Plot

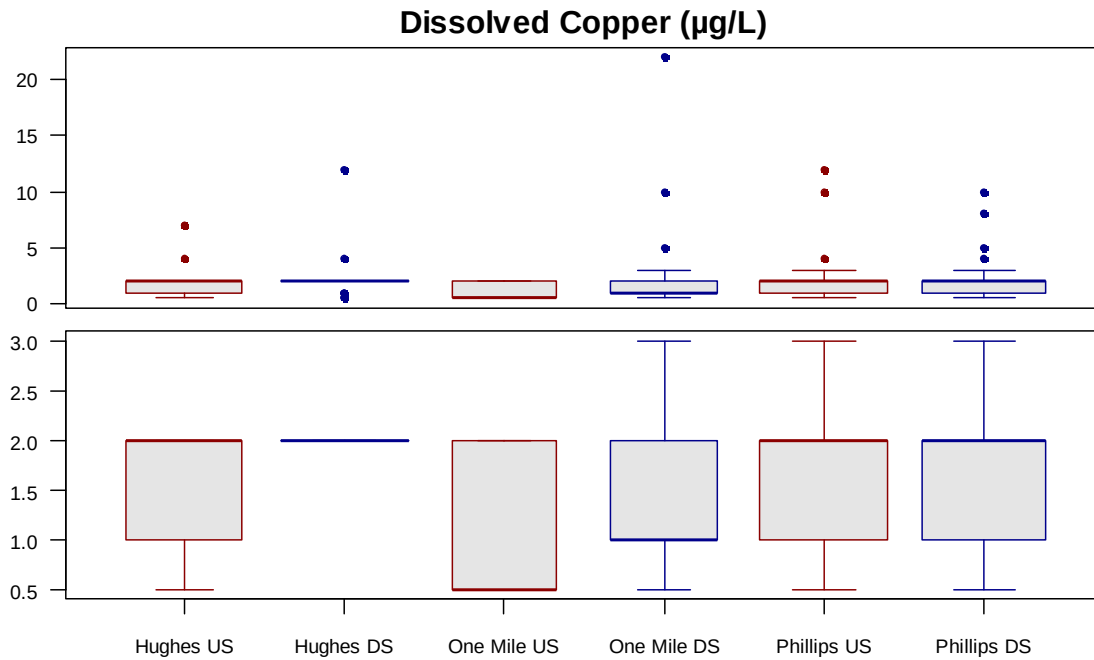


Figure 61 – Dissolved Copper Comparison to Guidelines

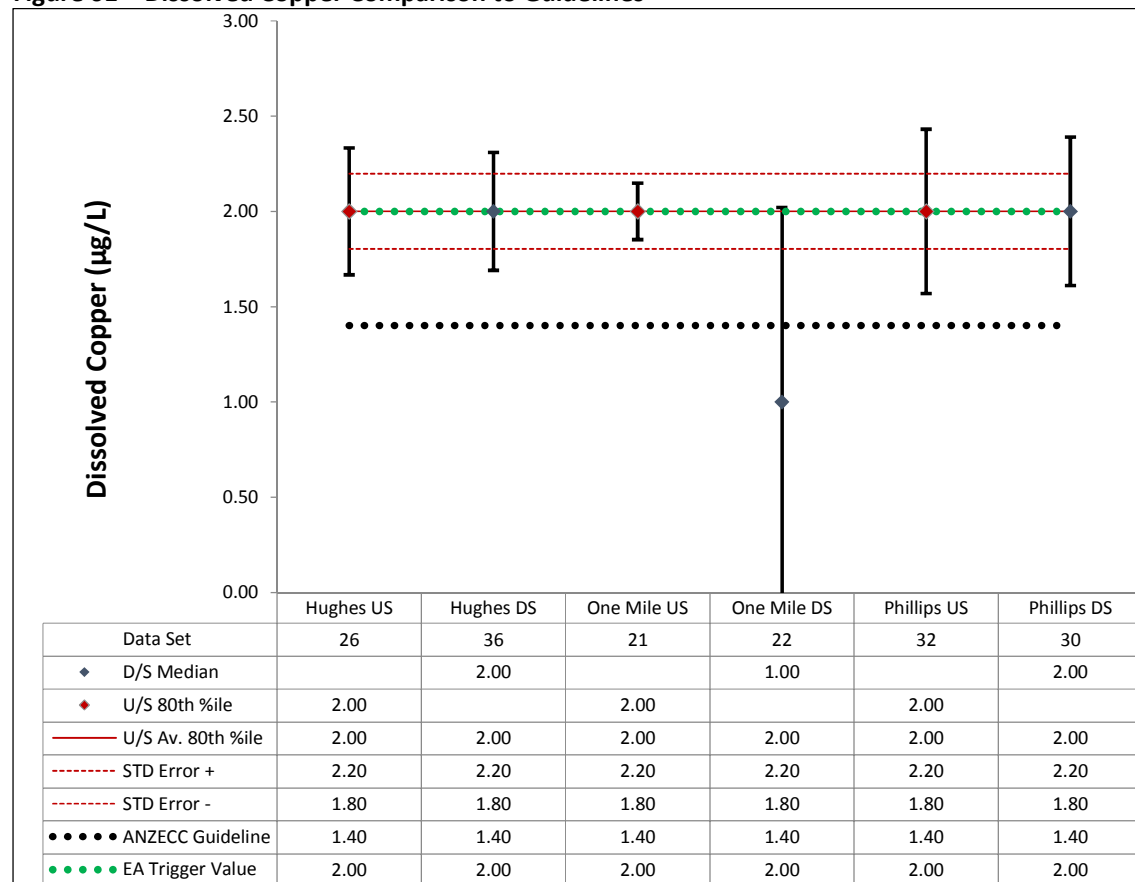


Figure 62 – Total Copper Box & Whisker Plot

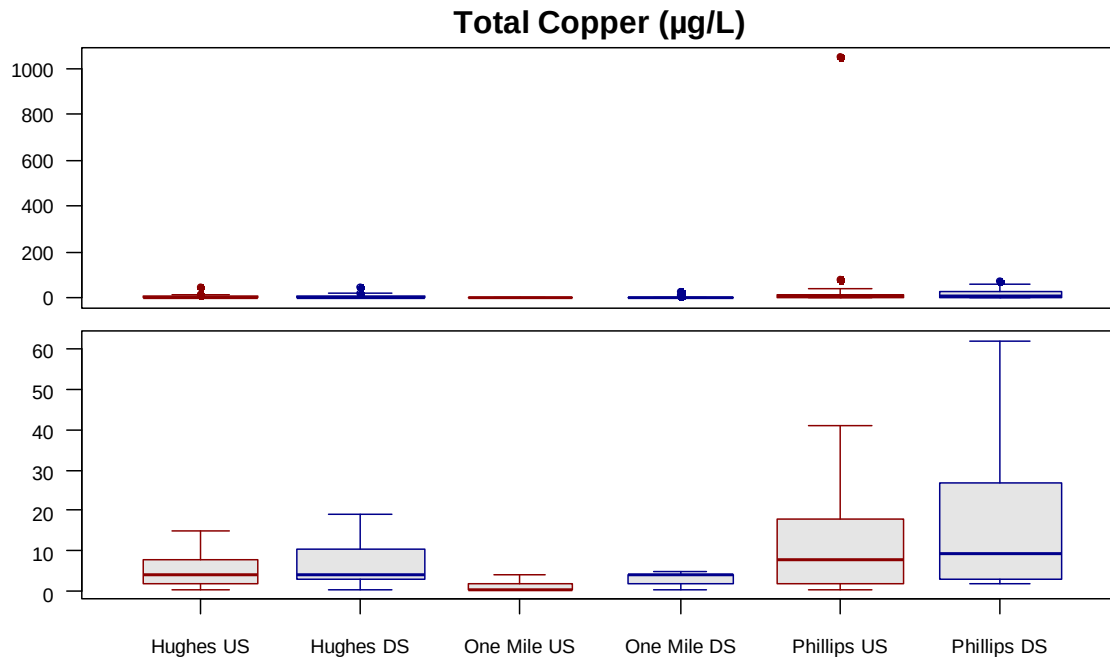
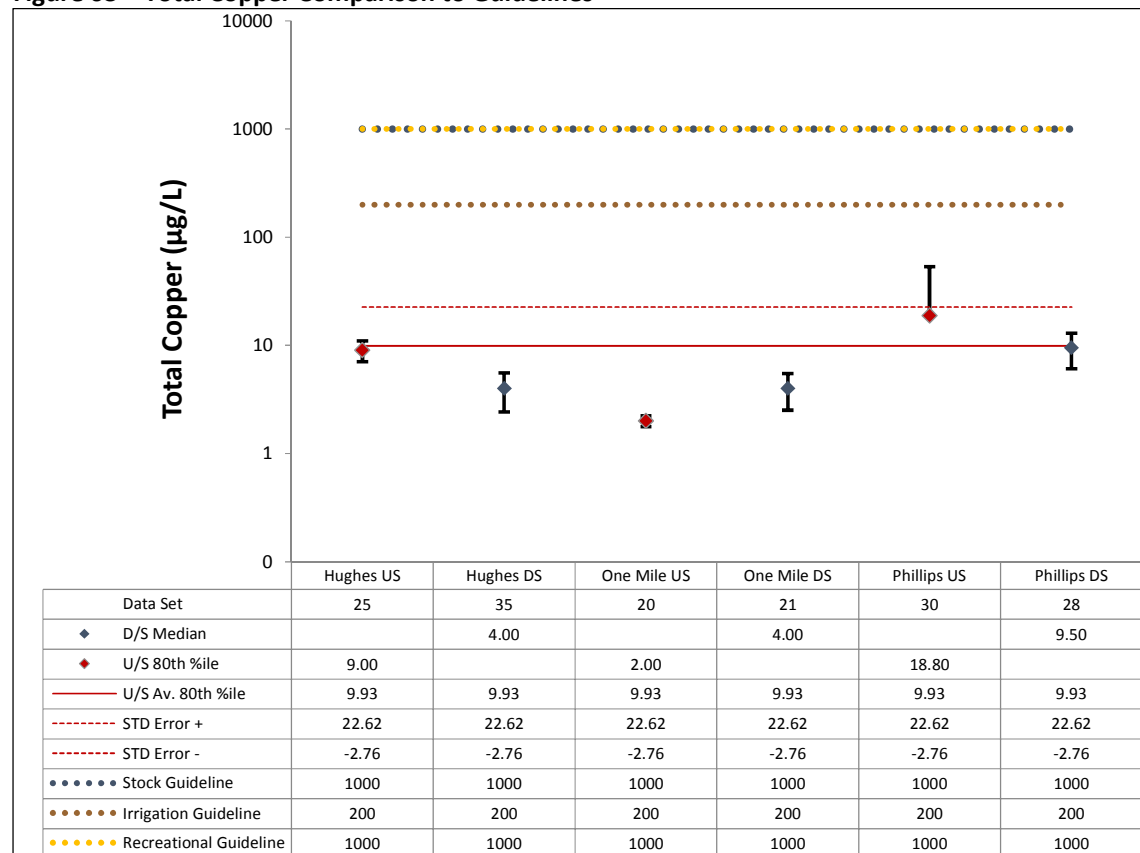


Figure 63 – Total Copper Comparison to Guidelines



6.4.21 Iron

6.4.21.1 Dissolved Iron

Dissolved iron levels slightly decrease as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 64).

The downstream medians were lower than the upstream 80th percentile and below the EA trigger.

No current guideline exists and therefore a new or interim guideline may be suggested (QWQG 2009). The average and individual upstream 80th percentiles (971µg/L) were below or within one standard error of the current EA trigger (1,130µg/L). This EA trigger value is based on the 80th percentile recorded previously, and as such exists as an interim local guideline. Since the updated average 80th percentile is accommodated within this value, and is within one standard error of the highest upstream 80th percentile (One Mile Creek), the trigger could be retained as the guideline.

6.4.21.2 Total Iron

Total iron levels generally increased as Hughes, One Mile, and Phillips creeks progress through the mining lease (Figure 66 & Figure 67).

The average upstream 80th percentile (13,598µg/L) was well above the ANZECC guidelines for irrigation (200µg/L) and recreation (300µg/L) (Figure 67), indicating the guidelines are over stringent for local conditions or the streams are naturally unsuitable for these applications.

Downstream medians were below the average upstream 80th percentile but above the irrigation and recreation guidelines.

There are naturally high total iron levels in Hughes, One Mile and Phillips creeks and mining activity does not increase these levels unacceptably for SMD ecosystems.

Figure 64 – Dissolved Iron Box & Whisker Plot

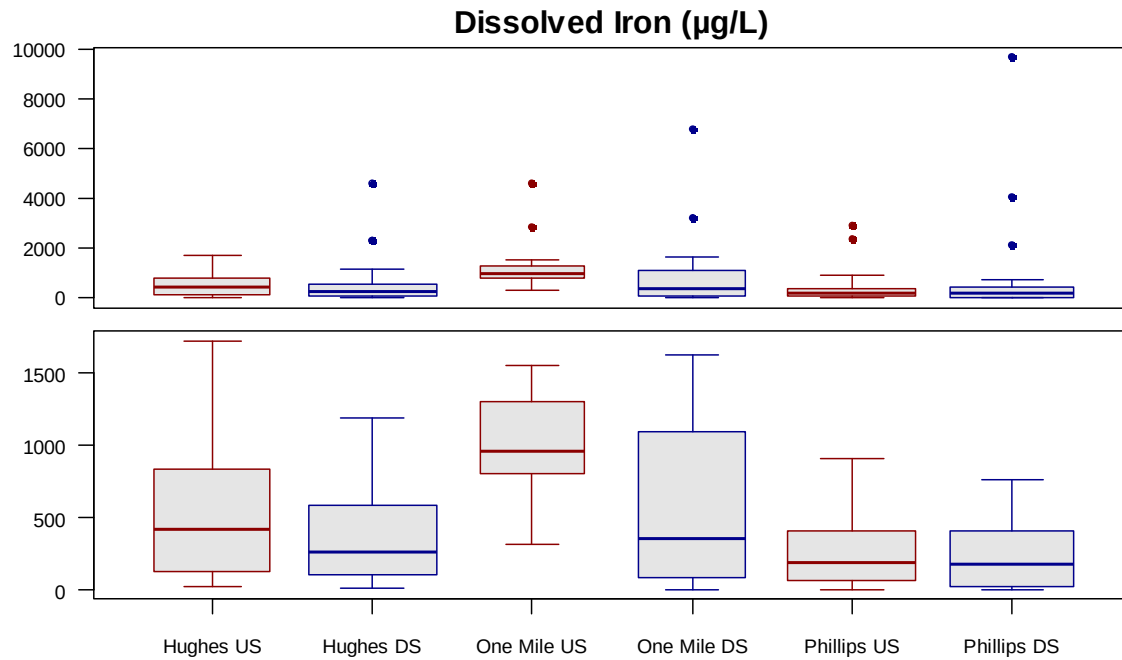


Figure 65 – Dissolved Iron Comparison to Guidelines

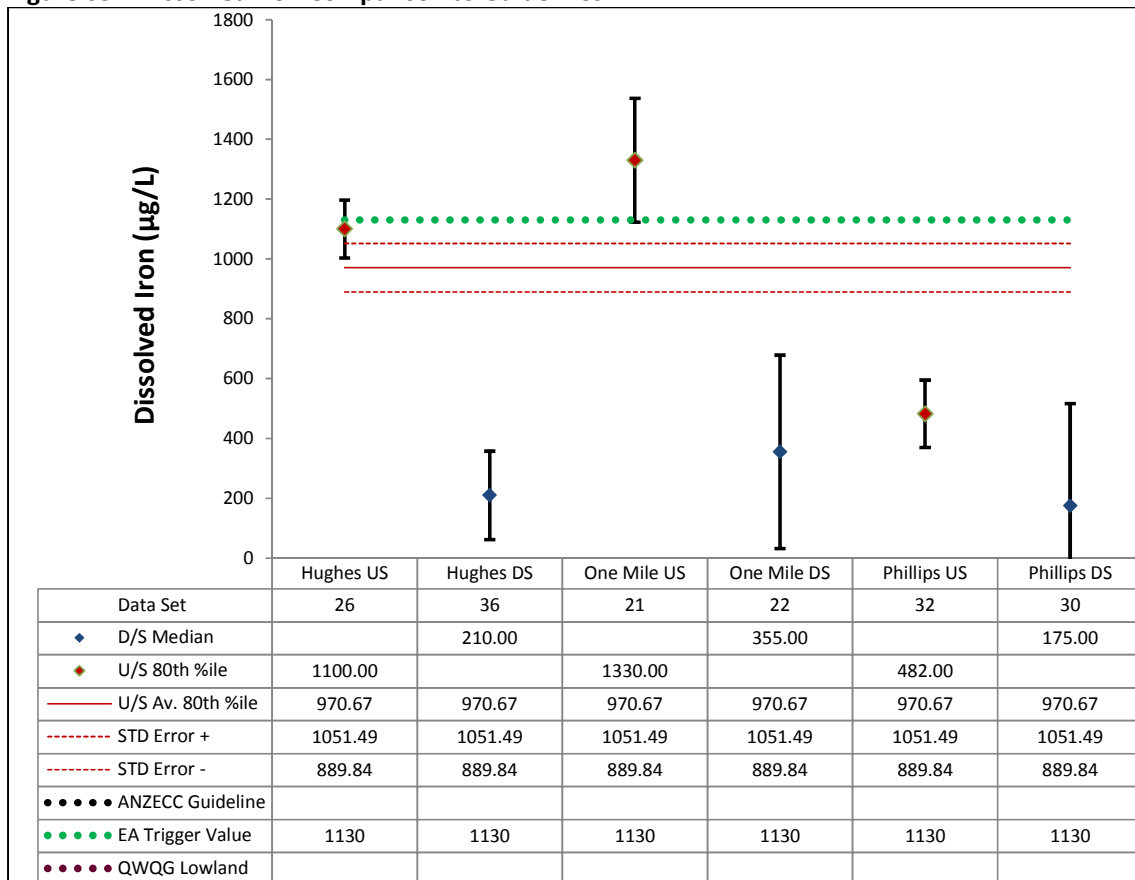


Figure 66 – Total Iron Box & Whisker Plot

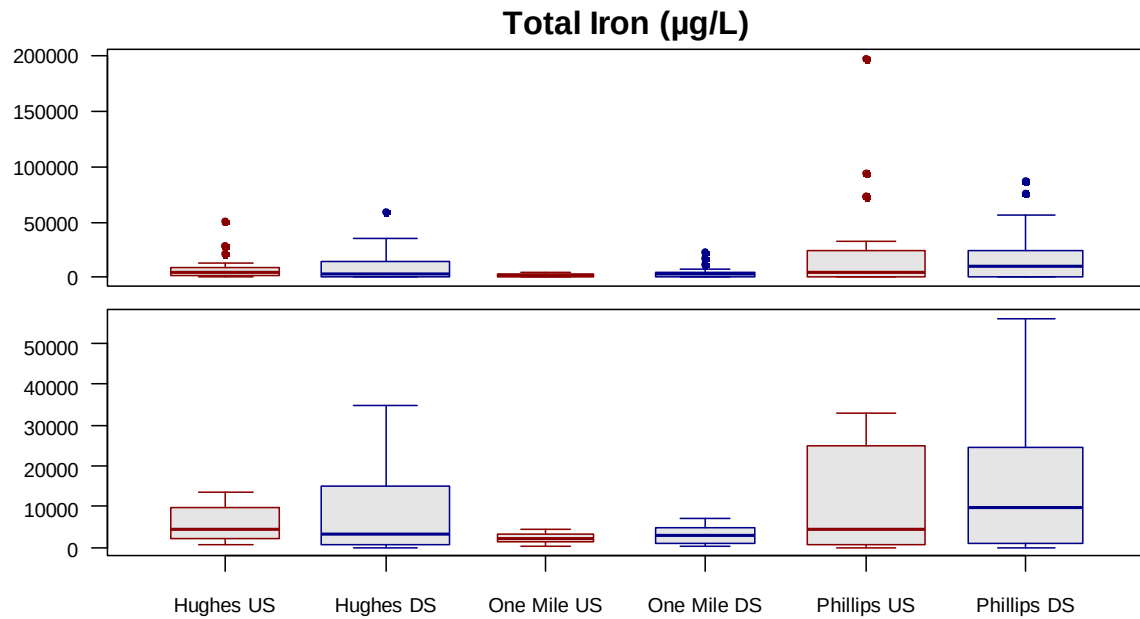
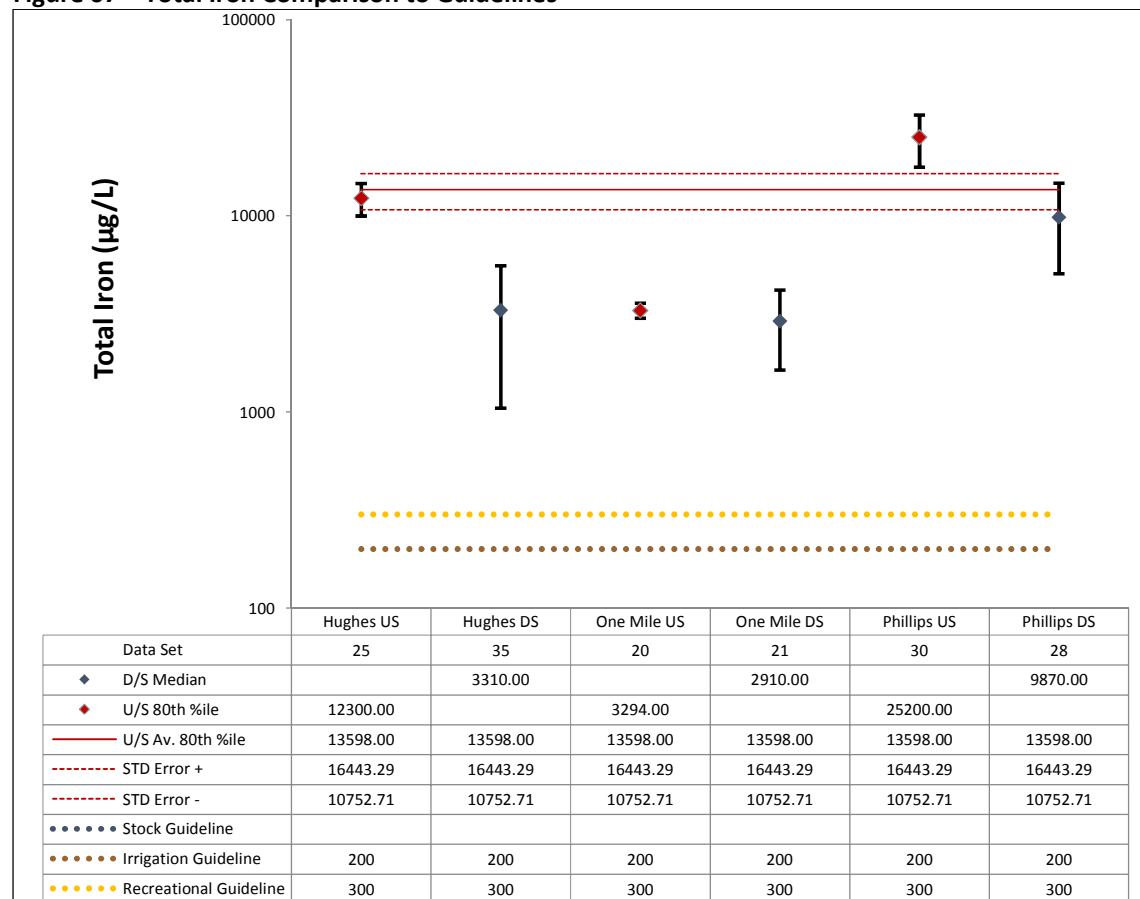


Figure 67 – Total Iron Comparison to Guidelines



6.4.22 Lead

6.4.22.1 Dissolved Lead

Dissolved lead levels remain static as Hughes, One Mile and Phillips creeks progress through the mine lease (Figure 68). A total of 22 outliers were identified for upstream and downstream sites, which indicates that the occasional excursion from generally static lead levels is a natural variation.

Most (>85%) upstream and downstream results were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L.

The average upstream 80th percentile (0.53µg/L) was below the ANZECC ecosystem (SMD) guideline of 3.4µg/L, and above the downstream median values (Figure 69).

The results indicate dissolved lead is below levels of concern and do not appear to be altered by mining activity. Should this analyte be used as a trigger, the ANZECC guideline (3.4µg/L) would accommodate the local conditions.

6.4.22.2 Total Lead

Total lead levels increased slightly as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 70), however, downstream medians were below or within one standard error of the upstream 80th percentiles.

The average upstream 80th percentile (11.5µg/L) was well below the ANZECC guidelines for stock watering (100µg/L), irrigation (2,000µg/L), and recreation ((50µg/L) (Figure 71).

Total lead levels in Hughes, One Mile, and Phillips creeks are below the level of concern for the local environment and appear not be unacceptably altered by mining activity.

Figure 68 – Dissolved Lead Box & Whisker Plot

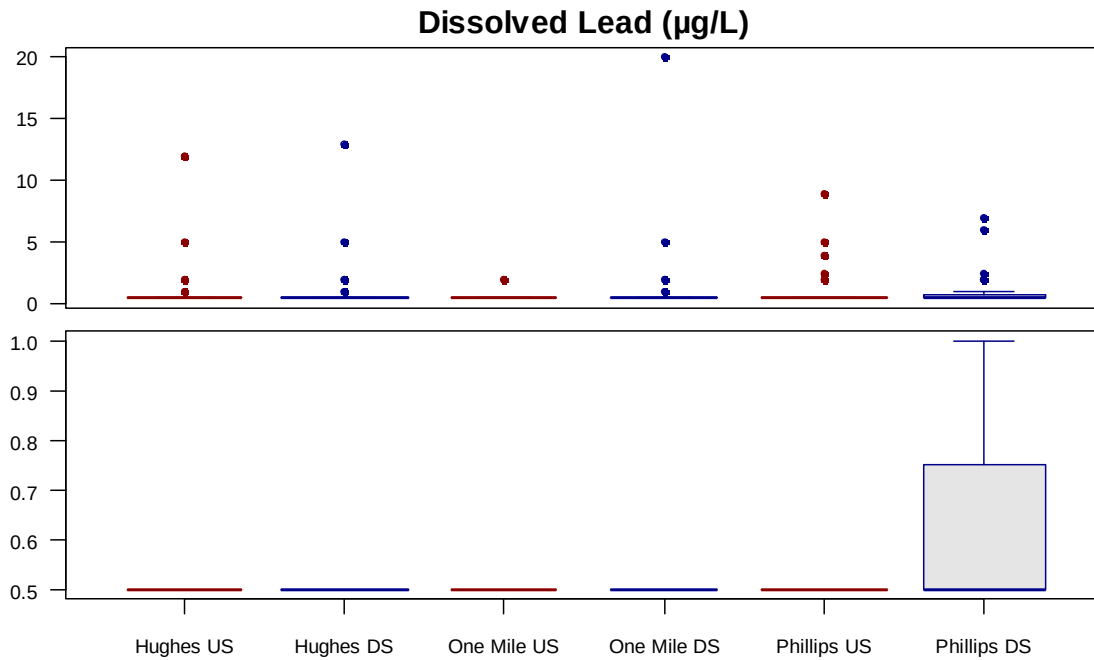


Figure 69 – Dissolved Lead Comparison to Guidelines

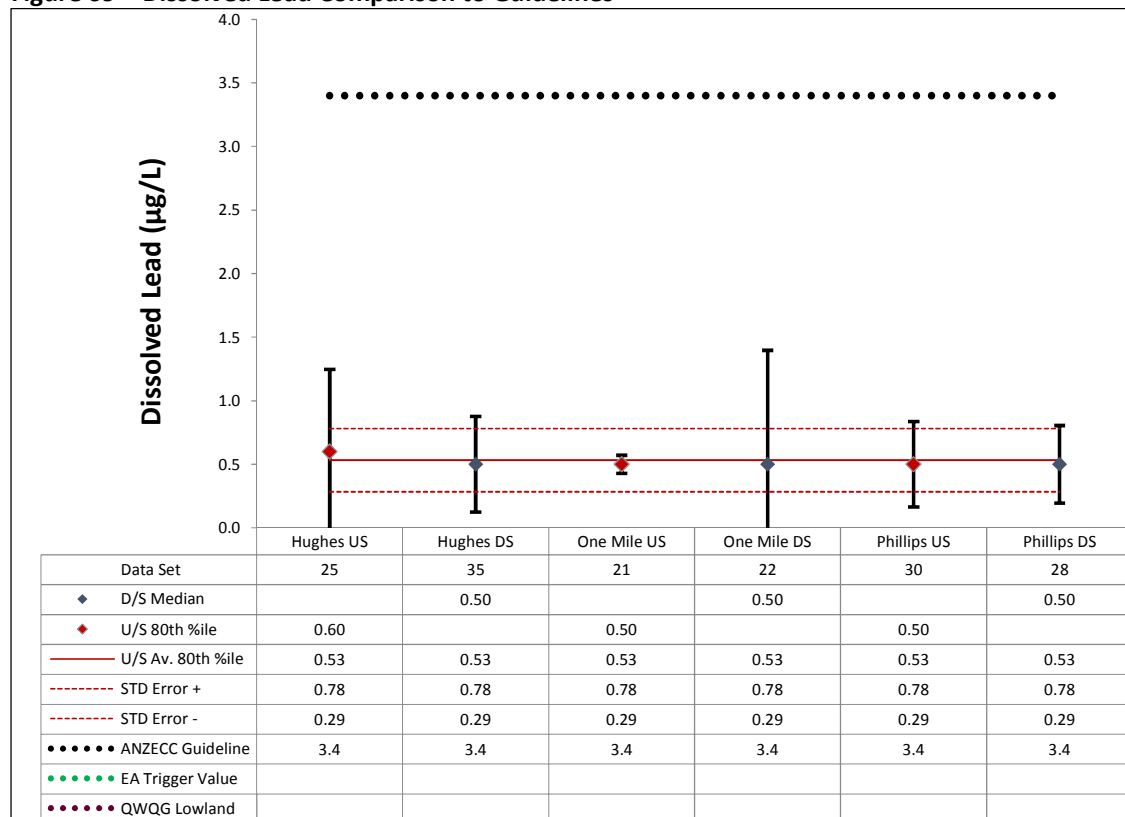


Figure 70 – Total Lead Box & Whisker Plot

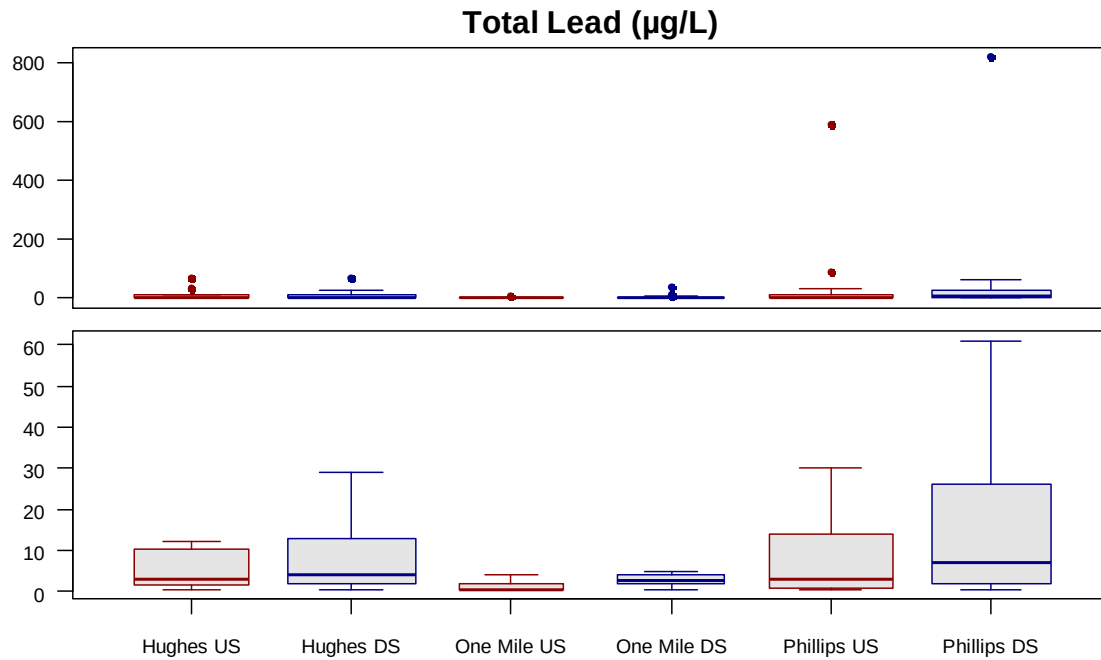
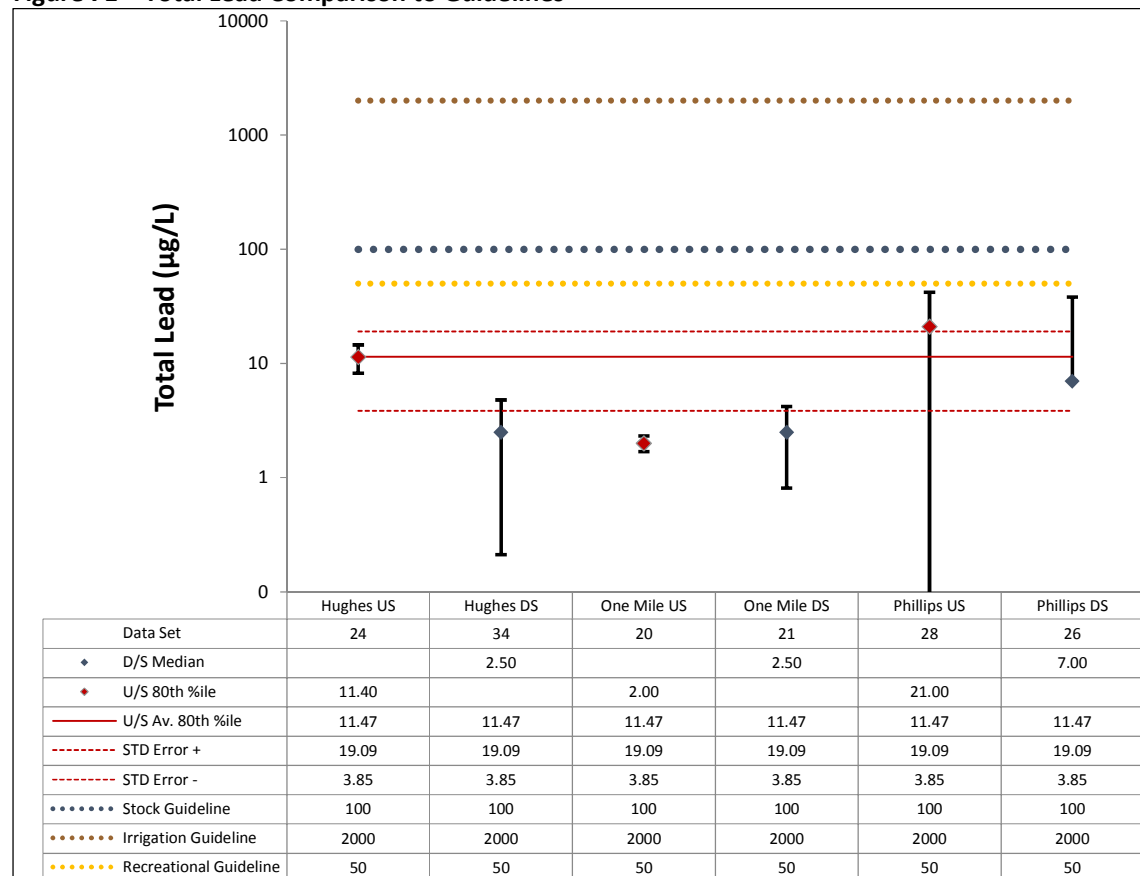


Figure 71 – Total Lead Comparison to Guidelines



6.4.23 Manganese

6.4.23.1 Dissolved Manganese

Dissolved manganese medians were steady or decreased slightly as Hughes, Phillips and One Mile creeks progressed through the mine lease (Figure 72). The significant number of outliers both upstream and downstream suggests that occasionally high manganese values (higher than the ANZECC guideline) occur naturally in the local streams.

The average upstream 80th percentile (38.8µg/L) was significantly lower than the ANZECC guideline (1,900µg/L) and above the downstream medians (Figure 73).

The results indicate dissolved manganese is well below levels of concern and does not appear to be altered by mining activity. Should this analyte be used as a trigger, the ANZECC guideline (1,900µg/L) accommodates local conditions.

6.4.23.2 Total Manganese

Total manganese levels generally decrease as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 74).

The average upstream 80th percentile (273µg/L) was above the ANZECC guidelines for irrigation (200µg/L) and recreation (100µg/L) (Figure 75).

Downstream medians for Hughes (51µg/L) and One Mile (44µg/L) creeks were below irrigation and recreation guidelines. Phillips Creek (211µg/L) was above the recreation and irrigation guidelines (Figure 75).

Downstream medians for all streams were below the respective upstream 80th percentiles.

Total manganese levels in Hughes, One Mile, and Phillips Creeks are below levels of concern for the local environment and do not appear to be increased by mining activity.

Figure 72 – Dissolved Manganese Box & Whisker Plot

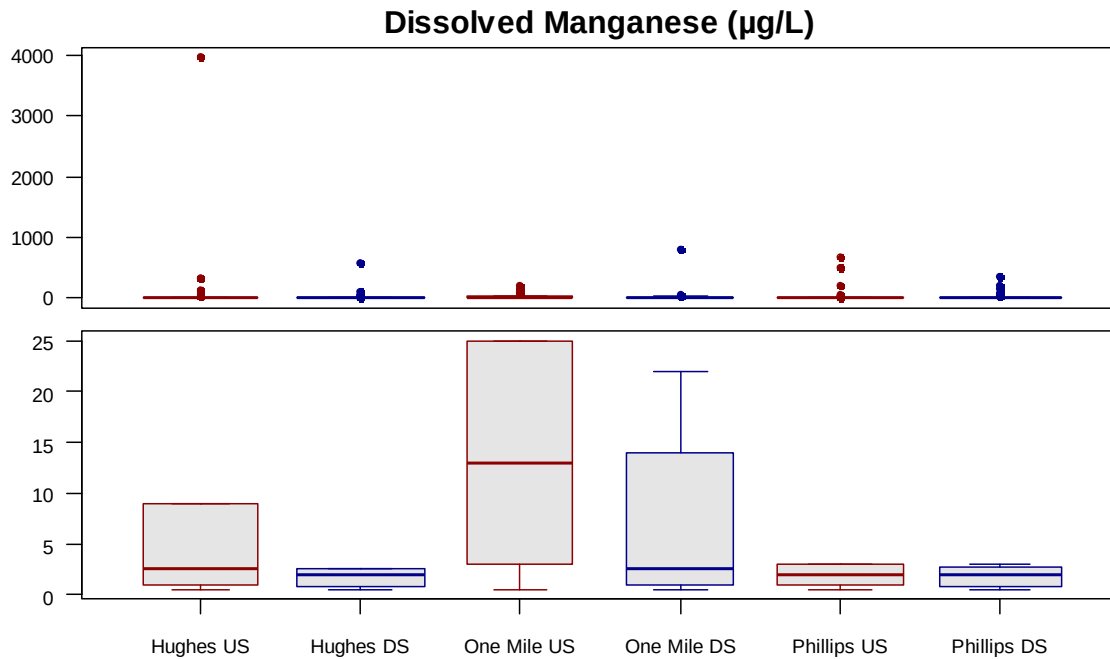


Figure 73 – Dissolved Manganese Compared to Guidelines

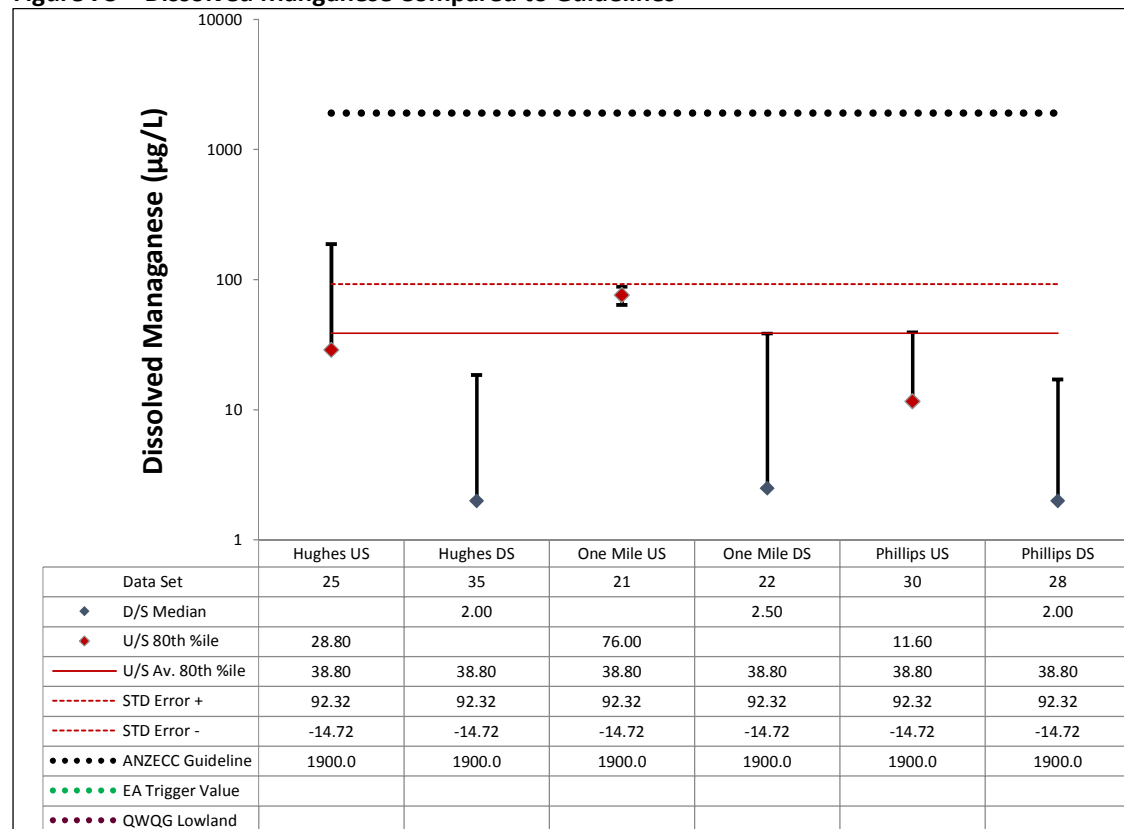


Figure 74 – Total Manganese Box & Whisker Plot

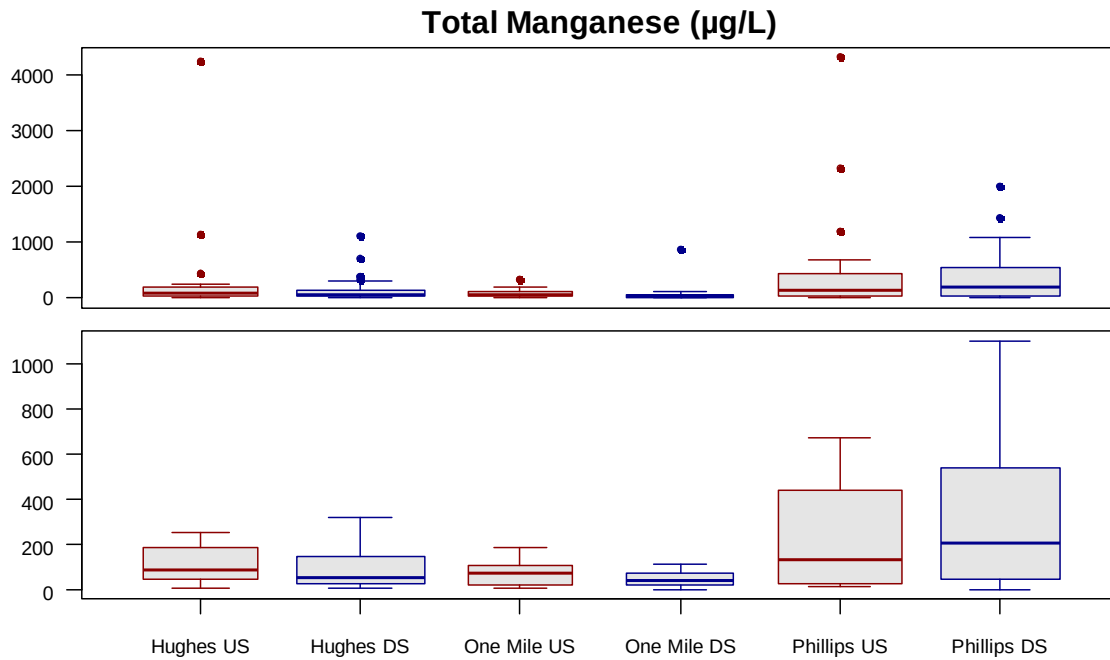
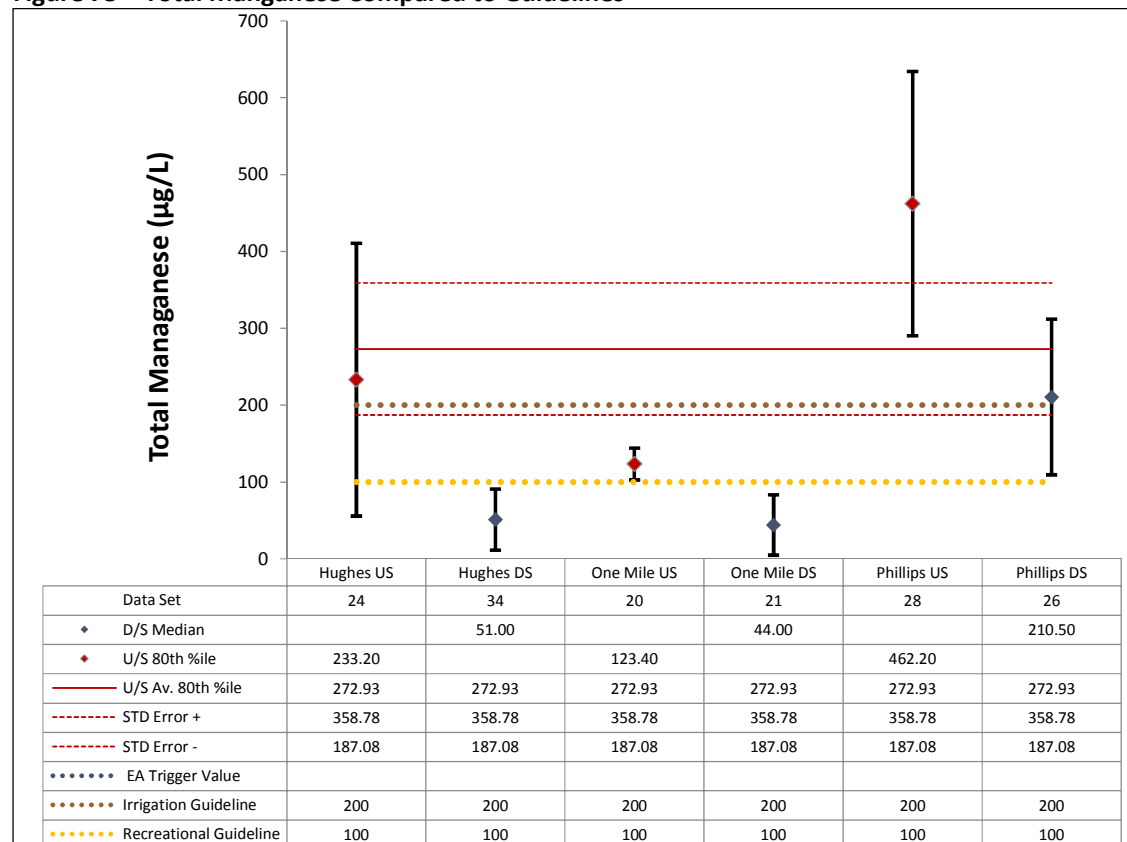


Figure 75 – Total Manganese Compared to Guidelines



6.4.24 Mercury

6.4.24.1 Dissolved Mercury

Dissolved mercury levels remained steady as Hughes, One Mile, and Phillips creeks progressed through the mine lease, however this was a function of the limits of reporting (LOR) (Figure 76).

All upstream and downstream results (except 5 results) were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L.

The average upstream 80th percentile (0.05µg/L) was below the ANZECC ecosystem (SMD) guideline of 0.06µg/L, and equivalent to downstream median values (Figure 77).

The results indicate dissolved mercury is below levels of concern and detection, and does not appear to be altered by mining activity. Should this analyte be used as a trigger, the ANZECC guideline would be appropriate (0.06µg/L), however this is below the typical LOR of 0.1µg/L. A trigger twice the LOR (giving 0.2µg/L) would be more practical in reducing false alarms and for future statistical analysis when using the *50% LOR rule*. This value was the trigger used in previous EAs and has practical merit.

6.4.24.2 Total Mercury

Total mercury levels remained steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 78).

All results were below the limit of detection and this is reflected in upstream and downstream medians and average 80th percentiles being the same (0.05µg/L).

The average 80th percentile upstream value (0.05µg/L) was well below the ANZECC guidelines for stock and irrigation (2µg/L) and recreation (1µg/L) (Figure 79).

Total mercury levels in Hughes, One Mile, and Phillips creeks are below levels of concern and do not appear to be increased by mining activity.

Figure 76 – Dissolved Mercury Box & Whisker Plot

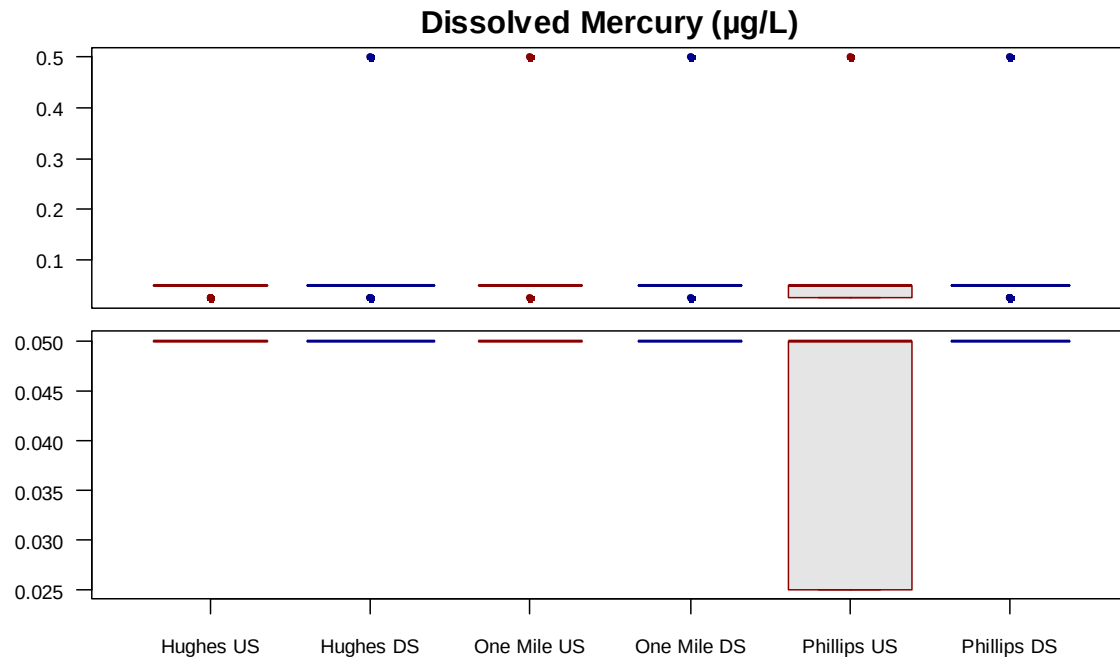


Figure 77 – Dissolved Mercury Comparison to Guidelines

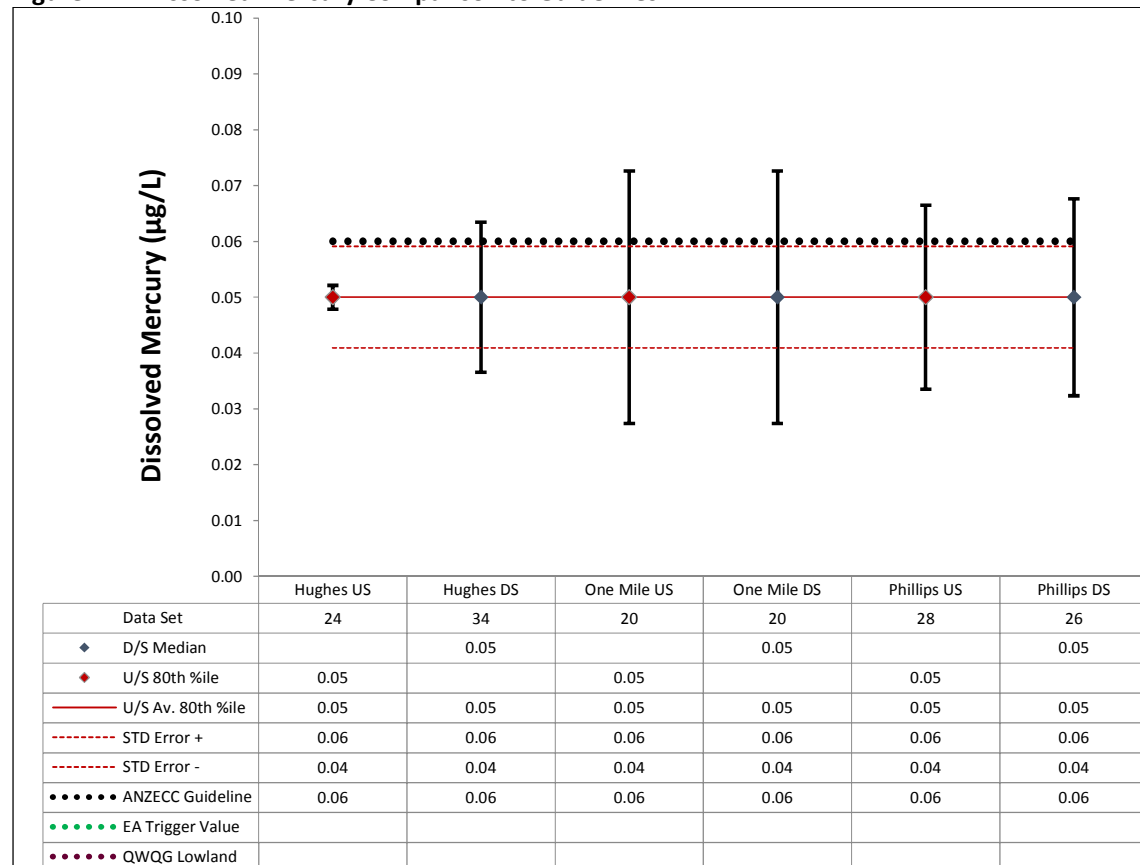


Figure 78 – Total Mercury Box & Whisker Plot

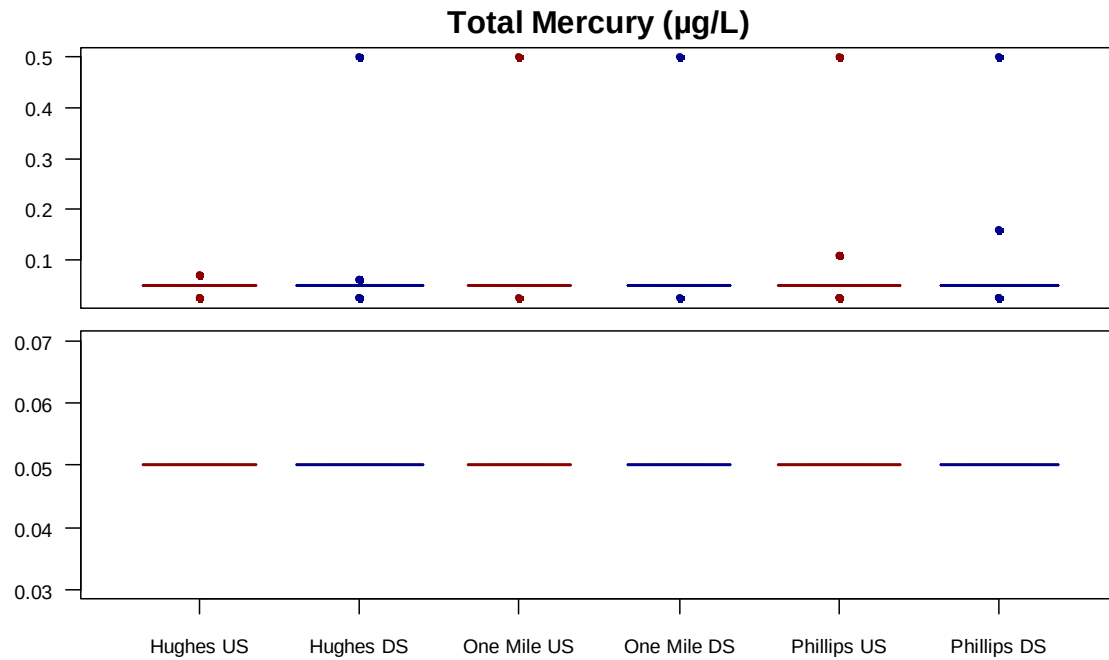
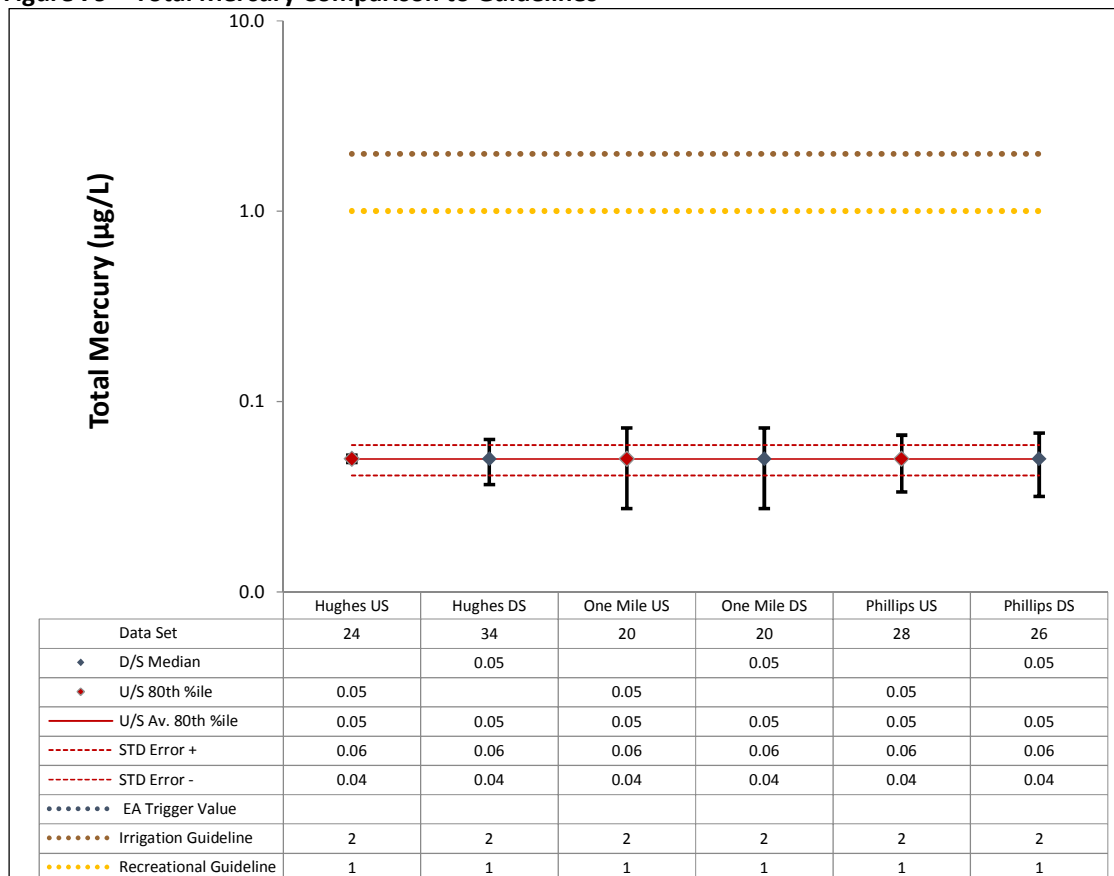


Figure 79 – Total Mercury Comparison to Guidelines



6.4.25 Molybdenum

6.4.25.1 Dissolved Molybdenum

Dissolved molybdenum levels remain steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 80).

Most upstream and downstream results (>75%) were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L.

The average upstream 80th percentile (0.5µg/L) was equivalent to median downstream values (Figure 81). The mine water release event during nil natural flow (30 Jun 2011 to 8 Jul 2011) accounted for the outliers greater than 4µg/L at Hughes Creek downstream. Removing this mine water release event data did not change the Hughes Creek downstream median (Appendix A) which was equivalent to the upstream 80th percentile (0.5µg/L).

The results indicate dissolved molybdenum is below levels of concern and not being significantly altered by mining activity. Proximity of results to the LOR has skewed the data set and would make setting a local guideline inappropriate.

6.4.25.2 Total Molybdenum

Total molybdenum levels remained steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 82).

The average 80th percentile upstream (0.67µg/L) was well below the ANZECC guidelines for stock (150µg/L) and irrigation (10µg/L) (Figure 83).

The mine water release event during nil natural flow (30 Jun 2011 to 8 Jul 2011) accounted for the outliers of 4µg/L or greater at the Hughes Creek downstream site. Removing this event data did not change the Hughes Creek downstream median (Appendix A) which was equivalent to the upstream 80th percentile (0.5µg/L).

Total molybdenum levels in Hughes, One Mile, and Phillips creeks are below levels of concern and do not appear to be increased by mining activity.

Figure 80 – Dissolved Molybdenum Box & Whisker Plot

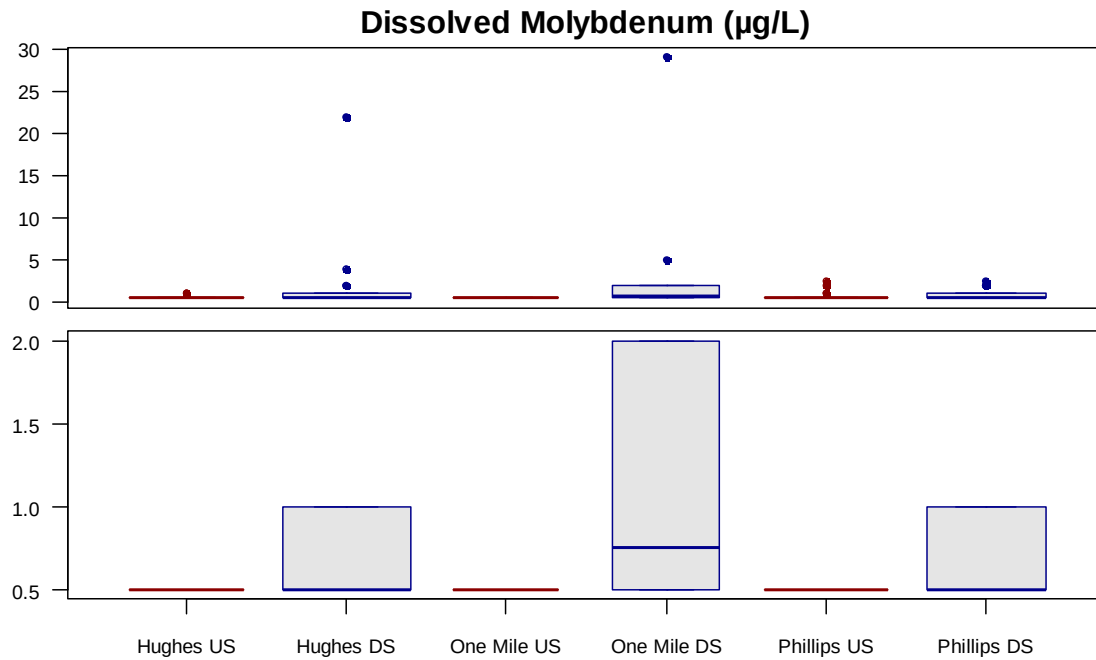


Figure 81 – Dissolved Molybdenum Compared to Guidelines

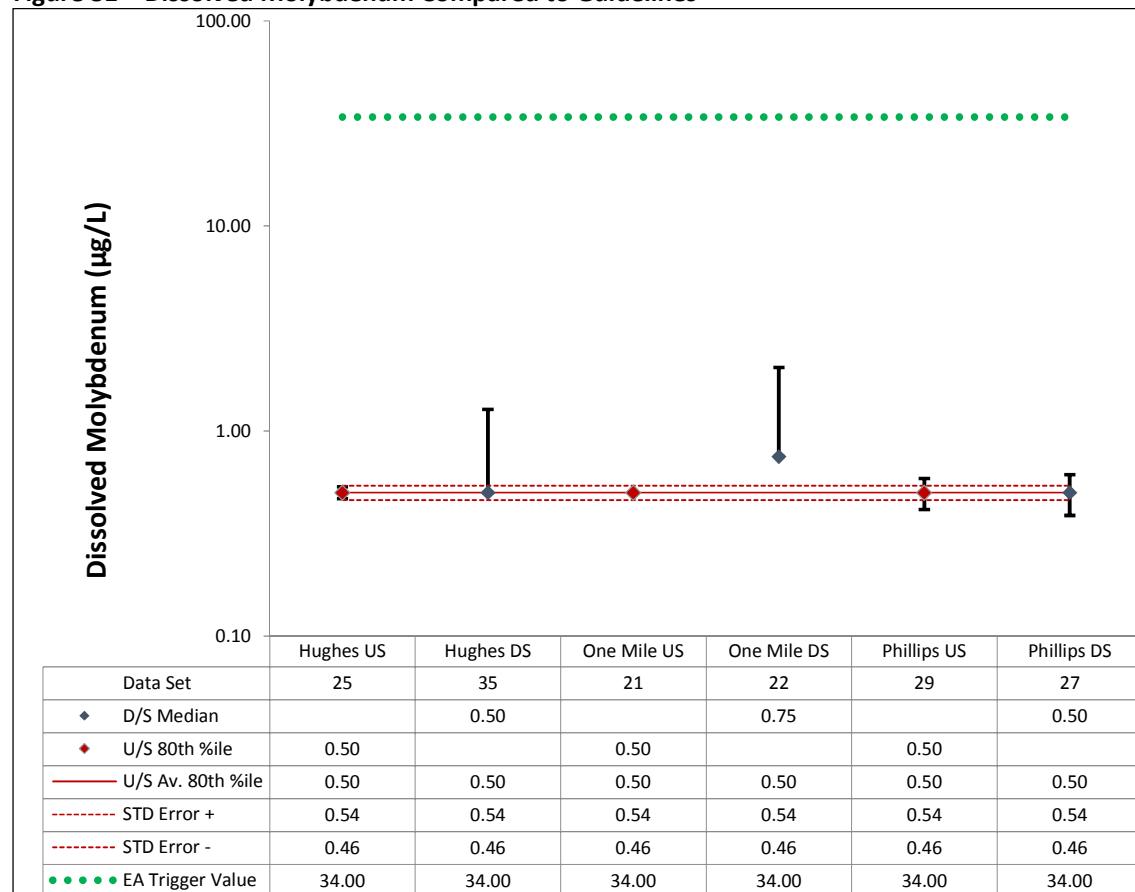


Figure 82 - Total Molybdenum Box & Whisker Plot

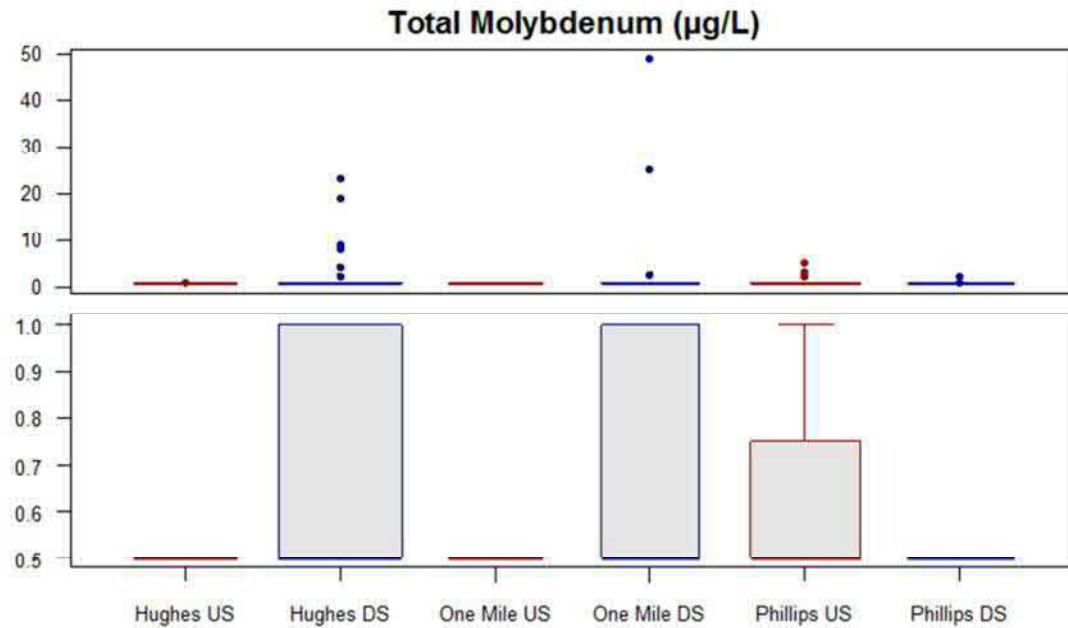
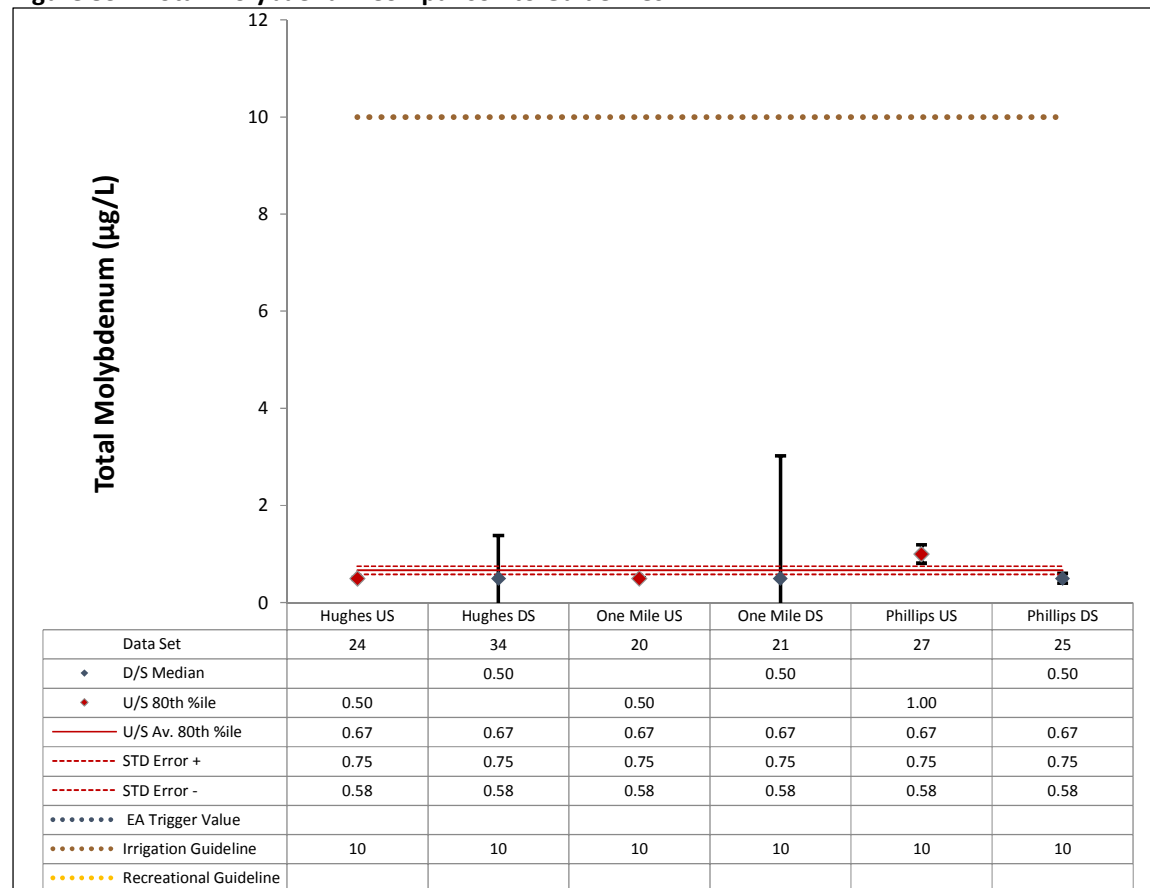


Figure 83 – Total Molybdenum Comparison to Guidelines



6.4.26 Nickel

6.4.26.1 Dissolved Nickel

Dissolved nickel medians remained steady as Hughes and One Mile creeks progressed through the mine lease. The median for upstream Phillips Creek ($2\mu\text{g/L}$) increased downstream ($3\mu\text{g/L}$), however remained below the upstream 80th percentile (Figure 84).

The average 80th percentile upstream ($3.5\mu\text{g/L}$) was below the ANZECC guideline ($11\mu\text{g/L}$) (Figure 85).

The results indicate dissolved nickel is below levels of concern and not being unacceptably altered by mining activity. The ANZECC guideline ($11\mu\text{g/L}$) adequately accommodates local conditions.

6.4.26.2 Total Nickel

Total nickel levels generally increase as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 86). However, downstream medians remained below the average upstream 80th percentile and ANZECC guidelines.

The average 80th percentile upstream ($22.4\mu\text{g/L}$) was well below the ANZECC guidelines for stock ($1,000\mu\text{g/L}$), irrigation ($200\mu\text{g/L}$), and recreation ($100\mu\text{g/L}$) (Figure 87).

Total nickel levels in Hughes, One Mile, and Phillips creeks were below levels of concern and do not appear to have increased unacceptably by mining activity.

Figure 84 – Dissolved Nickel Box & Whisker Plot

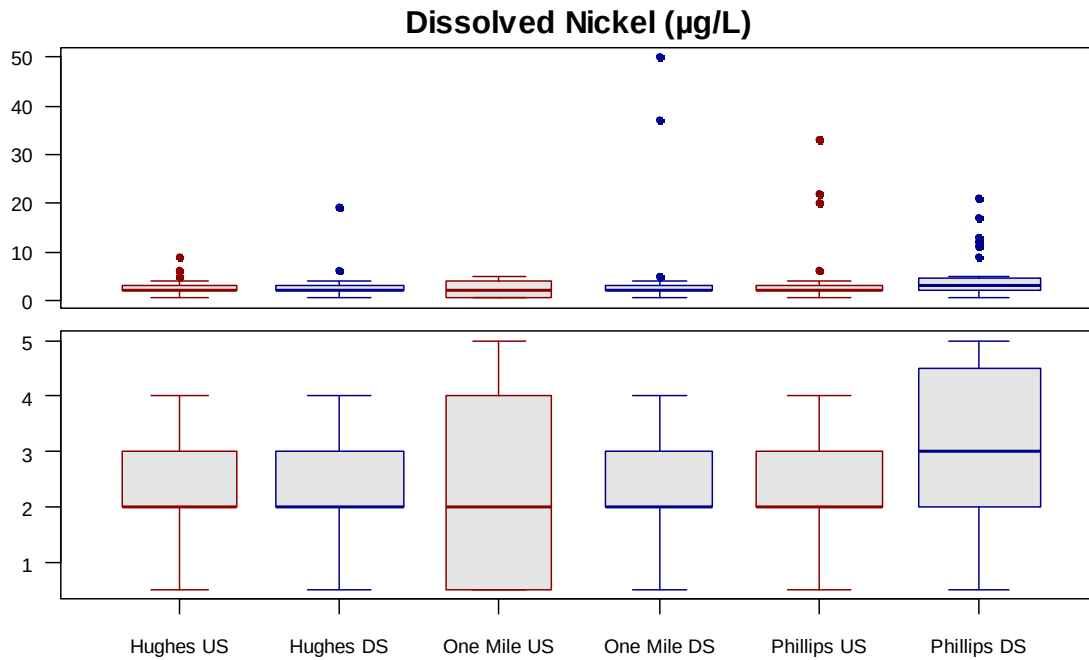


Figure 85 – Dissolved Nickel Comparison to Guidelines

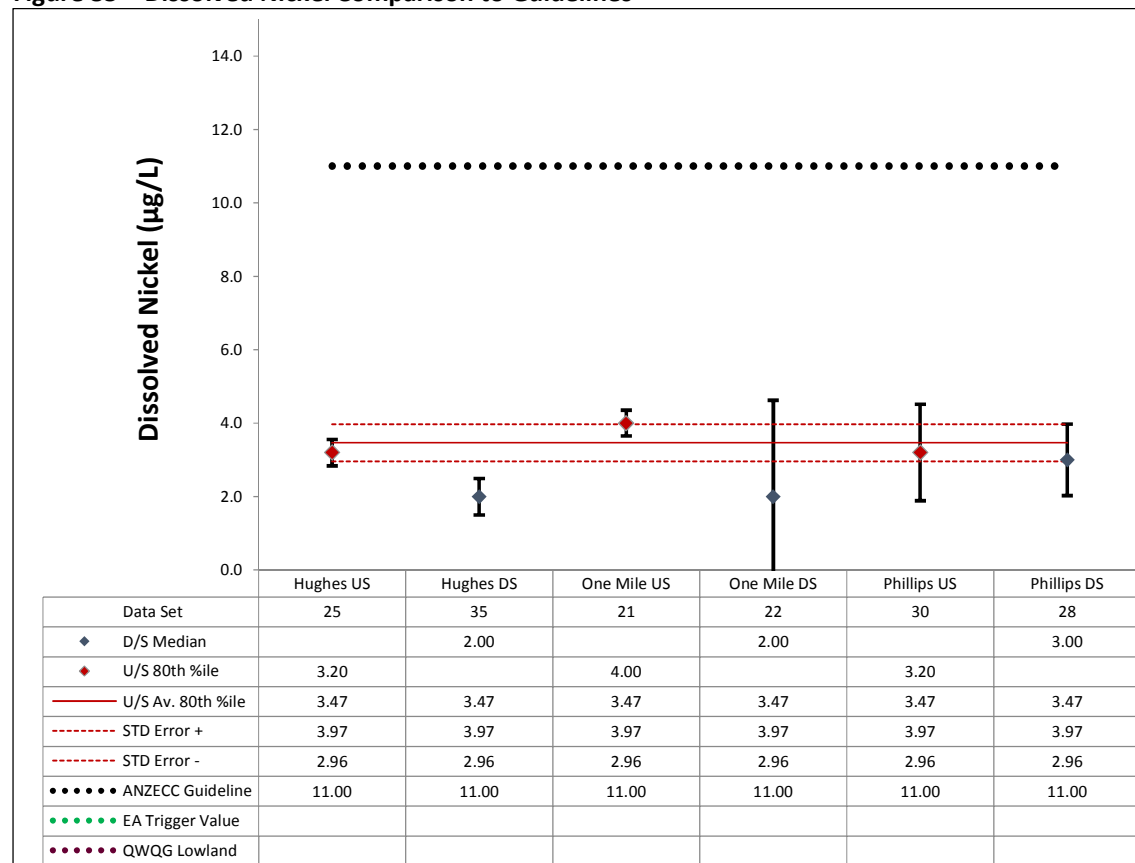


Figure 86 - Total Nickel Box & Whisker Plot

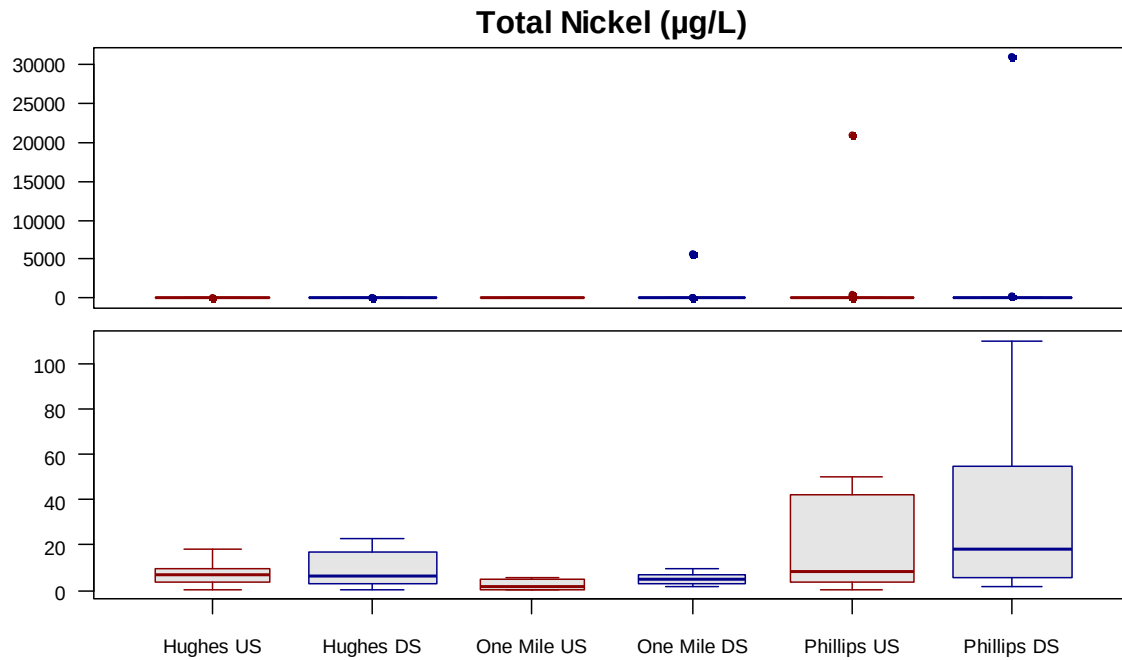
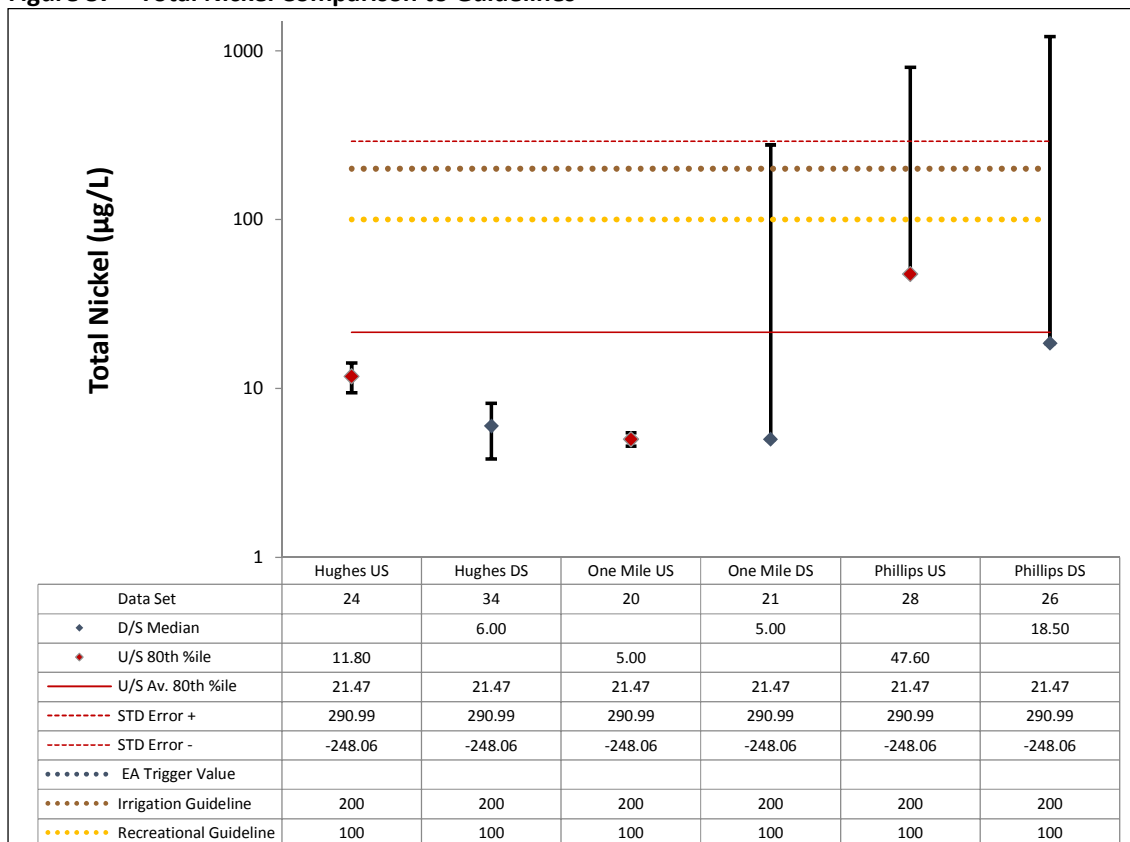


Figure 87 – Total Nickel Comparison to Guidelines



6.4.27 Selenium

6.4.27.1 Dissolved Selenium

Dissolved selenium levels increased as Hughes, One Mile, and Phillips creeks progressed through the mine lease. The upstream median range of 0.25 - 0.3µg/L increased downstream to 0.4 – 0.8µg/L (Figure 88).

The One Mile Creek median was slightly greater than one standard error higher than the upstream 80th percentile. The One Mile Creek finding requires qualification in that the upstream site may be unrepresentative of the catchment due to the addition of pipeline water from Bedford Weir at the sample site. The new upstream site, implemented in May 2012, will provide a better future guide to the change in water quality in One Mile Creek, as only one sample was available for this report.

Hughes and Phillips creeks were within one standard error of the upstream 80th percentiles. All downstream medians (0.4 to 0.85µg/L) were five-fold lower than the ANZECC guideline. The mine water release event (30 Jun 2011 to 8 Jul 2011) accounted for the high outliers (3.5µg/L - 6µg/L) at the Hughes Creek downstream site. Removing the data for this event did not change the downstream median of 0.5µg/L (Appendix A).

The average upstream 80th percentile (0.37µg/L) was below the ANZECC ecosystem (SMD) guideline (5µg/L) (Figure 89).

The results indicate dissolved selenium in One Mile Creek may have changed slightly in excess of limits deemed acceptable for slightly-to-moderately disturbed ecosystems, but remains well below levels of concern for ecosystem protection defined by the ANZECC guideline.

6.4.27.2 Total Selenium

Total selenium levels increase as Hughes, One Mile and Phillips creeks progress through the mine lease (Figure 90). However, downstream medians remained within one standard error of the average upstream 80th percentile. The mine water release event data (30 Jun 2011 to 8 Jul 2011) accounted for the higher outliers at the Hughes Creek downstream site; however removing data for this event did not change the downstream median of 0.6µg/L (Appendix A).

The average upstream 80th percentile (0.48µg/L) was well below the ANZECC guidelines for stock watering and irrigation (20µg/L), and recreation (10µg/L) (Figure 91).

Total selenium levels in Hughes, One Mile, and Phillips creeks are below levels of concern and acceptable for SMD ecosystems.

Figure 88 – Dissolved Selenium Box & Whisker Plot

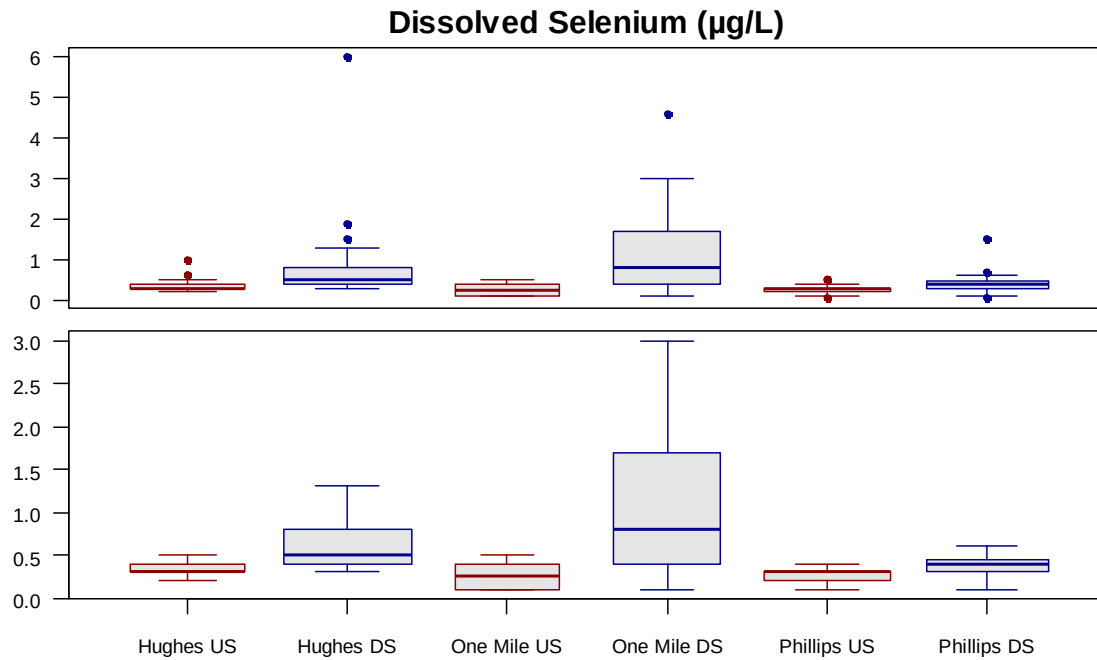


Figure 89 – Dissolved Selenium Comparison to Guidelines

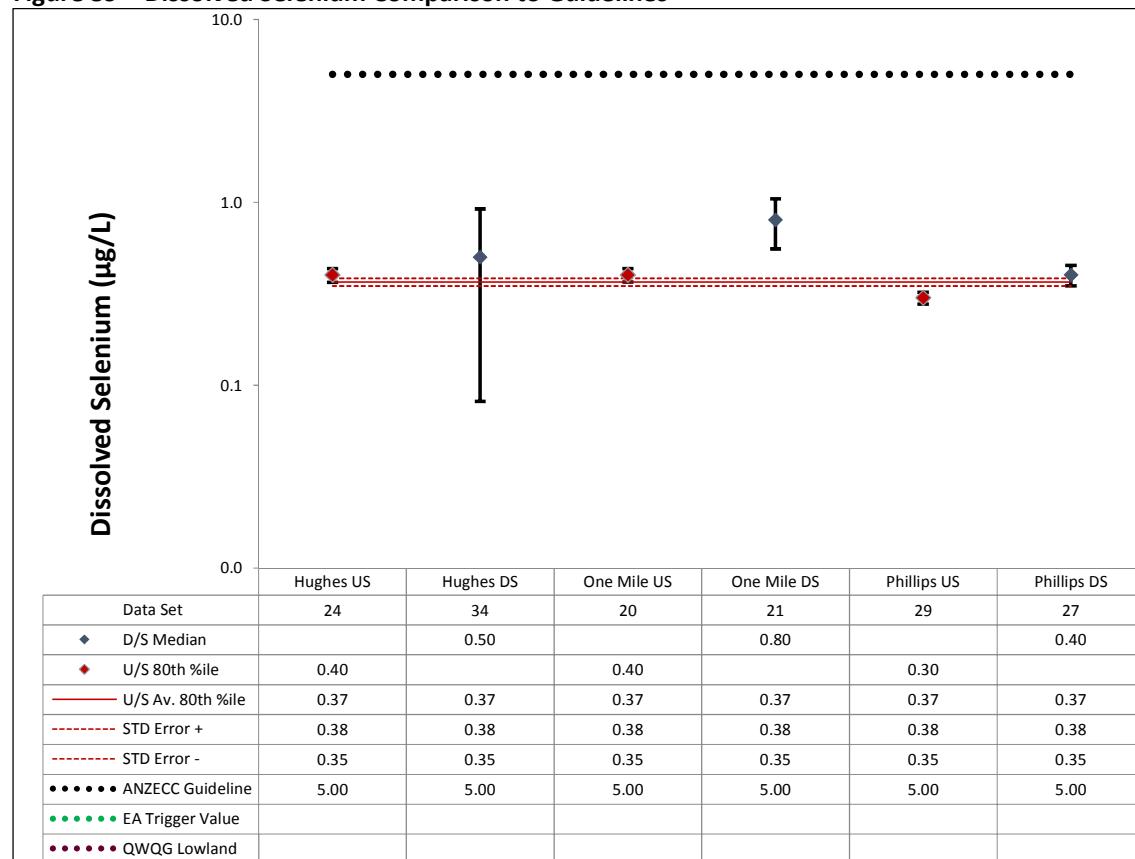


Figure 90 – Total Selenium Box & Whisker Plot

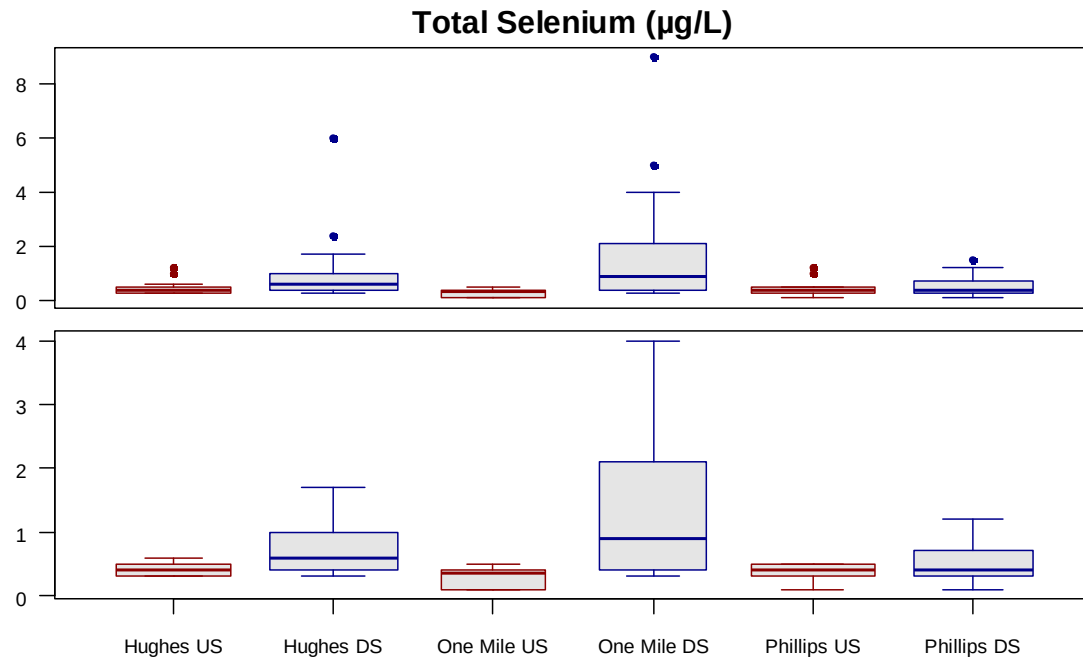
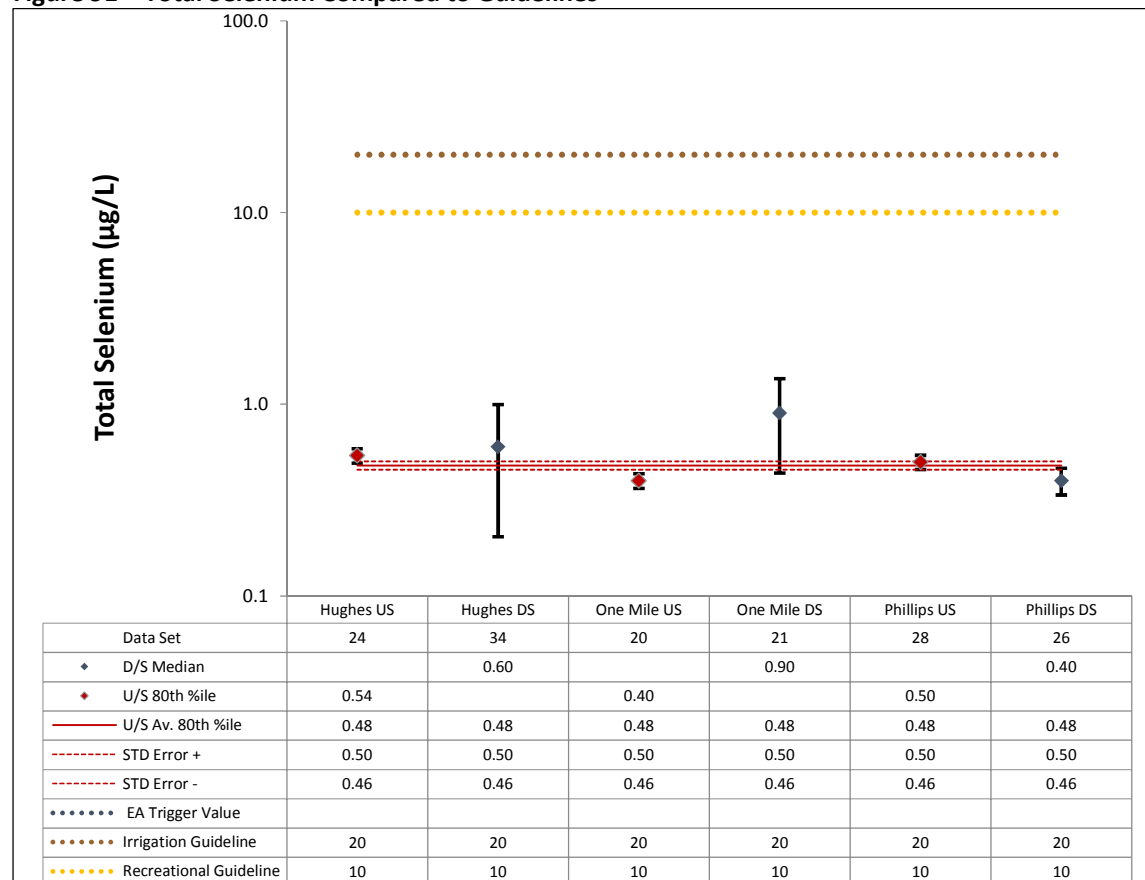


Figure 91 – Total Selenium Compared to Guidelines



6.4.28 Silver

6.4.28.1 Dissolved Silver

Dissolved silver levels remain steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 92).

Most (79%) upstream and downstream results were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L.

The average upstream 80th percentile (0.12µg/L) was above the ANZECC ecosystem (SMD) guideline of 0.05µg/L (Figure 93), indicating a new or interim guideline may be suggested (QWQG 2009). However, since the majority of results were influenced by the LOR, no new guideline is proposed here outside of considering the LOR for the test method used at the time.

Downstream medians (0.05µg/L) were below the average upstream 80th percentile.

The results indicate dissolved silver measurements are mostly below detection limits and not being altered by mining activity.

6.4.28.2 Total Silver

Total silver levels remain steady as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 94).

The average upstream 80th percentile (0.12µg/L) was below the ANZECC recreational guideline (50µg/L), and there is no guideline applicable to stock watering (Figure 95).

Downstream medians were below the average upstream 80th percentile.

Total silver levels in Hughes, One Mile, and Phillips creeks are below levels of concern and acceptable for SMD ecosystems.

Figure 92 – Dissolved Silver Box & Whisker Plot

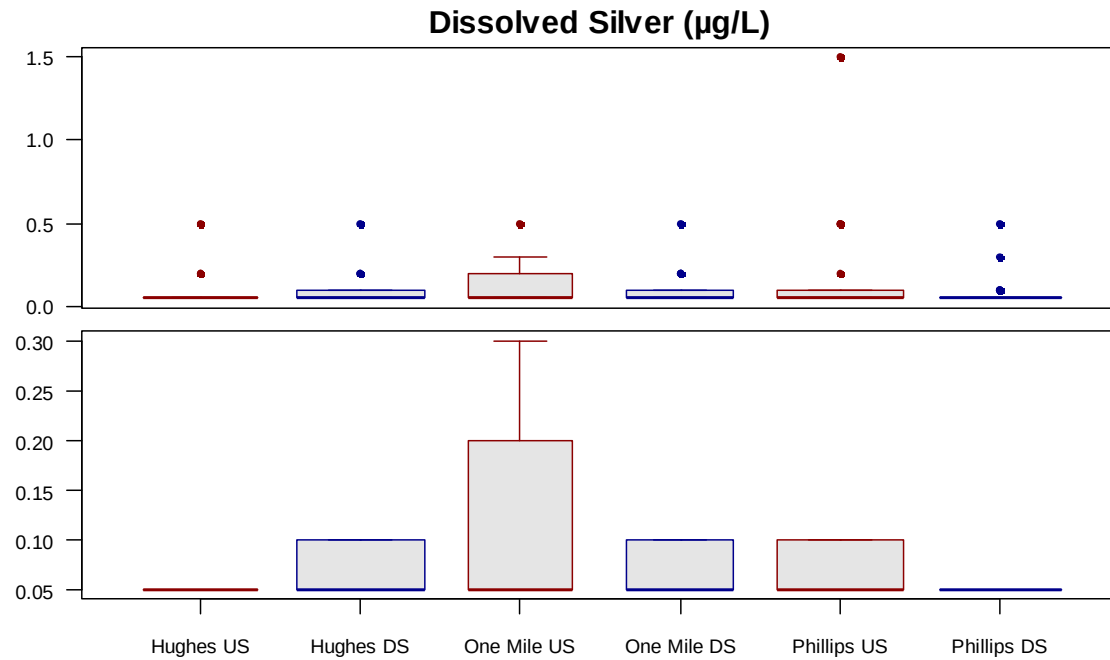


Figure 93 – Dissolved Silver Comparison to Guidelines

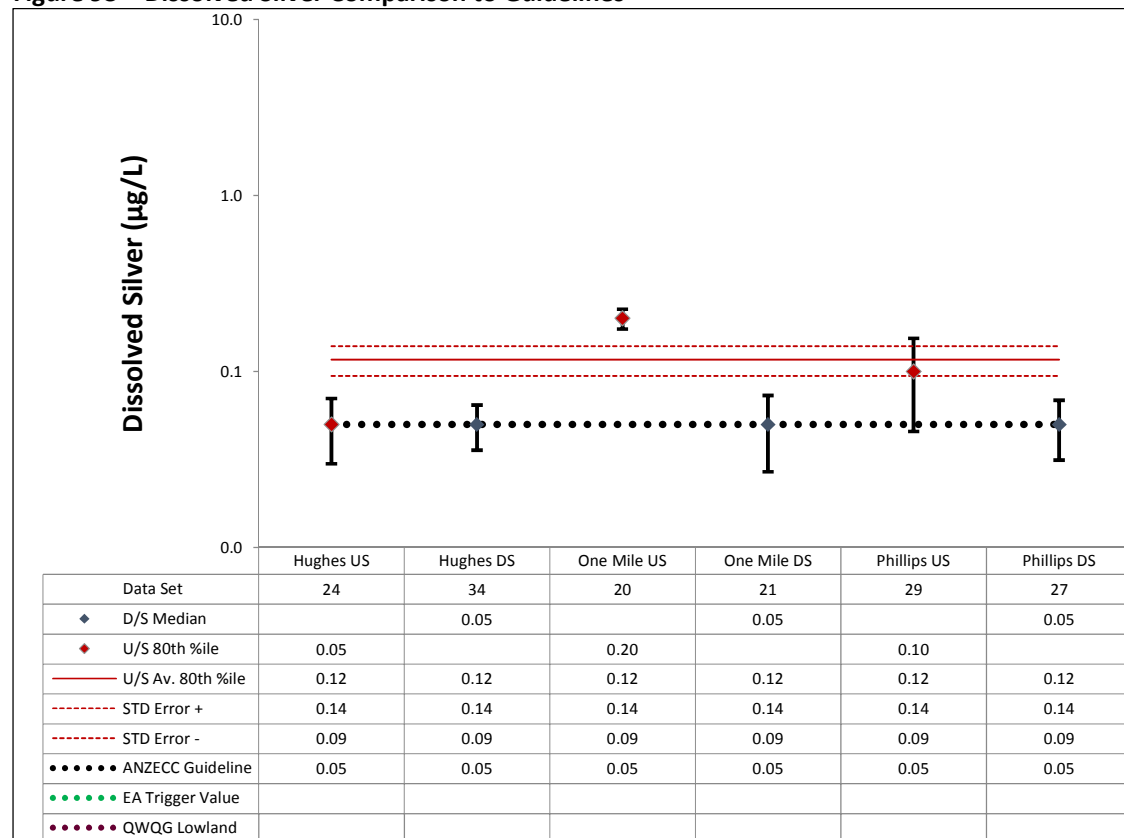


Figure 94 – Total Silver Box & Whisker Plot

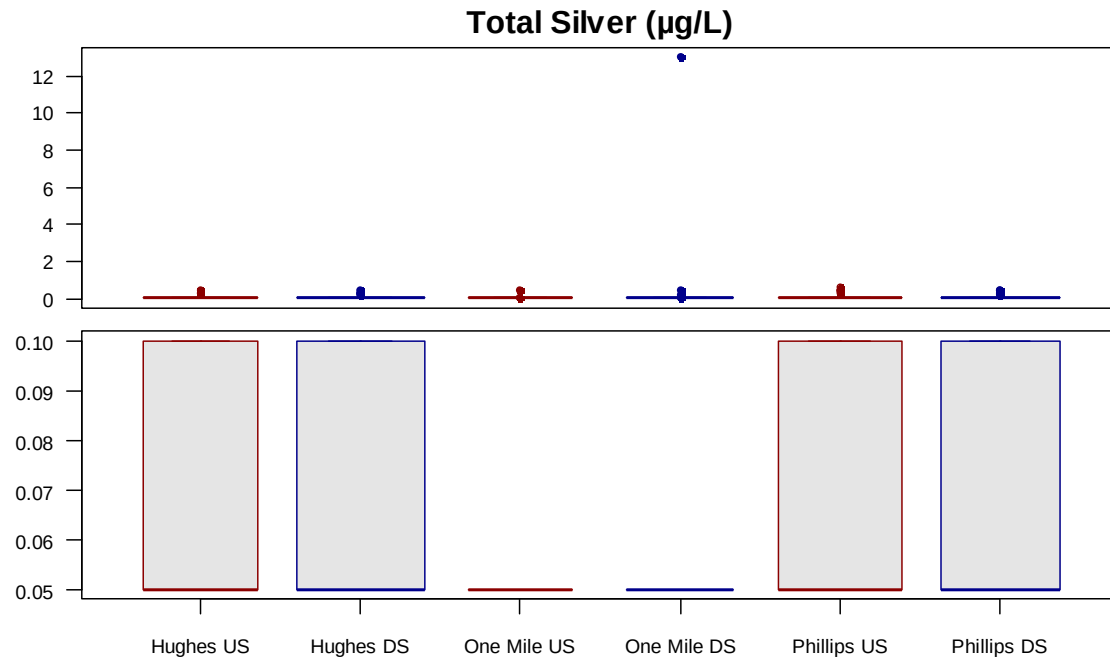
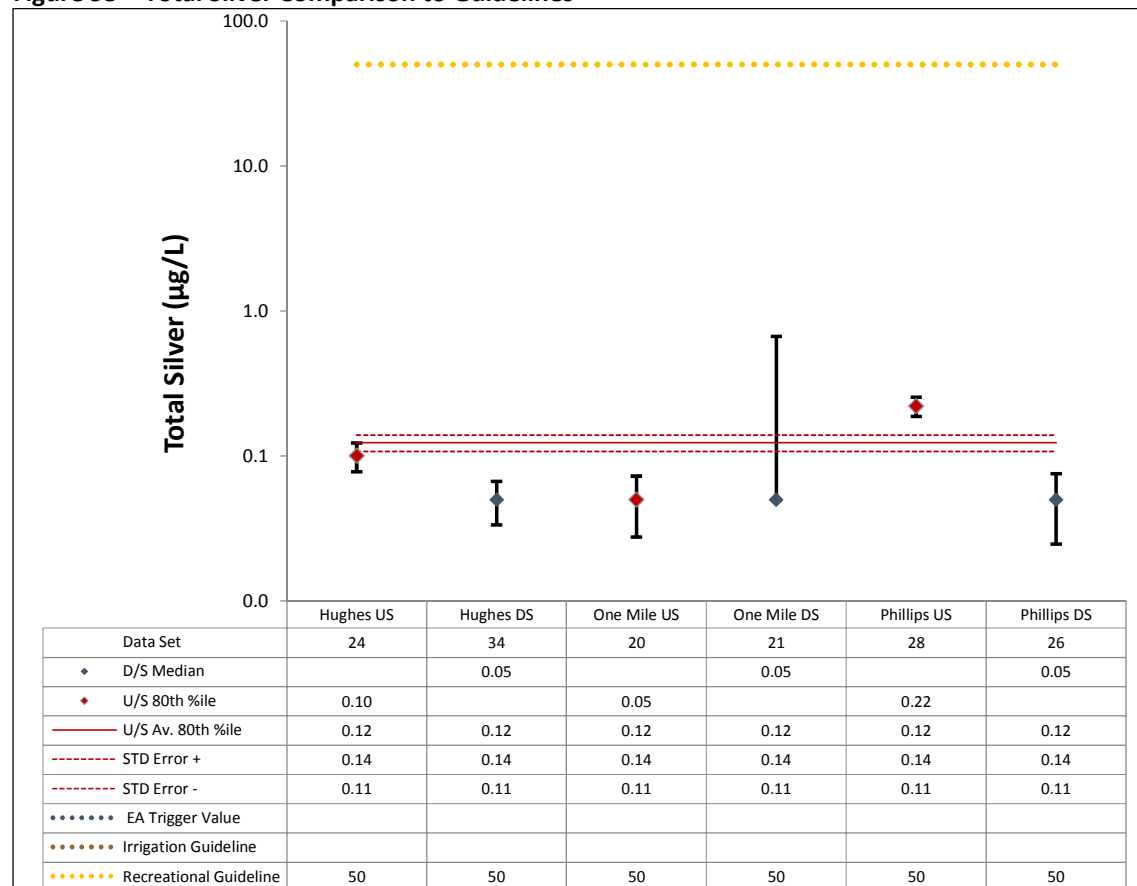


Figure 95 – Total Silver Comparison to Guidelines



6.4.29 Uranium

6.4.29.1 Dissolved Uranium

Dissolved uranium levels increase slightly as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 96).

The average upstream 80th percentile (0.4µg/L) was below the EA trigger (1µg/L), and there are no guidelines applicable for dissolved uranium (Figure 97).

Downstream medians were below or within one standard error of the individual upstream 80th percentiles, and below the EA trigger. The mine water release event data (30 Jun 2011 to 8 Jul 2011) accounted for the high outliers (3.5µg/L - 6µg/L) at the Hughes Creek downstream site. Removing the data for this event reduces the median from 0.35µg/L to 0.25µg/L (Appendix A). This lower median, considered more representative of downstream water quality, was also below the Hughes Creek upstream 80th percentile (0.37µg/L) and the EA trigger value (1µg/L).

Uranium levels after mining were not increased above levels acceptable for slightly-to-moderately disturbed systems. Should this analyte be retained as a trigger, the current EA trigger value would be appropriate.

6.4.29.2 Total Uranium

Total uranium levels slightly increase as Hughes, One Mile, and Phillips creeks progress through the mine lease (Figure 98).

The average upstream 80th percentile (0.7µg/L) was well below the ANZECC guidelines for stock watering (200µg/L) and irrigation (10µg/L) (Figure 99).

The downstream medians were below or within one standard error of the individual upstream 80th percentiles (plus one standard error). The mine water release event data (30 Jun 2011 to 8 Jul 2011) accounted for the high outliers (5.9µg/L - 7.1µg/L) at the Hughes Creek downstream site. This mine water was not considered representative of general downstream water conditions.

Total uranium in Hughes, One Mile, and Phillips creek is significantly lower than levels of concern and acceptable for SMD ecosystems.

Figure 96 – Dissolved Uranium Box & Whisker Plot

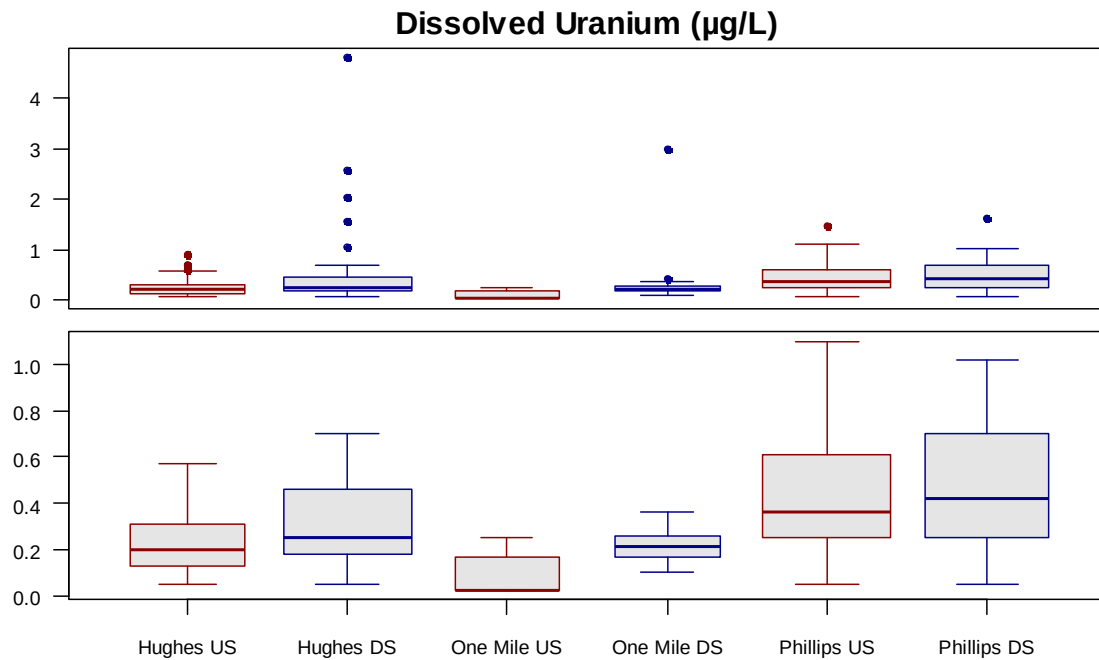


Figure 97 – Dissolved Uranium Comparison to Guidelines

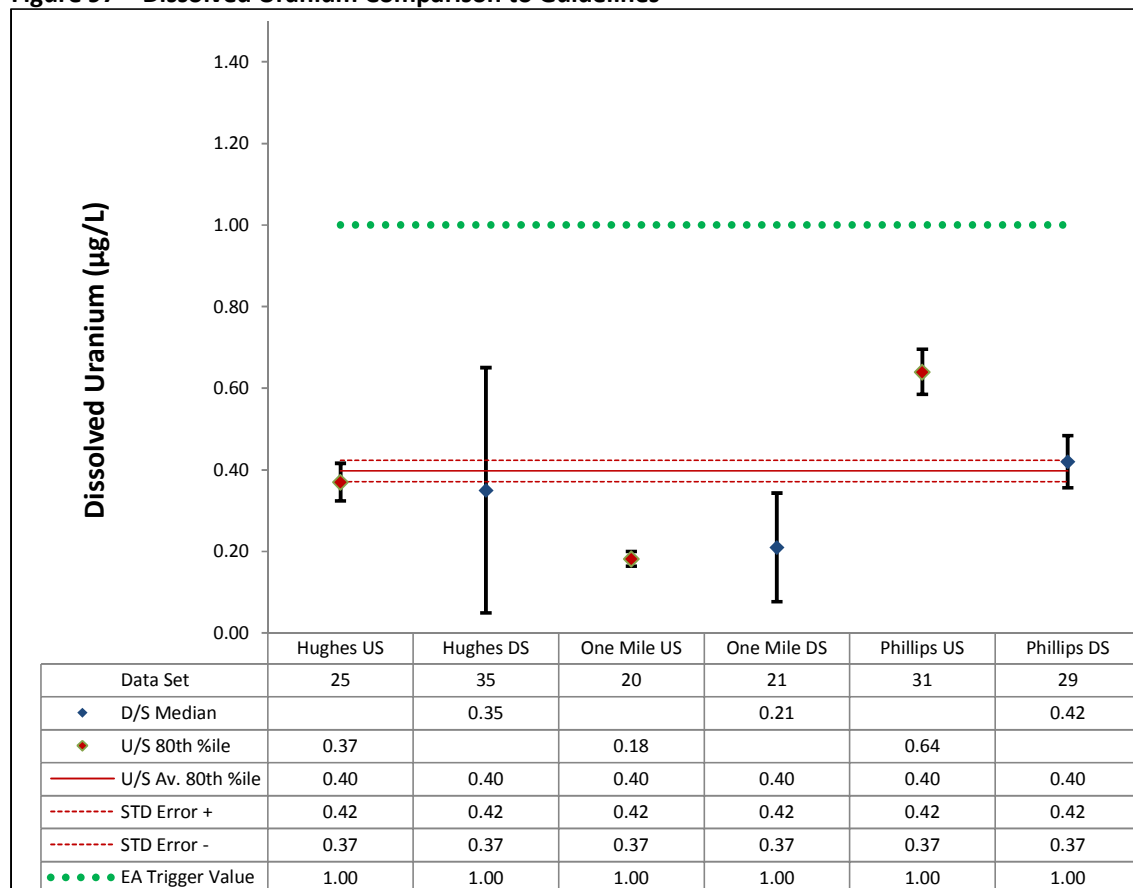


Figure 98 – Total Uranium Box & Whisker Plot

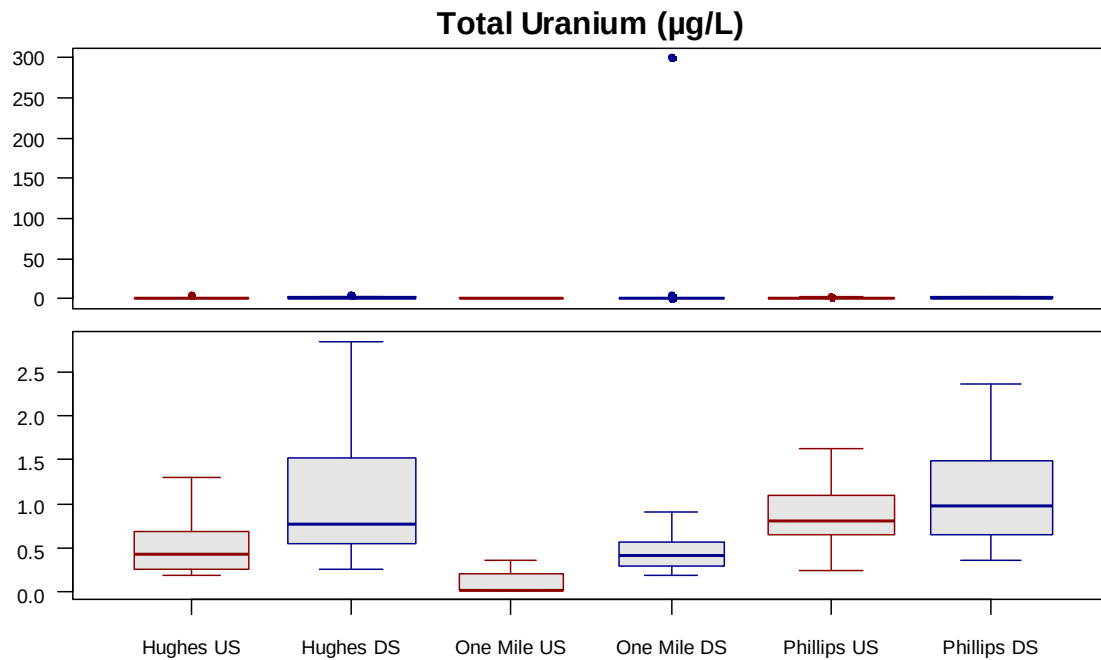
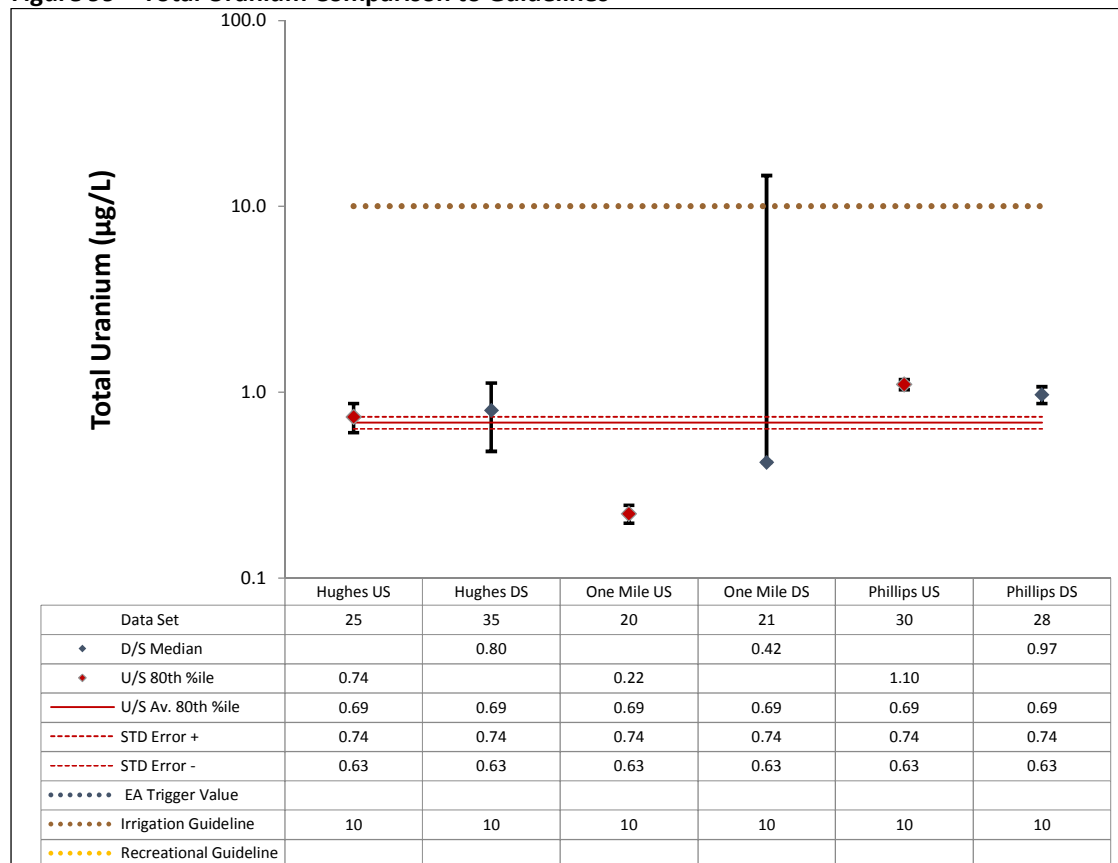


Figure 99 – Total Uranium Comparison to Guidelines



6.4.30 Vanadium

6.4.30.1 Dissolved Vanadium

Dissolved vanadium medians decrease slightly as Hughes and Phillips creeks progress through the mine lease. The median for upstream One Mile Creek ($0.7\mu\text{g/L}$) increased downstream to $0.8\mu\text{g/L}$ (Figure 100).

The downstream medians were lower than the average and individual upstream 80th percentiles. There are no applicable ecosystem guidelines for vanadium (Figure 101) and therefore a local guideline can be suggested (QWQG 2009).

The process to propose a local guideline, as outlined in QWQG (2009), involved assessment of individual upstream reference data for variability, then applying the relevant guideline approach. This assessment found that streams were greater than the 'highly variable' category, that is reference sites differed by greater than two standard errors, and an individual stream assessment approach is suggested. As Hughes and One Mile creeks are within one standard error of their average 80th percentile, it is suggested that a local guideline of $1.85\mu\text{g/L}$ is appropriate for these streams. For Phillips Creek an individual guideline value $7\mu\text{g/L}$ is suggested based on the 80th percentile.

The results indicate dissolved vanadium is not being significantly altered by mining activity.

6.4.30.2 Total Vanadium

Total vanadium levels slightly increase as Hughes, One Mile and Phillips creeks progress through the mine lease (Figure 102).

The average upstream 80th percentile ($20.5\mu\text{g/L}$) was well below the ANZECC guidelines for irrigation ($100\mu\text{g/L}$) (Figure 103).

Downstream medians were within one standard error of the average or corresponding upstream 80th percentile.

Total vanadium levels in Hughes, One Mile, and Phillips creeks are below levels of concern and acceptable for SMD ecosystems.

Figure 100 - Dissolved Vanadium Box & Whisker Plot

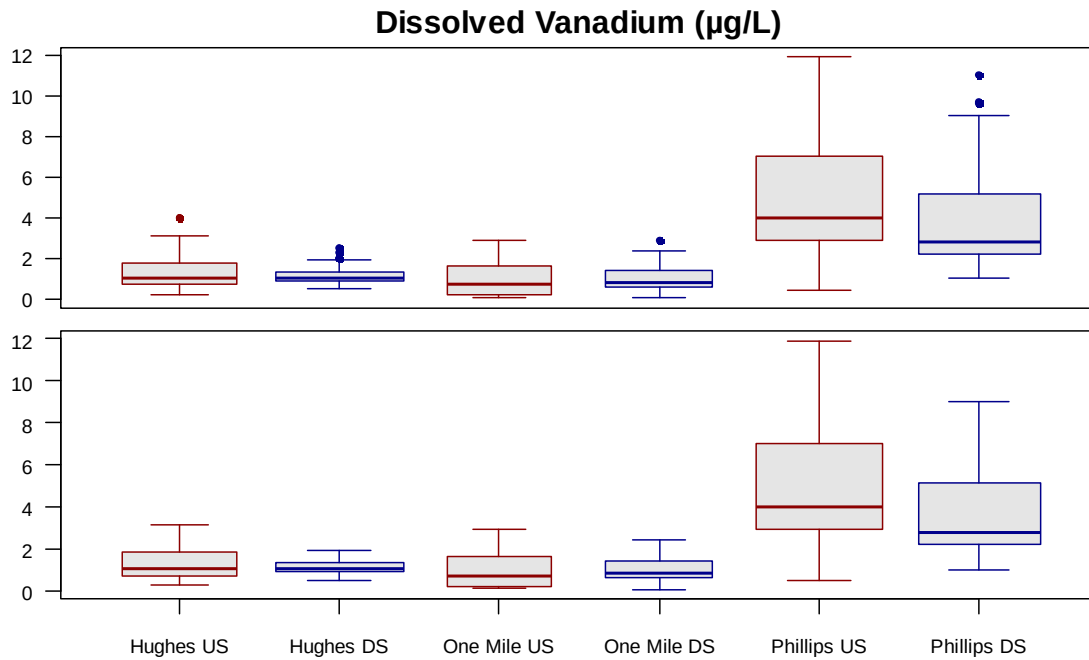


Figure 101 – Dissolved Vanadium Comparison to Guidelines

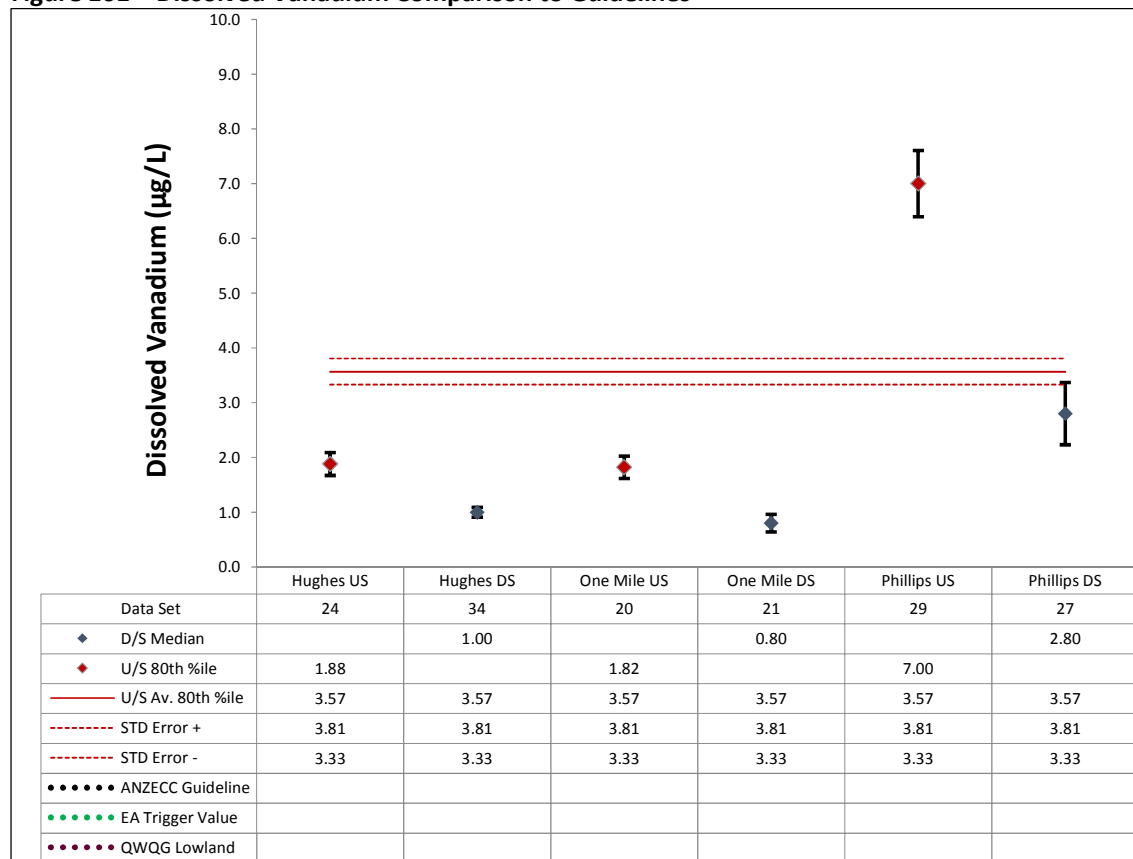


Figure 102 – Total Vanadium Box & Whisker Plot

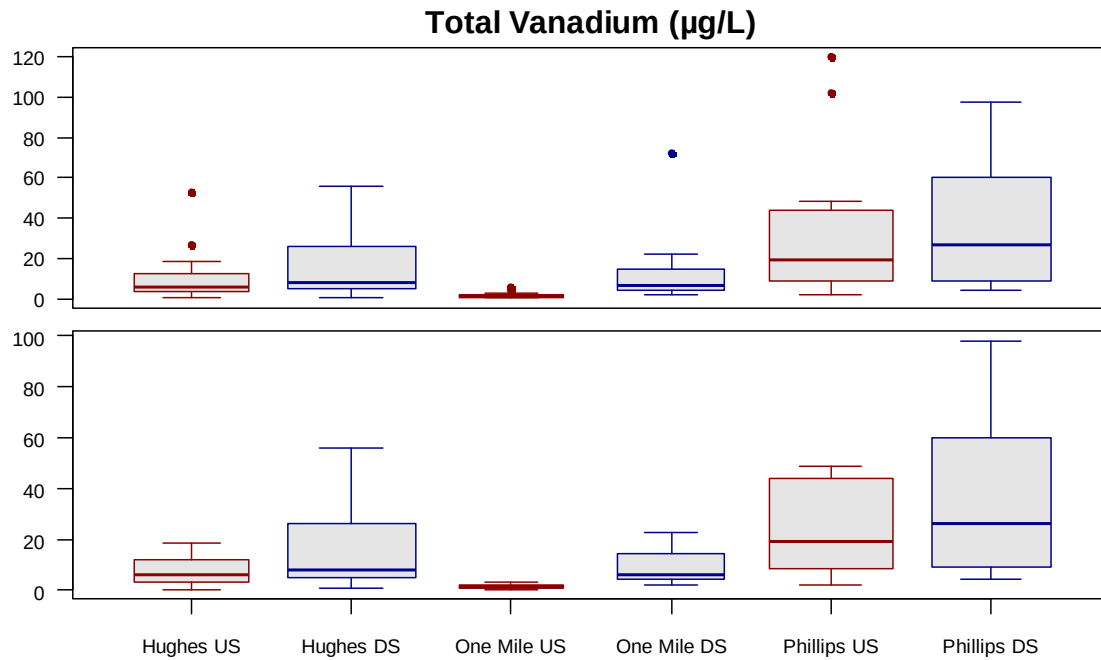
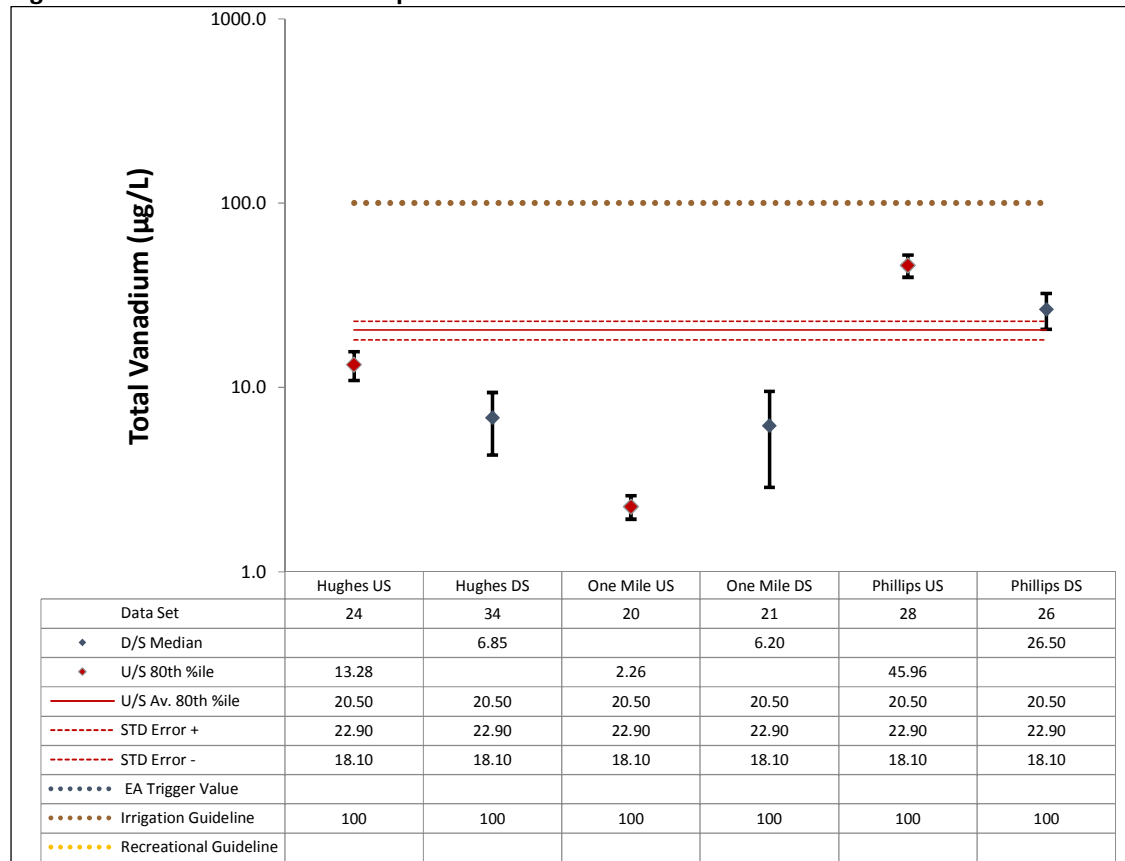


Figure 103 – Total Vanadium Comparison with Guidelines



6.4.31 Zinc

6.4.31.1 Dissolved Zinc

Dissolved zinc levels remained steady as Hughes, One Mile and Phillips creeks progress through the mine lease.

The majority (>85%) of the upstream and downstream results were below detection limits, and medians were skewed according to the *50% LOR rule*. If applying the *0% LOR rule*, the median for all upstream and downstream sites would be 0µg/L. This is reflected in upstream and downstream medians and 80th percentiles being the same.

The average upstream 80th percentile (2.5µg/L) was below the EA trigger and ANZECC ecosystem (SMD) guideline of 8µg/L (Figure 105).

The results indicate dissolved zinc is below levels of concern and not increased by mining activity. Should this analyte be retained as a trigger, the current ANZECC guideline would be appropriate.

6.4.31.2 Total Zinc

Total zinc levels increased as One Mile and Phillips creeks progressed through the mine lease, although remain at relatively low levels. The upstream medians of 2.5 and 13.5µg/L respectively increased downstream to 8.5 and 27.5µg/L (Figure 106). The Hughes Creek median decreased from 13µg/L to 10µg/L downstream.

Downstream medians were below the average upstream 80th percentile, indicating the change in concentration is acceptable for SMD ecosystems.

The average upstream 80th percentile (23µg/L) was well below the ANZECC guidelines of 2000-20,000µg/L (Figure 107).

Total zinc levels in Hughes, One Mile, and Phillips creeks are well below levels of concern.

Figure 104 – Dissolved Zinc Box & Whisker Plot

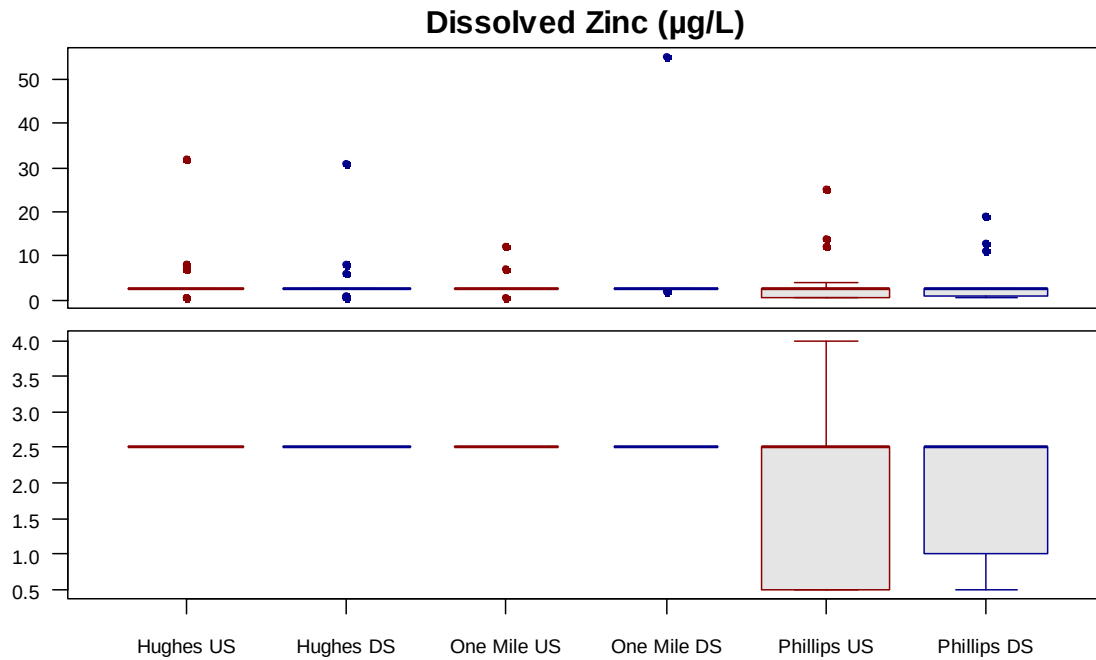


Figure 105 – Dissolved Zinc Comparison to Guidelines

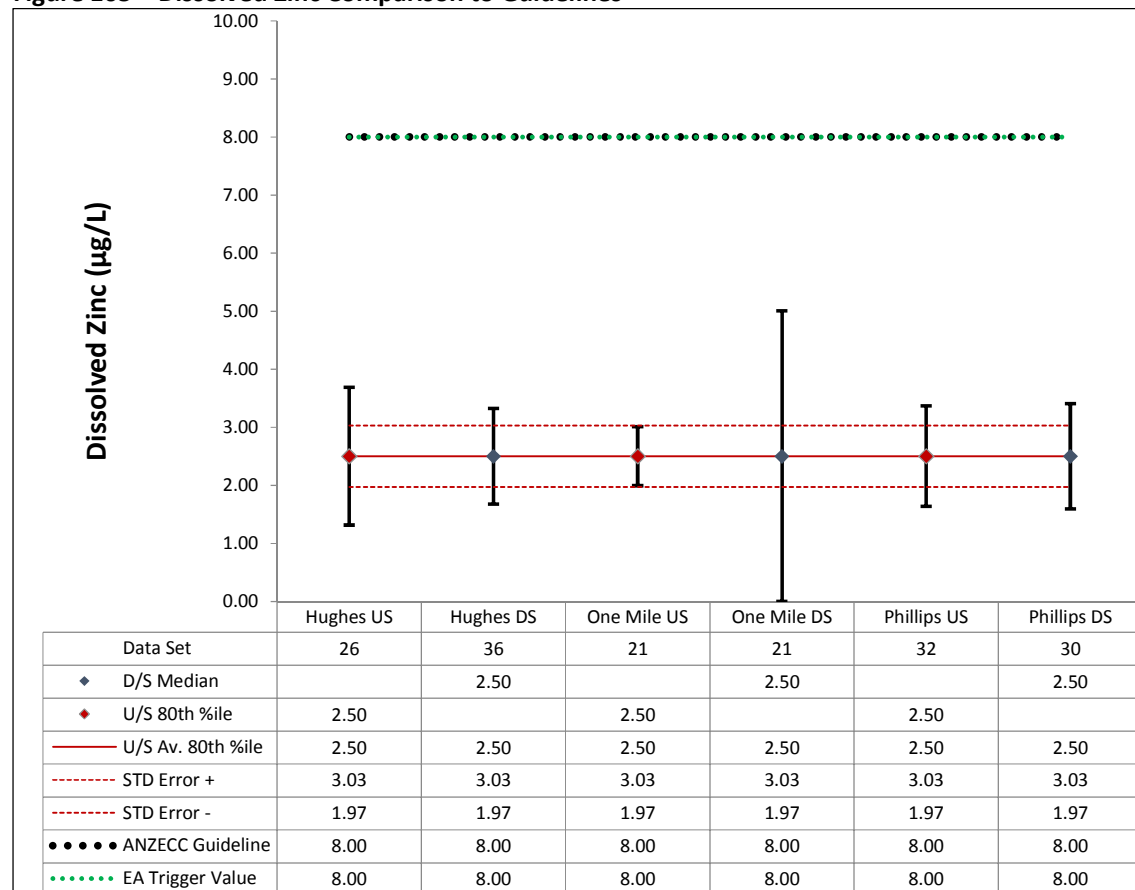


Figure 106 - Total Zinc Box & Whisker Plot

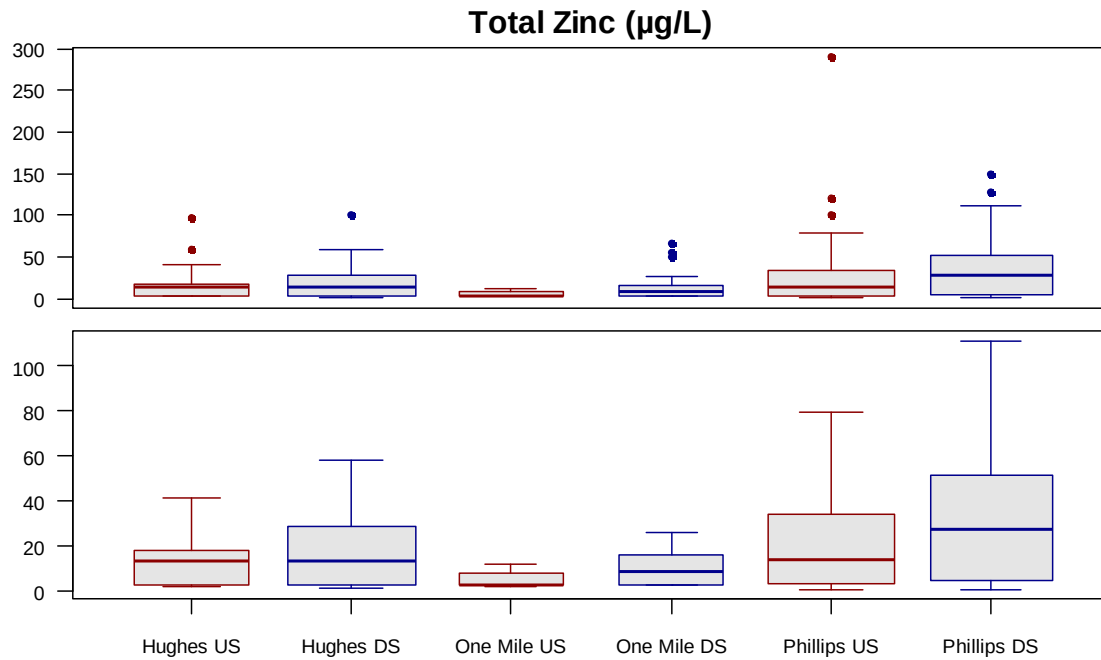
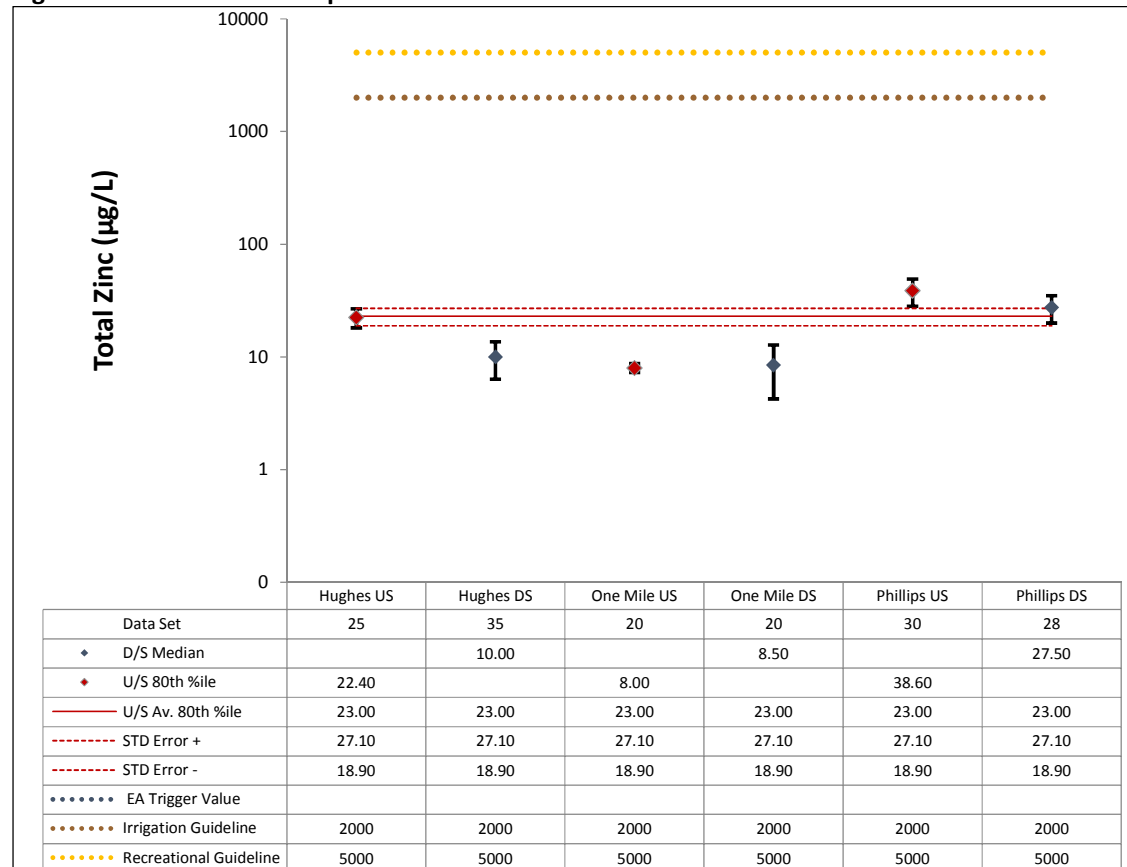


Figure 107 – Total Zinc Comparison to Guidelines



6.5 APPLICABILITY OF CURRENT LIMITS, GUIDELINES & TRIGGERS

Table 11 provides a summary of results in terms of applicability of current guidelines and where appropriate, offers potential alternatives based on local reference site data.

These suggested changes do not consider whether a particular analyte should or should not be included on the mine's list of triggers, but rather offer a value to apply for those analytes should they be included.

The 80th (20th) percentiles for reference sites were based on three upstream sites – Hughes, One Mile and Phillips creeks. Each creek was well represented with strong data sets evenly spread between the three sites. Proposed local guidelines and upstream 80th percentiles are qualified as the One Mile Creek upstream site was previously located at the spillway of One Mile Dam, an in-stream storage which receives pipeline water from Bedford Weir, and as such, may not be representative of true conditions for this catchment. Only one sample was available for the new site which is further upstream away from the in-stream storage.

Data coverage for temperature and dissolved oxygen was insufficient to offer potential local guidelines. Monitoring of these parameters will require a greater range of diurnal and seasonal data coverage.

Distinction is made between potential local guidelines and suggested trigger values. Potential local guidelines are based on the statistical analysis of results and application of the methodology provided in the Queensland Water Quality Guidelines (2009). Suggested trigger values include consideration of practical issues such as the detection limit for analytes and a possible single site trigger value rather than a series of trigger values for each stream across the site. The values suggested are by no means prescriptive and are open to further consideration of aspects outside of the scope of this report.



Table 11 – Summary of Water Quality Results and Potential Local Guideline or Trigger

Analyte	Units	80 th (20 th) percentiles for reference sites			Current guidelines & triggers		Potential local guideline and/or trigger	
		No. of samples	Average	Average (±)SE	Applicable guideline(s)	EA trigger	Comment on potential local guideline and/or trigger	Calculated or retained value
EC	µS/cm	358	478	489	720 (QWQG)	2000	Retain QWQG as guideline. EA trigger accommodates natural variation in all streams and aligns with ecotoxicology studies for 95% protection in the Fitzroy basin.	720 (guideline) 2000 (trigger)
pH (upper)	pH	358	7.93	7.95	Max 8.0 (QWQG) Max. 8.5 (Draft sub reg.)	9.0 (max)	Retain current EA trigger value	9.0 (max)
pH (lower)	pH	358	7.35 (20 th)	7.33 (20 th)	Min. 6.5 (QWQG)	6.5 (min)	Retain current EA trigger value	6.5 (min)
Dissolved Oxygen	% Saturation	25 7-10 (per site)	(20 th) 6.7-7.5 mg/L (95-105%) Insufficient data	(20 th) 6.4-7.4mg/L (92-104%) Insufficient data	90-110% (upland-QWQG) 85-110% (lowland-QWQG)	None	Insufficient data coverage. Retain QWQG until further information.	90-110 (upland) 85-110 (lowland)
Temp	°C	127	30.6 (insufficient data)	30.9 (insufficient data)	80 th %ile temp distribution (QWQG)	None	Insufficient data coverage. Retain QWQG until further information.	80 th %ile temp distrib.
Temp	°C	127	25.6 (20 th) (insufficient data)	25.3 (20 th) (insufficient data)	20 th %ile temp distribution (QWQG)	None	Insufficient data coverage. Retain QWQG until further information	20 th %ile temp distrib.
Turbidity	NTU	94	387	429	25 (upland-QWQG) 50 (lowland-QWQG)	None	Naturally highly variable. No guideline proposed.	Compare control & test at same hydrograph stage
TSS	mg/L	353	280	309	10 (lowland-QWQG)	None	Naturally highly variable. No guideline proposed.	Compare control & test at same hydrograph stage
Sulfate	mg/L	352	20	21	1000 (ANZECC-stock)	1000	Retain current ANZECC value as guideline.	1000 (guideline)
Ammonia	µg/L	73	43	50	10 (upland-QWQG)	None	Local 80 th percentile more	43



WATER QUALITY

Analyte	Units	80 th (20 th) percentiles for reference sites			Current guidelines & triggers		Potential local guideline and/or trigger	
		No. of samples	Average	Average (±)SE	Applicable guideline(s)	EA trigger	Comment on potential local guideline and/or trigger	Calculated or retained value
					20 (lowland-QWQG)		appropriate than QWQG values	
Nitrate	µg/L	72	123	145	700 (ANZECC)	None	Retain current ANZECC value	700
TPH (C6-9)	µg/L	77	10	10.2	None	20	Retain current EA trigger value	20
TPH (C10-36)	µg/L	77	42	62	None	100	Retain current EA trigger value	100
Fluoride	µg/L	72	161	169	2000 (ANZECC-stock)	None	Retain current ANZECC value	2000
Total Hardness	mg/L	23	127	151	None	None	Insufficient data coverage	-
Metals (Dissolved)								
Aluminium	µg/L	79	499	610	55 (ANZECC)	416	Adopt local 80 th percentile plus 2 standard errors, based on the “highly variable” category in QWQG (2009), or site wide guideline or trigger, otherwise use individual stream guidelines.	721 (site-wide or trigger) 760 (Hughes) 430 (One Mile) 288 (Phillips)
Arsenic	µg/L	76	0.83	0.91	13 (ANZECC)	None	Retain current ANZECC value	13
Boron	µg/L	76	57	60	370 (ANZECC)	None	Retain current ANZECC value	370
Cadmium	µg/L	73	0.04	0.04	0.2 (ANZECC)	None	Retain current ANZECC value	0.2
Chromium	µg/L	76	0.87	0.92	1 (ANZECC) for CrVI	1	Retain current ANZECC value for Hughes and Phillips creeks and adopt local 80 th percentile for One Mile Creek	1 1.2 (One Mile Ck)
Cobalt	µg/L	76	0.53	1.14	None	None	Data influenced by LOR. No guideline proposed.	-
Copper	µg/L	79	2.0	2.2	1.4 (ANZECC)	2	Adopt local average 80 th percentile for all streams, and thereby retain the EA trigger value	2
Iron	µg/L	79	971	1051	None	1130	Retain EA trigger as it was based on previous local data, and the individual stream 80 th %iles are accommodated or within one	1130



WATER QUALITY

Analyte	Units	80 th (20 th) percentiles for reference sites			Current guidelines & triggers		Potential local guideline and/or trigger	
		No. of samples	Average	Average (±)SE	Applicable guideline(s)	EA trigger	Comment on potential local guideline and/or trigger	Calculated or retained value
							standard error of this value.	
Lead	µg/L	76	0.53	0.78	3.4 (ANZECC)	None	Retain current ANZECC value	3.4
Manganese	µg/L	76	39	92	1900 (ANZECC)	None	Retain current ANZECC value	1900
Mercury	µg/L	72	0.05 (50% LOR)	0.06	0.06 (ANZECC)	None	Retain current ANZECC value. Consider LOR for trigger.	0.06 0.2 (based on LOR)
Molybdenum	µg/L	75	0.5 (50% LOR)	0.54	None	34	Data influenced by LOR. No guideline proposed.	-
Nickel	µg/L	76	3.5	4.0	11 (ANZECC)	None	Retain current ANZECC value	11
Selenium	µg/L	73	0.37	0.38	5 (ANZECC)	None	Retain current ANZECC value	5
Silver	µg/L	73	0.12 (highly influenced by 50% LOR)	0.14	0.05 (ANZECC)	None	Data influenced by LOR. No new guideline proposed.	0.05 (ANZECC)
Uranium	µg/L	76	0.4	0.42	None	1	EA trigger accommodates local conditions	1 (trigger)
Vanadium	µg/L	73	3.6	3.8	None	None	Adopt local 80 th percentile for Hughes and One Mile creeks and adopt local 80 th percentile for Phillips Creek	1.9 (Hughes/One Mile) 7 (Phillips)
Zinc	µg/L	79	2.5 (50% LOR)	3.0	8	8	Retain current ANZECC value	8

7. SEDIMENT QUALITY

7.1 PROGRAM DESIGN

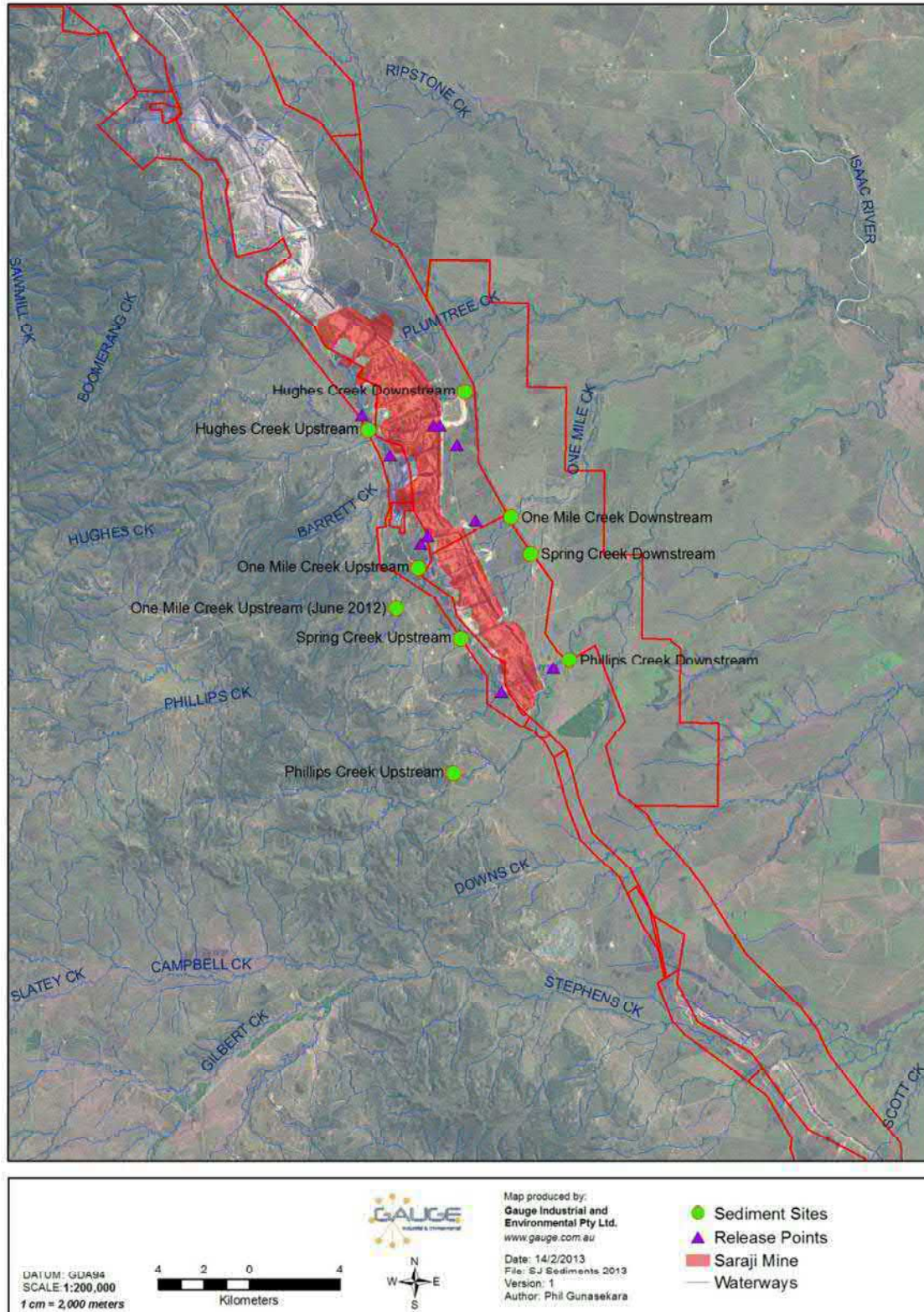
Sediment surveys were undertaken by the Central Queensland University (CQU) between December 2011 and June 2013 (Sellens, *et al*, 2011; Shrestha, *et al*., 2012; pers.comm. CQU, 2014) and included Hughes, One-Mile, Spring and Phillips creeks (Table 12 and Figure 108).

The results of a survey conducted in June 2011 had not been reported due to issues (potential errors) with laboratory testing in that batch of samples (Sellens, *et al*, 2011).

Table 12 – Sediment Survey Program and Sites

Stream	Site	Monitoring Point	Coordinates (GDA94)		Survey date and surveyor				
			Latitude	Longitude	Dec 2011	Feb 2012	Jun 2012	Feb 2013	Jun 2013
					CQU	CQU	CQU		
Hughes Creek	Upstream	MP 1	-22.3845	148.2656	Dry	Dry	Dry	✓	✓
	Downstream	MP 5	-22.3690	148.3068	✓	✓	Dry	✓	✓
One Mile Creek	Upstream	MP 2	-22.4393	148.2875	Dry	✓	Dry	Dry	✓
	Upstream (June 2012)	MP 2	-22.4554	148.2782	-	-	-		
	Downstream	MP 6	-22.4187	148.3271	Dry	Dry	Dry	✓	✓
Spring Creek	Upstream	MP 4	-22.4673	148.3061	Dry	Dry	Dry	Dry	✓
	Downstream	MP 8	-22.4335	148.3356	✓	✓	✓	✓	✓
Phillips Creek	Upstream	MP 3	-22.5211	148.3034	✓	✓	✓	✓	✓
	Downstream	MP 7	-22.4754	148.3527	✓	✓	✓	✓	✓

Figure 108 - Sediment Monitoring Sites



7.2 METHODOLOGY & QUALITY ASSURANCE

The CQU sediment surveys were conducted according to the Queensland Monitoring and Sampling Manual 2009 (Version 2, Sept 2010).

Sediment samples were collected in duplicate and stored on ice, and analysed by a NATA accredited laboratory (ALS -Environmental). The CQU sediment testing was limited to the following analytes:

- *Moisture content*
- *Total concentrations of metals/metalloids (aluminium, arsenic, boron, cadmium, chromium, copper, cobalt, iron, lead, mercury, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc)*

Particle size analysis was undertaken during the 2013 sediment surveys.

7.3 SEDIMENT QUALITY GUIDELINES

The ANZECC guidelines recognise sediment as an interactive medium between water quality and benthic biota, which represents an integral part of the aquatic ecosystem.

The ANZECC Interim Sediment Quality Guidelines (ISQG) derives values for ecosystem protection from international sources until reliable data on Australian and New Zealand sediment toxicity can be established. These ANZECC sediment values identify both high and low triggers. The guidelines recommend exceedences above the high threshold be subject to further investigation and exceedences of the low threshold become the discretion of management as to whether further investigation is required.

In the absence of guidelines, ANZECC recommend adopting a trigger value of two times (or up to three times for disturbed systems) the background concentration.

The ANZECC ISQG-low and ISQG-high guidelines for analytes used in this study are shown in Table 13.

Table 13 – ANZECC Interim Sediment Quality Guidelines for Sediment Analytes

Sediment Guidelines			
Parameter	Units	ANZECC (ISQG-low)	ANZECC (ISQG-High)
Aluminium	mg/kg	None available	None available
Arsenic	mg/kg	20	70
Boron	mg/kg	None available	None available
Cadmium	mg/kg	1.5	10
Chromium	mg/kg	80	370
Cobalt	mg/kg	None available	None available
Copper	mg/kg	65	270
Iron	mg/kg	None available	None available
Lead	mg/kg	50	220
Manganese	mg/kg	None available	None available
Mercury	mg/kg	0.15	1
Molybdenum	mg/kg	None available	None available
Nickel	mg/kg	21	52
Selenium	mg/kg	None available	None available

Sediment Guidelines			
Parameter	Units	ANZECC (ISQG-low)	ANZECC (ISQG-High)
Silver	mg/kg	1	3.7
Uranium	mg/kg	None available	None available
Vanadium	mg/kg	None available	None available
Zinc	mg/kg	200	410

7.4 RESULTS & DISCUSSION

Metals in sediments within each catchment are presented in Figure 111 to Figure 128. For the calculation of median values (Table 14), where results were below the detection, a value of half the lowest Limit of Reporting (LOR) was used.

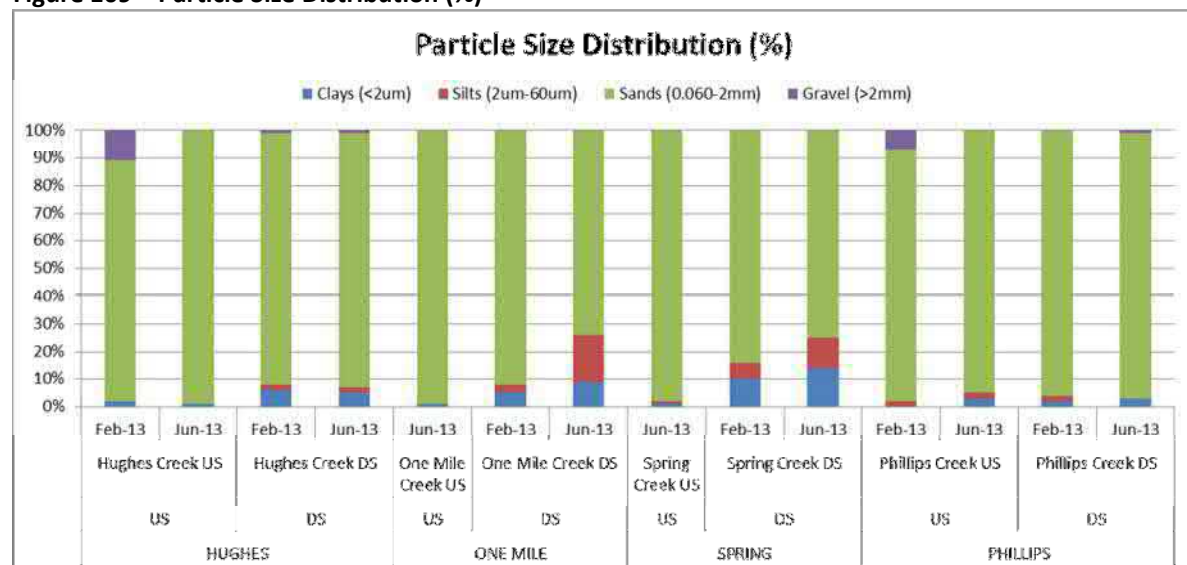
7.4.1 Particle Size

Particle size analysis was done in the February 2013 and June 2013 surveys (Figure 109 and Table 19). Stream bed sediments were divided into the size fractions of clay (<0.002mm), silts (0.002-0.06mm), sands (0.06-2mm) and gravel (>2mm).

All upstream and downstream sites were dominated by sand.

The downstream sites for Hughes, One Mile and Spring creeks contained a higher percentage of fines (clays and silt) ranging from 7-26%, compared to upstream sites containing 1-2% of fines. This variation in sediment content requires consideration in the interpretation of chemical composition as higher proportions of fines can contribute to increased extractable chemical loadings. The fines content in Phillips Creek was more balanced with both upstream and downstream sites averaging 3.5% fines.

Figure 109 – Particle Size Distribution (%)



7.4.2 Comparison with Trigger Values

The ANZECC & ARMICANZ (2000) Interim Sediment Quality Guidelines (ISQG) provides trigger values for a number of metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Ag and Zn). In this study, all metals were below their respective ISQG triggers; and cadmium, mercury and silver were below the limit of reporting at all sites.

7.4.3 Comparison with Background Levels

For metals where no trigger values are provided (Al, B, Co, Fe, Mn, Mo, Se, U and V) the ANZECC guidelines suggest using a value of two times the background concentration as a trigger for further investigation.

The data set available was limited to one to five samples per site, restricting meaningful statistical comparison on an individual stream basis. The following general observations were made from comparison of medians upstream and downstream for individual streams and all streams combined (Table 14):

- Boron and selenium were less than the limit of reporting at all upstream and downstream sites.
- The combined stream medians for the other analytes increased downstream, however, increases were less than two-fold (or <100%). The exception was uranium which increased by 200% downstream. This result is qualified as concentrations were close to the limits of reporting (LOR) and 46% of results were below the LOR. The highest uranium levels recorded were at a background site (upstream One Mile Creek); suggesting uranium may be slightly enriched in the area. In conclusion, the uranium concentrations recorded downstream are considered a low risk as the levels were very low and within the range recorded at a background site in the area.
- On a stream by stream basis, all streams except Phillips Creek recorded greater than two-fold increases in metals downstream. Further monitoring is required to confirm the increase in Hughes, One-Mile and Spring creeks as the current assessment relies on 1-2 upstream samples, however the following initial observations were made:
 - Aluminium – Hughes and Spring creeks' downstream medians (1770 and 4130mg/kg) increased by two and five fold respectively. The change is notable but not alarming, as background levels in the study area recorded a higher median (6,745mg/kg) at upstream One Mile Creek.
 - Cobalt – Hughes, One-Mile and Spring creeks' downstream medians (4.7, 4.4 and 5mg/kg) increased two to six fold compared to upstream, however the concentrations are considered low risk as similar levels (4mg/kg) were recorded in the Phillips Creek background site.
 - Iron - Hughes, One-Mile and Spring creeks' downstream medians (22,700, 11,980 and 7,070mg/kg) increased two to three fold compared to upstream. The medians were higher than any background site in the area. The iron concentrations correlated with the percentage of fines (clay and silt) in the samples from these streams ($R^2=0.6$ to 0.93) (Figure 110). The increase in concentration appeared to be related to the amount of fine sediment collected rather than the proximity to mining. As the particle size correlations are based on only one upstream sample and two downstream samples, further

monitoring is required to confirm the increase downstream, and the correlation with sediment fines content.

- O Manganese - Hughes and Spring creeks' downstream medians (121 and 129mg/kg) increased by two and six fold respectively, compared to upstream. The change is notable however the concentrations are considered low risk as similar levels (108mg/kg) were recorded in the Phillips Creek background site.
- O Molybdenum – One-Mile and Spring creeks' downstream medians (0.65 and 0.2mg/kg) increased by five and two fold respectively, compared to upstream. The change is notable however the concentrations in Spring Creek are low risk as similar levels (0.2mg/kg) were recorded in the Phillips Creek background site. The levels recorded in One-Mile are above background concentrations in the study area, however the result is attributed to the sample taken in June 2013, which recorded molybdenum at 1.1, compared to 0.2 recorded just 4 months earlier in Feb 2013. The molybdenum concentrations in One-Mile Creek correlated very strongly ($R^2=0.93$) with the percentage of fines (clay and silt) in the sample (Figure 110). The increase in concentration appeared to be related to the amount of fine sediment collected rather than the proximity to mining. The June 2013 sample contained a much higher proportion of fines (9% clay and 17% silt) than the upstream sample (<1%) taken in the same survey. The result may also relate to natural variation at the downstream site, as the June 2013 result consistently contained significantly higher metals than the same site in Feb 2013. Unfortunately particle size data was not available for the Feb 2013 survey to make a direct comparison of fines content. As the particle size correlations are based on only one upstream sample and two downstream samples, further monitoring is required to confirm the increase downstream, and the correlation the fine sediment content.
- O Uranium - Hughes and Spring creeks' downstream medians (0.3 and 0.2) increased by two and four fold respectively, compared to upstream. The change was notable but not alarming, as background levels in the study area recorded a higher median (0.4) at upstream One Mile Creek.
- O Vanadium - Hughes and Spring creeks' downstream medians increased by seven and three fold respectively, compared to upstream. The levels recorded in Spring Creek (16) are low risk as similar levels (13) were recorded in Phillips and One-Mile creeks background sites. The median in Hughes Creek (40) is above the median background concentrations measured at sites in the study area (5-13). The vanadium concentrations in Hughes Creek correlated very strongly ($R^2=0.999$) with the percentage of fines (clay and silt) in the sample (Figure 110). The increase in concentration appeared to be related to the amount of fine sediment collected rather than the proximity to mining. As the results are based on only one upstream sample and two downstream samples, further monitoring is required to confirm the increase downstream, and the correlation with sediment fines content.

7.4.4 Conclusion

According to the ANZECC guidelines' decision tree, the initial data suggests most metals in sediments are "low risk" and require "no action" as downstream concentrations were below trigger values or not increased significantly above background. Iron, molybdenum and vanadium in individual streams require further monitoring (including particle size analysis) to confirm if levels have increased significantly downstream and if the increases are attributed to natural fine sediment levels, or mining and other past and present land use practices.

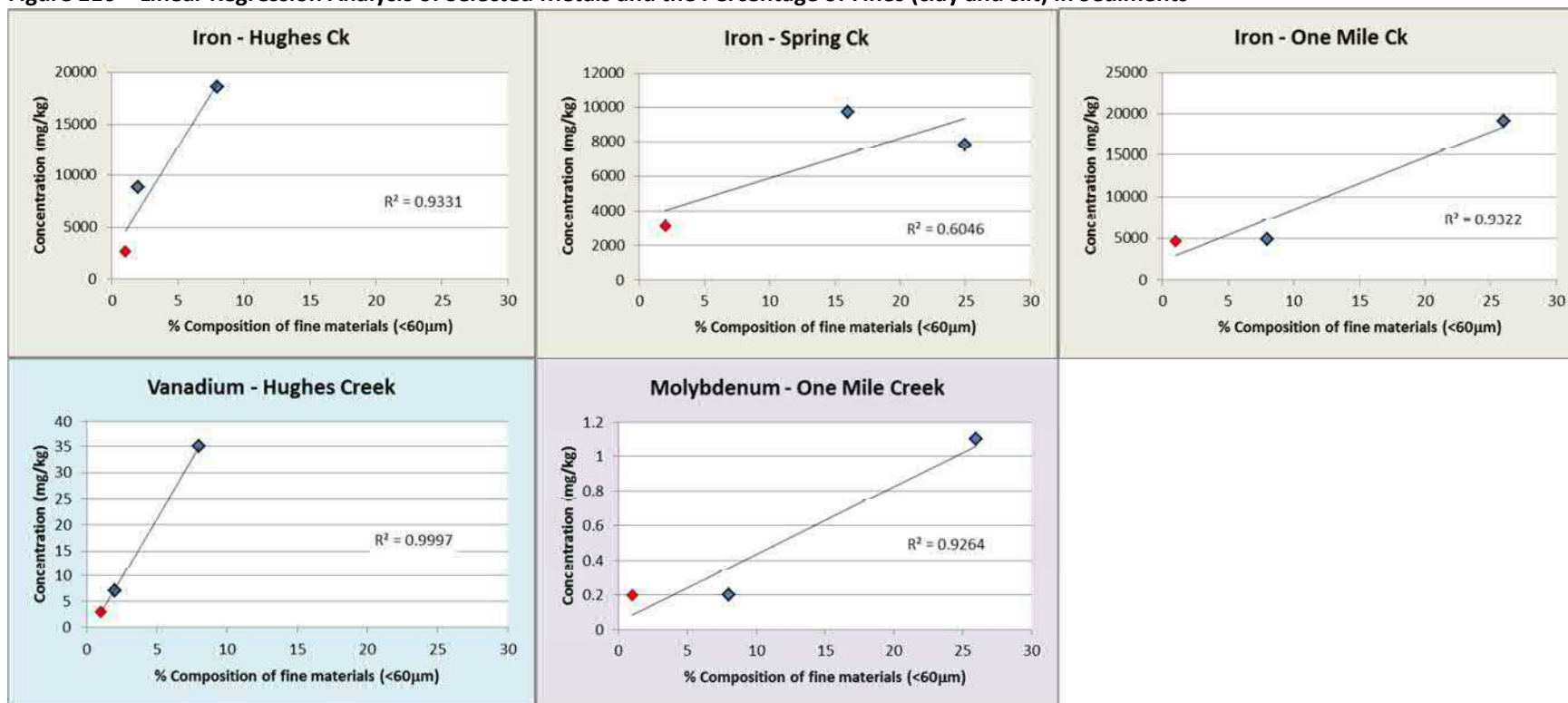


Table 14 – Comparison of Upstream and Downstream Medians for Metals in Sediments (mg/kg)

Median Values	No. of Samples	Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
Hughes Creek US	2	685	2.4	25	0.05	3.8	1.85	1.55	5770	4.5	42.3	0.05	0.25	2	0.5	0.05	0.125	5	10.55
Hughes Creek DS	4	1770	2.9	25	0.05	17.6	4.65	4.7	22700	2.65	120.5	0.05	0.125	9.35	0.5	0.05	0.3	39.5	12
% Change from US to DS (Hughes)		158	21	0	0	363	151	203	293	-41	185	0	-50	368	0	0	140	690	14
One Mile Creek US	2	6745	2.1	25	0.05	6.05	1.95	7.9	5815	7.75	52.1	0.05	0.125	5.8	0.5	0.05	0.425	13	18.3
One Mile Creek DS	2	3670	4.3	25	0.05	9.05	4.35	7.35	11980	6.95	83.5	0.05	0.65	9.2	1.25	0.05	0.25	16	18.6
% Change from US to DS (One Mile)		-46	102	0	0	50	123	-7	106	-10	60	0	420	59	150	0	-41	23	2
Spring Creek US	1	720	1.3	25	0.05	2.9	0.8	1.1	3120	2.5	18.6	0.05	0.1	1.1	0.5	0.05	0.05	5	3
Spring Creek DS	5	4130	1.4	25	0.05	11.2	5	5	7070	6.3	129	0.05	0.2	6.7	0.5	0.05	0.2	16	10.8
% Change from US to DS (Spring)		474	7.7	0	0	286	525	355	127	152	594	0	100	509	0	0	300	220	260
Phillips Creek US	5	1410	1.5	25	0.05	14.7	4	2	8910	2.8	108	0.05	0.2	7.8	0.5	0.05	0.05	13	9.9
Phillips Creek DS	5	2090	1.6	25	0.05	10.7	4.7	3	9420	2.7	194	0.05	0.2	10.8	0.5	0.05	0.05	11	10.8
% Change from US to DS (Phillips)		48	7	0	0	-27	18	50	6	-4	80	0	0	38	0	0	0	-15	9
All Upstream	10	1225	1.7	25	0.05	10.55	2.9	1.95	8020	2.85	89.1	0.05	0.15	7.05	0.5	0.05	0.05	10.5	9.05
All Downstream	16	2200	1.6	25	0.05	11.8	4.95	3.65	9575	3.85	130.5	0.05	0.2	8.8	0.5	0.05	0.15	16	10.8
% Change from US to DS (All)		80	-3	0	0	12	71	87	19	35	46	0	33	25	0	0	200	52	19
<LOR				100%	100%							100%			>96%	100%	46%		

* Medians calculated using a value of half the Limit of Reporting (LOR) when values were below detection limits.

Figure 110 – Linear Regression Analysis of Selected Metals and the Percentage of Fines (clay and silt) in Sediments



◆ = Downstream sample ◆ = Upstream sample

Figure 111 – Aluminium (total) in Sediments

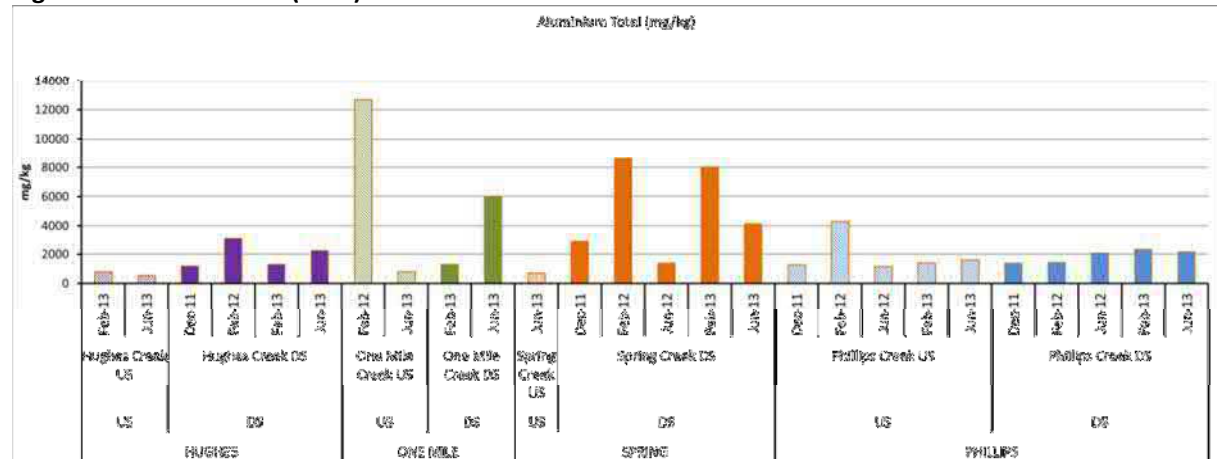


Figure 112 – Arsenic (total) in Sediments



Figure 113 – Boron (total) in Sediments

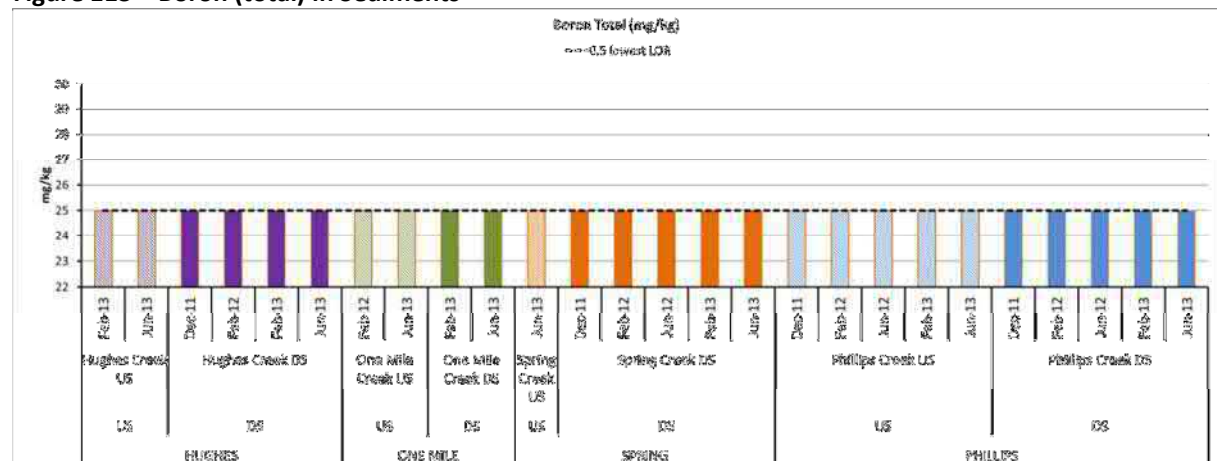


Figure 114 – Cadmium (total) in Sediments

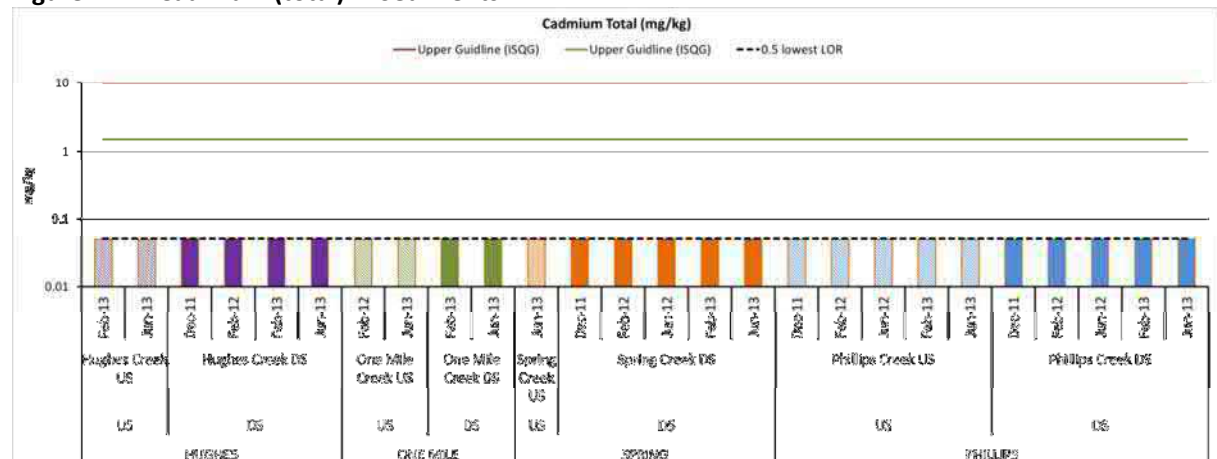


Figure 115 – Chromium (total) in Sediments

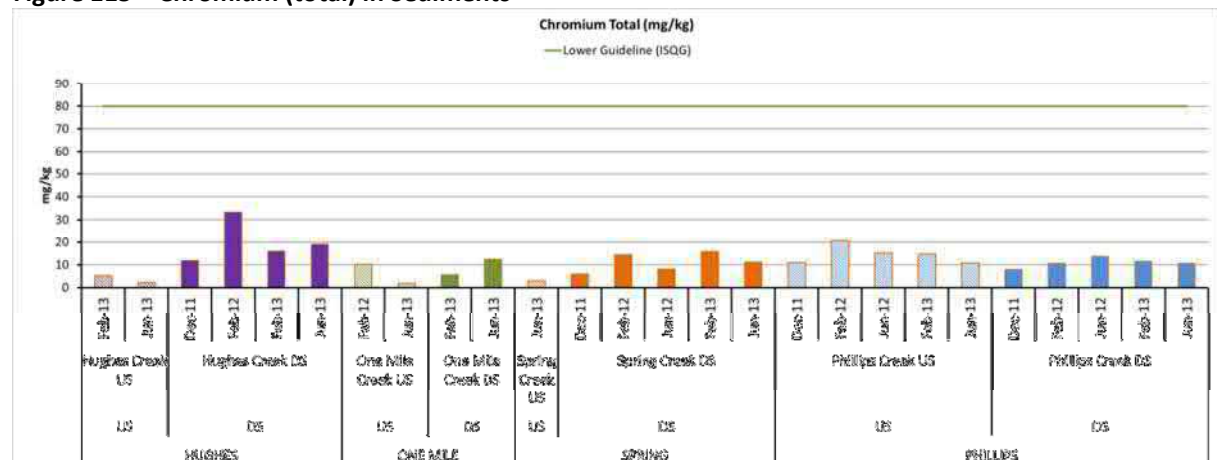


Figure 116 – Cobalt (total) in Sediments

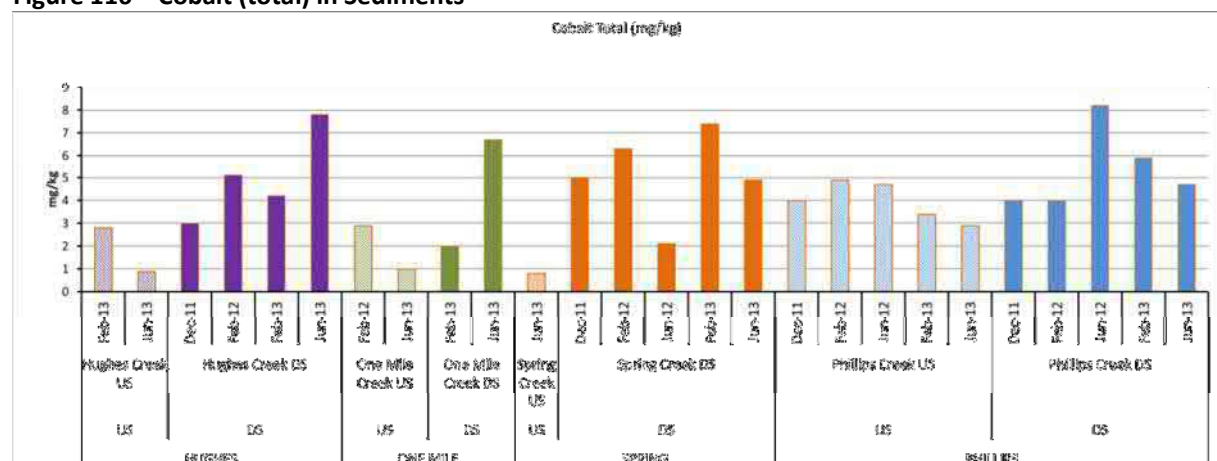


Figure 117 – Copper (total) in Sediments

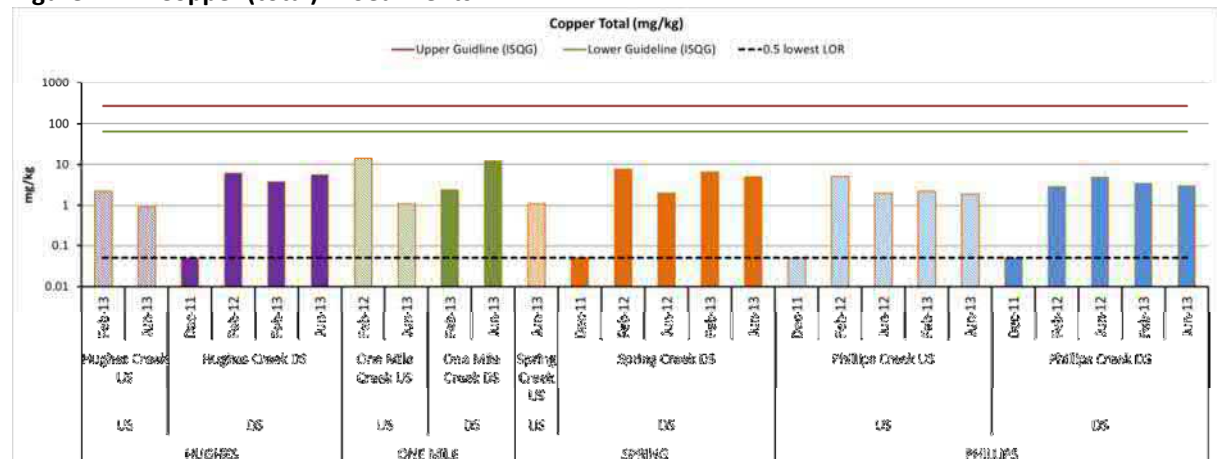


Figure 118 – Iron (total) in Sediments

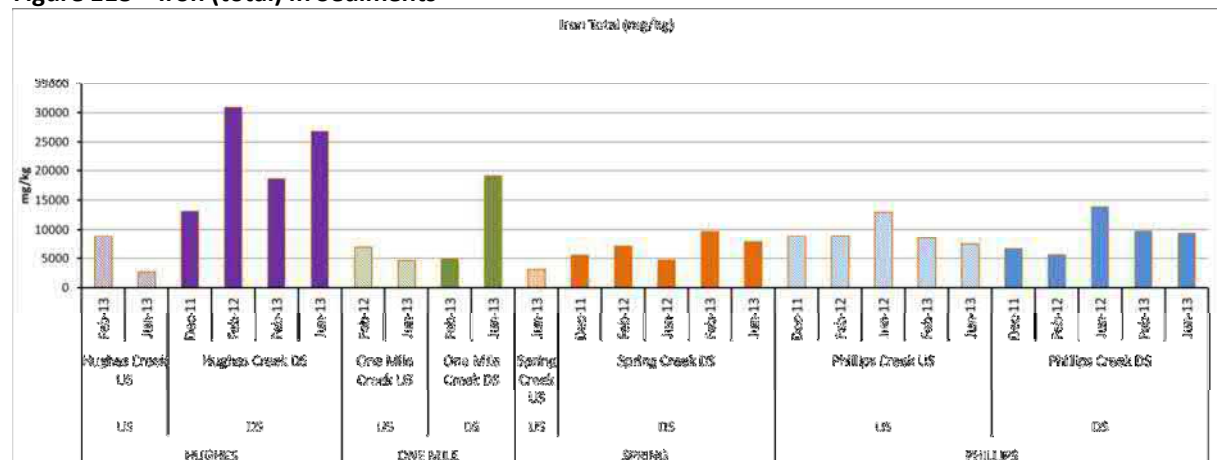


Figure 119 – Lead (total) in Sediments

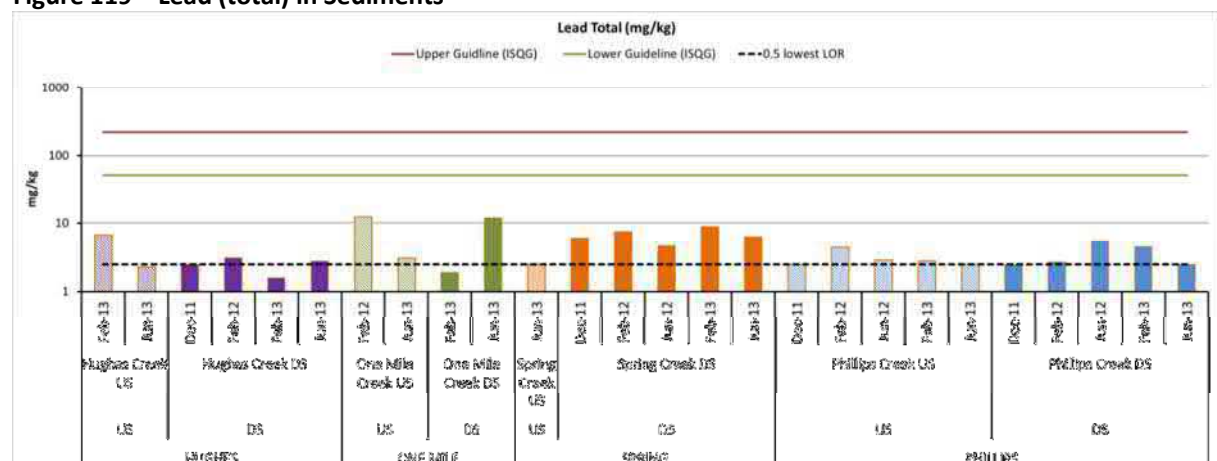


Figure 120 – Manganese (total) in Sediments

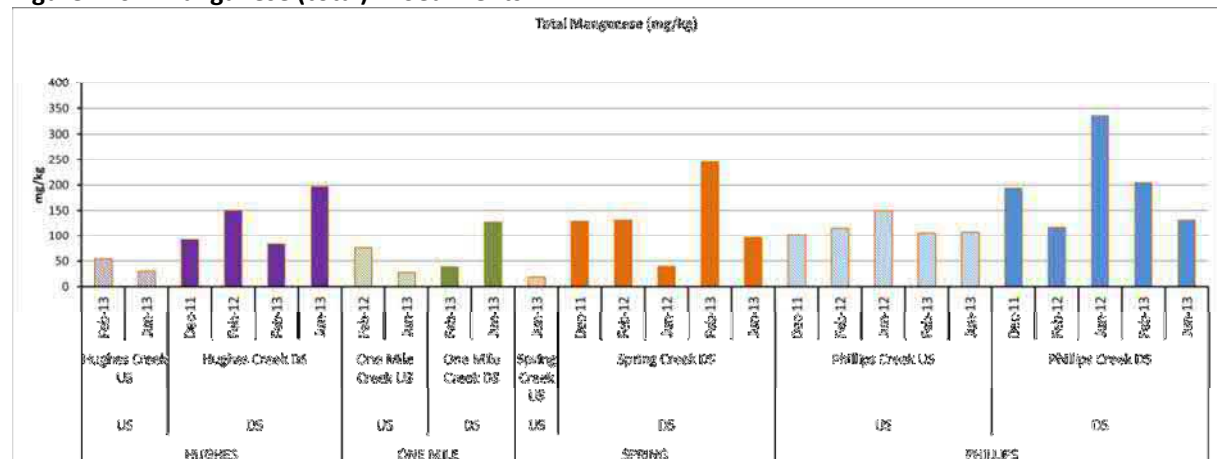


Figure 121 – Mercury (total) in Sediments

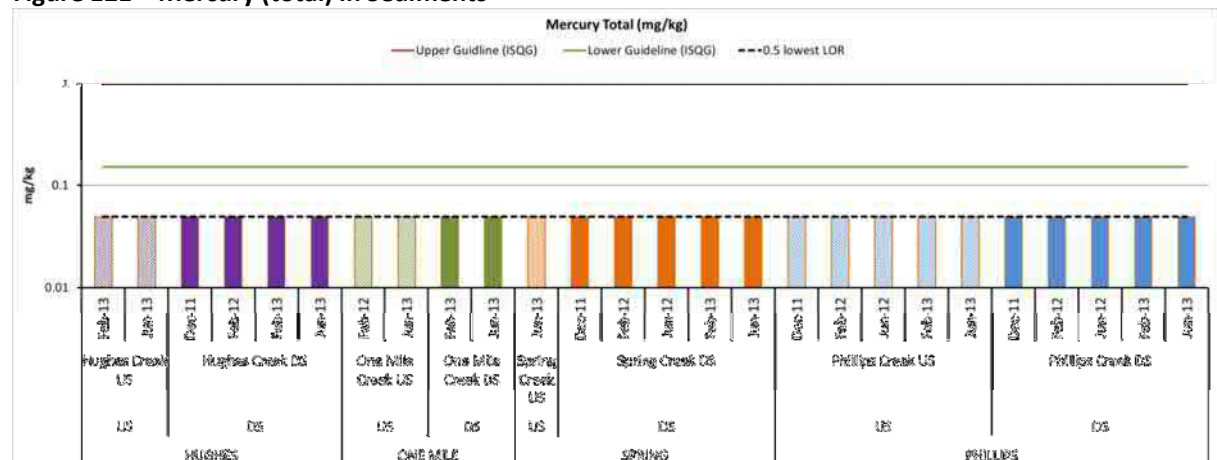


Figure 122 – Molybdenum (total) in Sediments

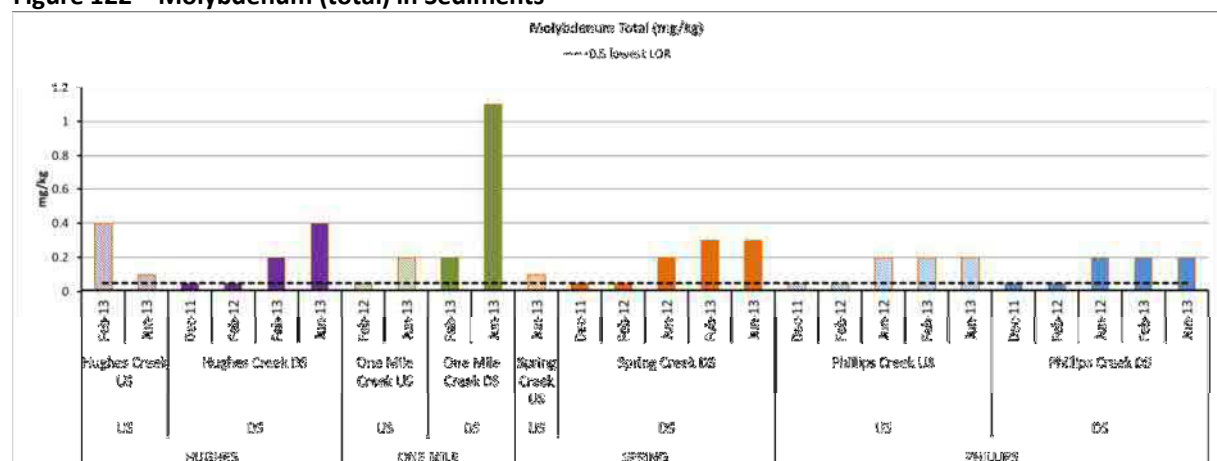


Figure 123 – Nickel (total) in Sediments

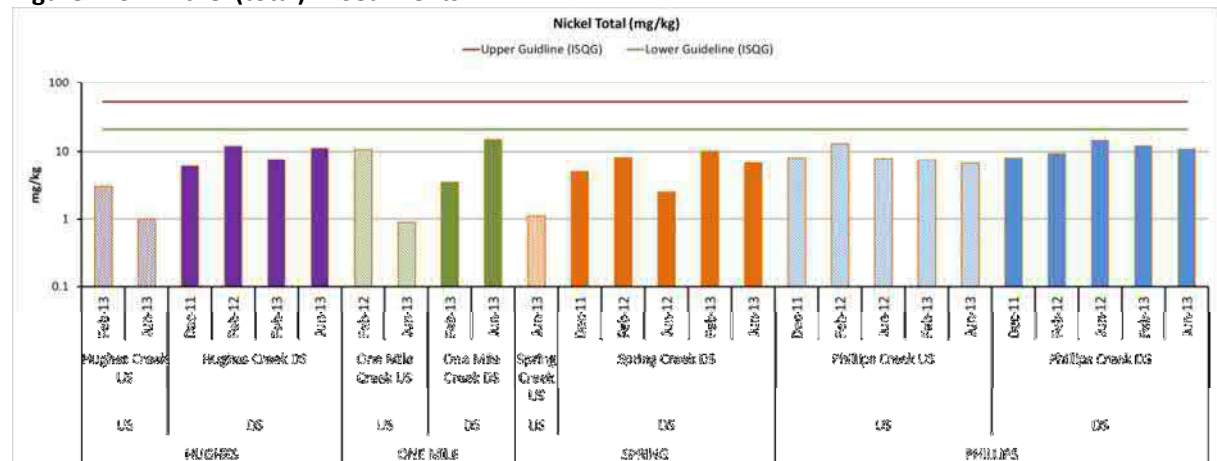


Figure 124 – Selenium (total) in Sediments

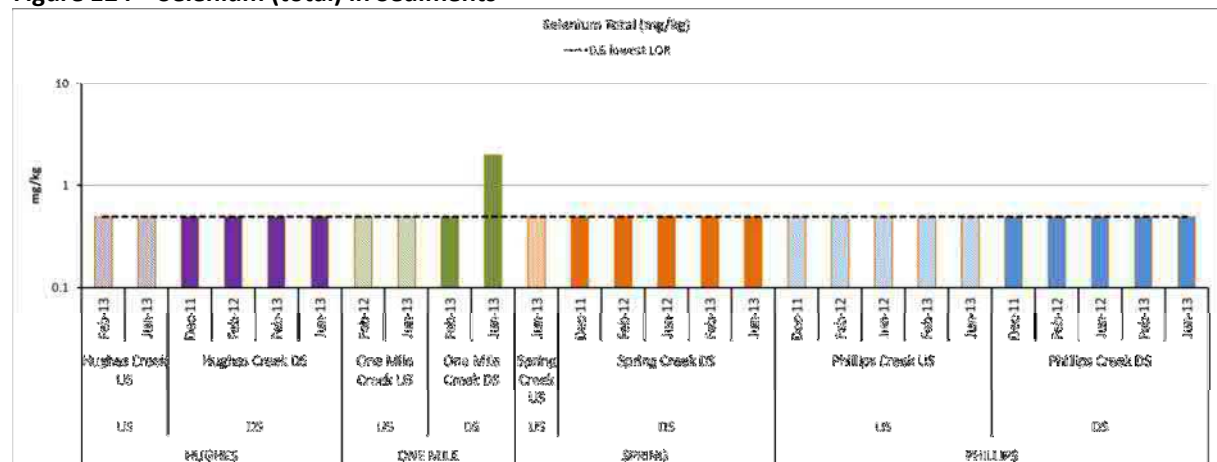


Figure 125 – Silver (total) in Sediments

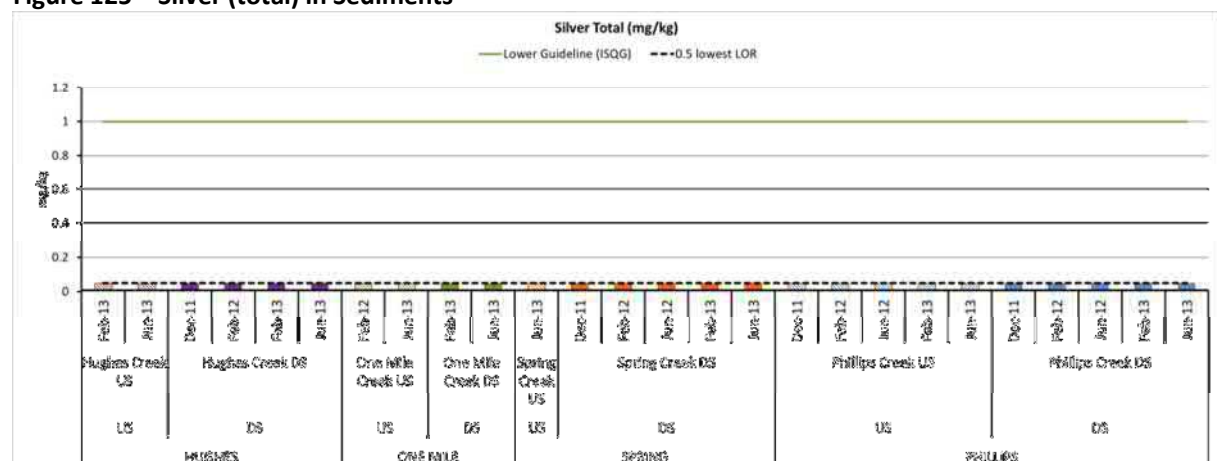


Figure 126 – Uranium (total) in Sediments

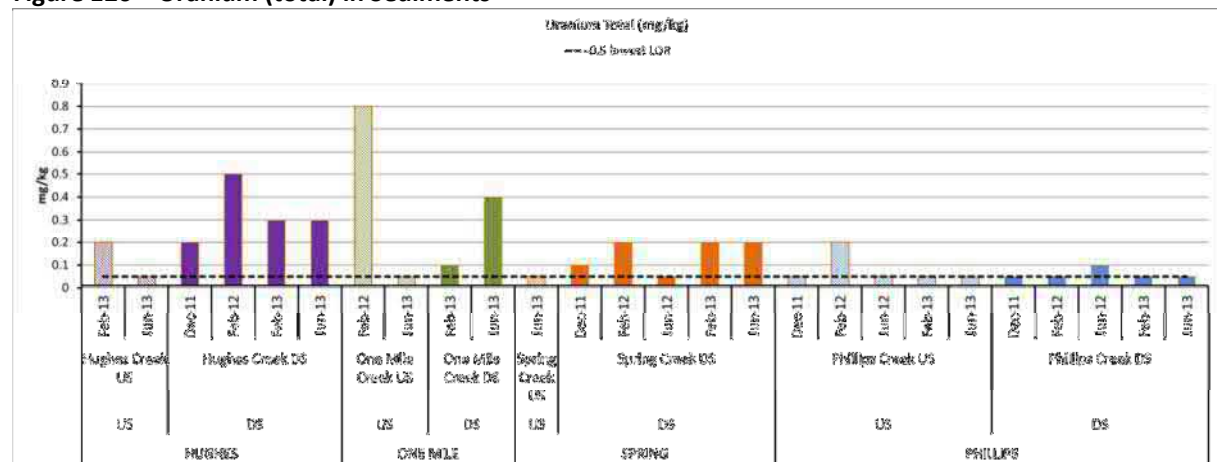


Figure 127 – Vanadium (total) in Sediments

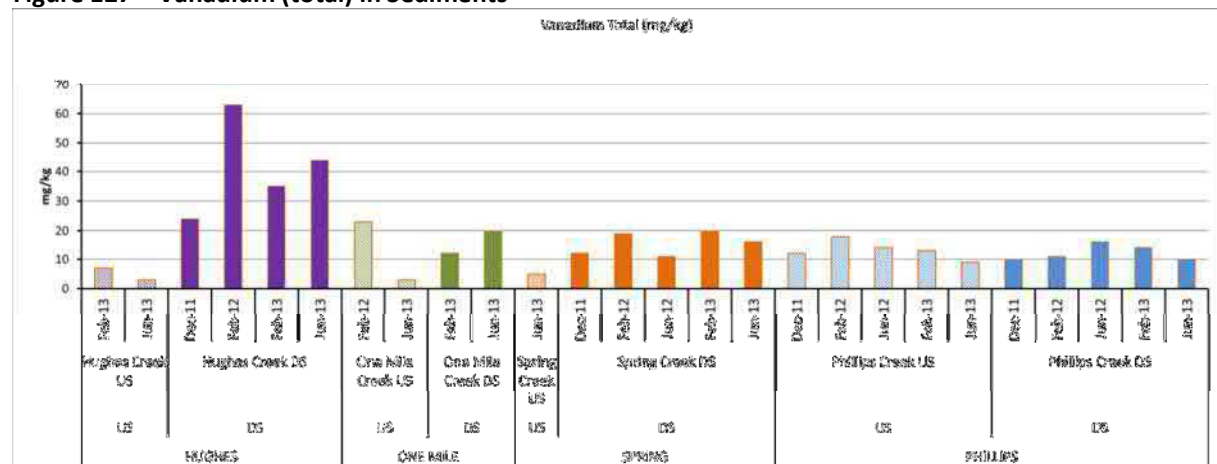
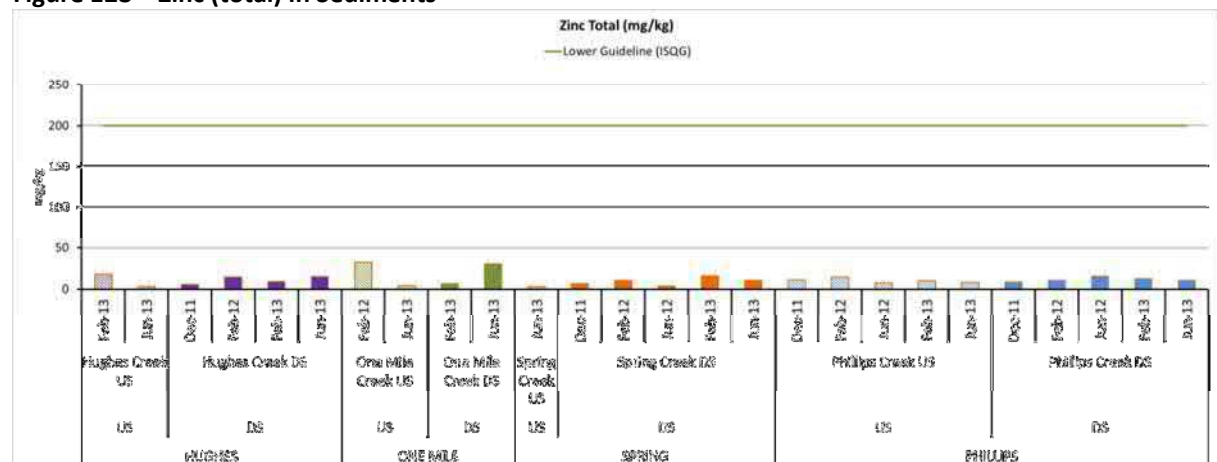


Figure 128 – Zinc (total) in Sediments



8. BIO-INDICATORS

8.1 PROGRAM DESIGN

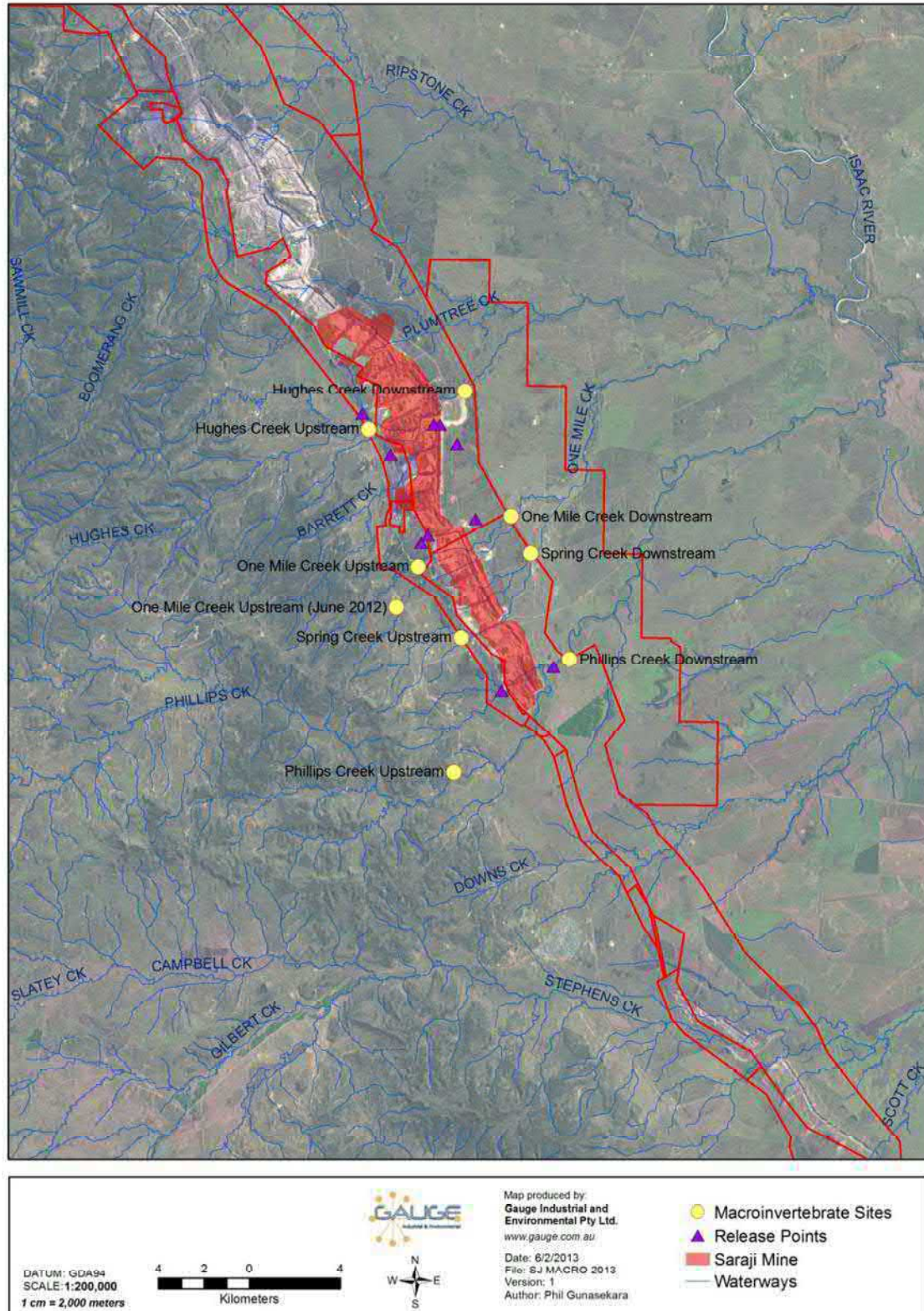
Macroinvertebrate surveys were conducted by the Central Queensland University (CQU) at the sites and times shown in Table 15 and Figure 129.

The surveys were limited to the “pool” habitat only in 2011 and 2012, and the “edge” habitat in 2013. Macroinvertebrate monitoring is considered an appropriate biological monitoring tool where there is natural, permanent or semi-permanent water (QWQG, 2009). The ephemeral streams in the study area restricted the opportunity to select appropriate sites. Some sites were completely dry during the surveys and were not sampled.

Table 15 – Macroinvertebrate Monitoring Program Sites and Dates

Stream	Site	Monitoring Point	Coordinates (GDA94)		Survey date, surveyor and habitat						
			Latitude	Longitude	Jun 2011	Jul 2011	Dec 2011	Feb 2012	Jun 2012	Feb 2013	Jun 2013
					CQU	CQU	CQU	CQU	CQU	CQU	CQU
					POOL	POOL	POOL	POOL	POOL	EDGE	EDGE
Hughes Creek	Upstream	MP 1	-22.3845	148.2656	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Downstream	MP 5	-22.3690	148.3068	✓	✓	Dry	Dry	Dry	Dry	Dry
One Mile Creek	Upstream	MP 2	-22.4393	148.2875	Dry	Dry	Dry	✓	-	Dry	Dry
	Upstream (June 2012)	MP 2	-22.4554	148.2782	-	-	-	-	Dry		
	Downstream	MP 6	-22.4187	148.3271	Dry	Dry	Dry	Dry	Dry	Dry	✓
Spring Creek	Upstream	MP 4	-22.4673	148.3061	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Downstream	MP 8	-22.4335	148.3356	✓	Dry	✓	Dry	✓	Dry	✓
Phillips Creek	Upstream	MP 3	-22.5211	148.3034	✓	Dry	✓	✓	✓	✓	✓
	Downstream	MP 7	-22.4754	148.3527	✓	Dry	Dry	Dry	✓	✓	✓

Figure 129 – Macroinvertebrate Monitoring Sites



8.2 METHODOLOGY & QUALITY ASSURANCE

The surveys were conducted in accordance with the Queensland Monitoring and Sampling Manual (2000) using Queensland AUSRIVAS methodology and included:

- (1) Aquatic habitat conditions,
- (2) Physio-chemical properties of the water column,
- (3) Aquatic macroinvertebrate sampling & identification, and
- (4) Data analysis.

Sampling, habitat assessment and data analysis were performed by personnel trained in AusRivAS methodology. The surveys conducted in June 2011 used the “live” pick method of sorting and selecting organisms in the field prior to preservation and laboratory identification. The other surveys were conducted by the “laboratory pick” methodology whereby the entire field sample is preserved and sorted in the laboratory. Laboratory water quality analysis was performed by Australian Laboratory Services (ALS).

Details of the methodologies and quality control used during each survey are detailed in Sellens, *et al* (2011) and Shrestha, *et al* (2012).

8.3 INDICES AND GUIDELINES

Data analysis for each habitat, site and survey included the following indices:

- **SIGNAL-2:** SIGNAL analysis of pollution sensitive groups using SIGNAL-2 (abundance-weighted) methodology outlined in Chessman (2001; 2003).
- **PET Taxa Richness:** PET taxa richness was calculated by tallying the total number of PET families at each site.
- **Taxa Richness:** Taxa richness, or number of taxa (*S*), was calculated by tallying the total number of taxa collected in a sample.
- **Taxa Abundance:** Taxa abundance (*N*) was calculated by tallying the total number of individuals at each site.
- **% Tolerant Taxa:** Percentage (%) tolerance scores for each site were calculated by dividing the number of taxa with SIGNAL scores less than 4, by the total number of SIGNAL taxa recorded.
- **Shannon Diversity Index:** A calculation based on the number of taxa and the relative evenness of the abundance across taxa.
- **O/E Families:** A modelling output which is a ratio relating the number of families of macroinvertebrates recorded in a sample to the number of families expected in that sample according to the predictions of the model for least-disturbed conditions.
- **O/E SIGNAL:** A modelling output which gives the ratio of the observed SIGNAL value for a sample to the expected SIGNAL value in that sample according to the predictions of the model for least-disturbed conditions.

The Queensland guidelines for macroinvertebrates in freshwaters in the Central Region are listed in Table 16. The guidelines refer to two habitat types:

- **Edge:** habitat along the stream bank, and
- **Composite:** a mixture of all bed habitats within the site (e.g. sandy pool, rocky pool, riffle, run & cascade). In this report, the “pool” habitat sample is the composite.

Table 16 - Macroinvertebrate SMD Guideline Scores for Freshwater Central Region

Indicator	Score Description	Guideline Range*
SIGNAL	1 (most tolerant of pollution) 10 (least tolerant of pollution)	3.33 - 3.85 (Composite) 3.31 - 4.20 (Edge)
% Tolerant Taxa (% of <4 SIGNAL score taxa)	0 – 100 %. Higher scores indicate streams containing taxa of higher pollution tolerance	25 – 50 (Composite) 44 – 56 (Edge)
PET Taxa Richness	Higher values indicate higher stream health	2 - 5 (Composite) 2 - 5 (Edge)
Taxa Richness	Higher values generally indicate higher stream health	12 – 21 (Composite) 23 – 33 (Edge)
“Composite” = “Pool” or “Bed” in this report		

*QWQG (2009)

8.4 RESULTS & DISCUSSION

8.4.1 Physical Habitat Conditions

In addition to water quality, habitat conditions can influence the macroinvertebrate assemblages present in a stream. An assessment of habitat condition, according to the criteria in the Queensland Monitoring and Sampling Manual (NRM, 2000), was made during the June 2011 and 2013 surveys (pers.comm C. Sellens, 2013; pers.comm.CQU, 2014). Nine habitat variables were scored at each site and rated as poor, fair, good or excellent (Table 17).

Physical habitat conditions suggest the streams in the study area are structurally less than optimal for supporting diverse macroinvertebrate communities. Hughes, One Mile and Spring creeks, and downstream Phillips Creek, generally rated “fair” overall. Downstream Phillips Creek was the best of the sites assessed, scoring a “good” rating. No assessment of upstream One Mile Creek was recorded.



Table 17 – Physical Habitat Assessment

REMP site name	Sample Run	Surveyor	Bottom Substrate Available Cover	Embeddedness	Velocity Depth Category	Channel Alteration	Bottom Scouring and Deposition	Pool Riffle Run Bend Ratio	Bank Stability	Bank Vegetative Stability	Streamside Vegetation Cover	Total Habitat Score
Hughes DS	Jun-11	CQU	Poor	Poor	Fair	Fair	Good	Poor	Fair	Good	Fair	Fair
Hughes DS	Jul-11	CQU	Poor	Poor	Fair	Fair	Good	Poor	Fair	Good	Fair	Fair
Hughes US	Jul-11	CQU	Poor	Poor	Poor	Poor	Excellent	Poor	Excellent	Excellent	Good	Fair
One Mile DS	Jun-13	CQU	Poor	Fair	Poor	Good	Good	Fair	Fair	Fair	Fair	Fair
Phillips DS	Jun-11	CQU	Poor	Poor	Fair	Fair	Excellent	Poor	Good	Excellent	Fair	Fair
Phillips DS	Feb-13	CQU	Fair	Fair	Fair	Excellent	Good	Fair	Fair	Good	Fair	Good
Phillips DS	Jun-13	CQU	Poor	Fair	Poor	Fair	Excellent	Poor	Good	Excellent	Fair	Fair
Phillips US	Jun-11	CQU	Excellent	Good	Good	Good	Excellent	Good	Excellent	Excellent	Fair	Good
Phillips US	Feb-13	CQU	Good	Good	Good	Good	Excellent	Fair	Good	Good	Fair	Good
Phillips US	Jun-13	CQU	Fair	Good	Fair	Good	Good	Fair	Excellent	Excellent	Fair	Good
Spring DS	Jun-11	CQU	Poor	Poor	Poor	Good	Excellent	Poor	Good	Good	Fair	Fair
Spring DS	Jun-13	CQU	Poor	Fair	Poor	Poor	Excellent	Poor	Good	Excellent	Fair	Fair

8.4.2 Aquatic Macroinvertebrates

8.4.2.1 Taxa Richness

Taxa richness is a measure of diversity by the number of macroinvertebrate taxa collected in a sample. Generally higher scores indicate sites in better condition, although this can also occur at disturbed sites with higher than normal levels of flow and nutrient levels (QWQG, 2009).

The sites in the study area were mostly below the Queensland guidelines for the pool habitat (Figure 130) and edge habitat (Figure 131). Phillips Creek was an exception in the pool habitat, generally scoring within guidelines. There was no notable difference between upstream and downstream sites on Phillips Creek in either pool or edge habitat. Comparative upstream and downstream sites for the same habitat type were not available for the other streams.

The results available suggest taxa richness in pool habitat in Phillips Creek is generally higher than the other streams in the study. In the edge habitat surveys conducted in 2013, upstream and downstream Phillips Creek was similar to downstream sites on One-Mile and Spring creeks.

Overall, assessment was limited to a preliminary finding that taxa richness in Phillips Creek does not appear to be notably affected downstream of mining. One-Mile and Spring creeks downstream are similar to Phillips Creek upstream. Further monitoring would be required for confirmation and assessment of the other streams in the study area.

Figure 130 – Taxa Richness in Pool Habitat

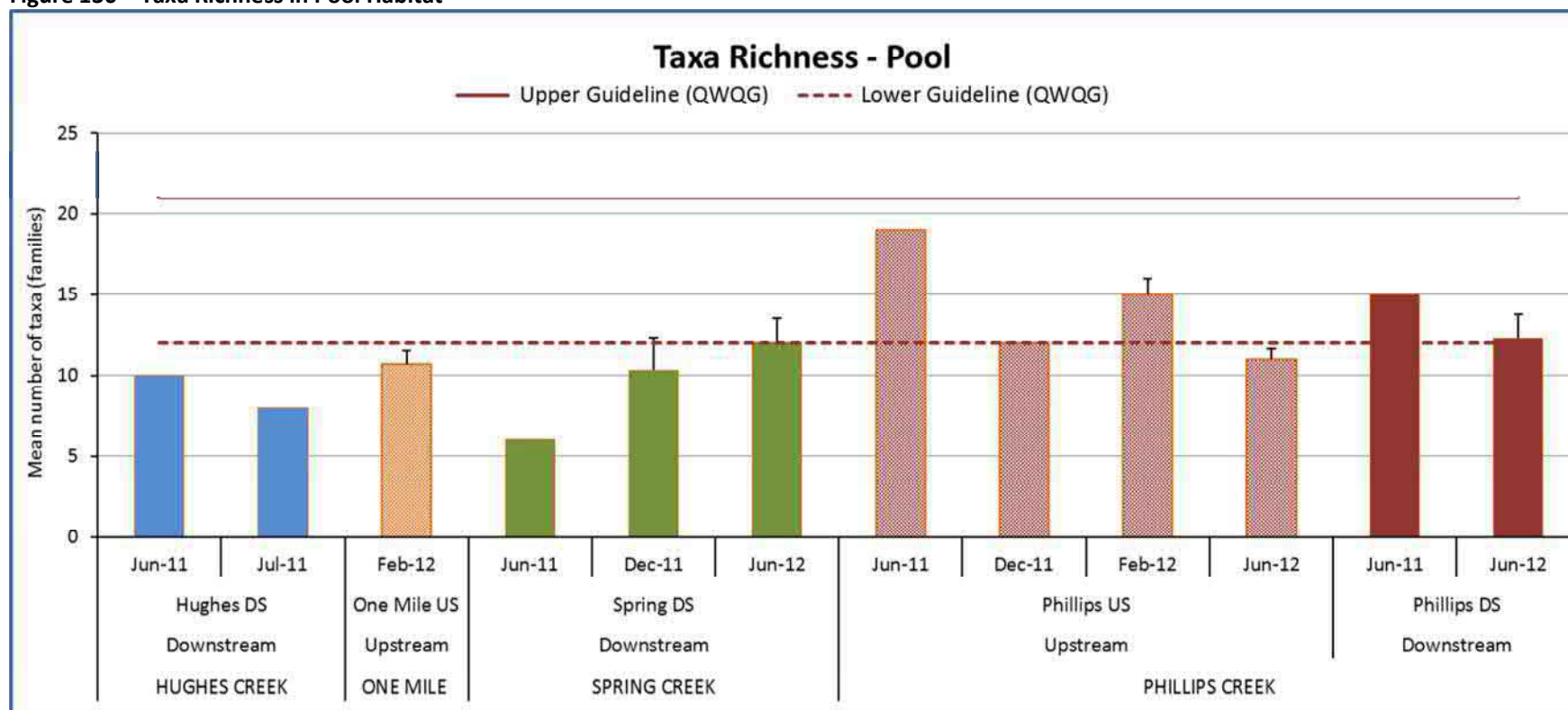
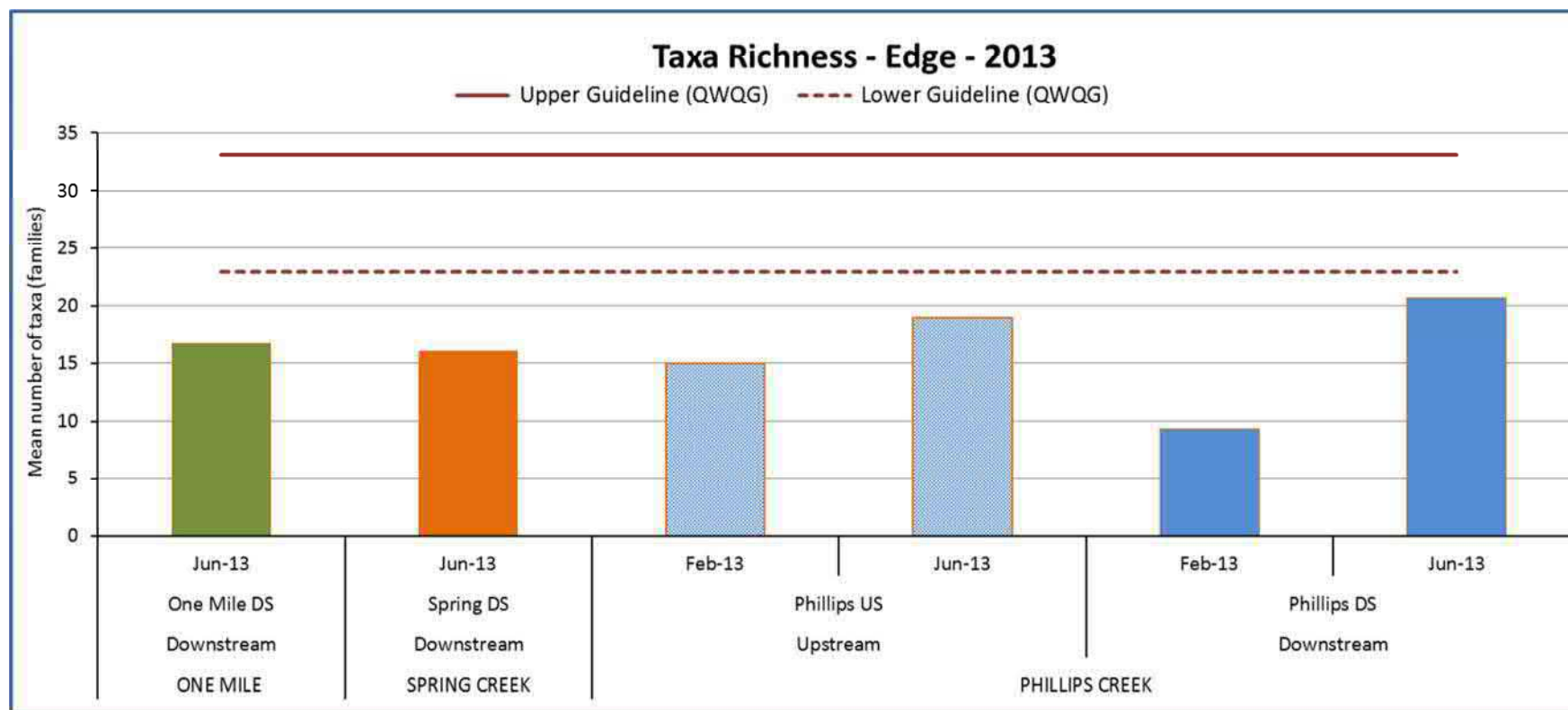


Figure 131 – Taxa Richness in Edge Habitat



8.4.2.2 PET Taxa Richness

PET taxa richness is an indicator of stream health which measures the number of families from three orders: *Plecoptera* (stoneflies), *Ephemeroptera* (mayflies) and *Trichoptera* (caddisflies). These orders are sensitive to changes in the environment and a lower PET score can indicate habitat degradation (QWQG, 2009).

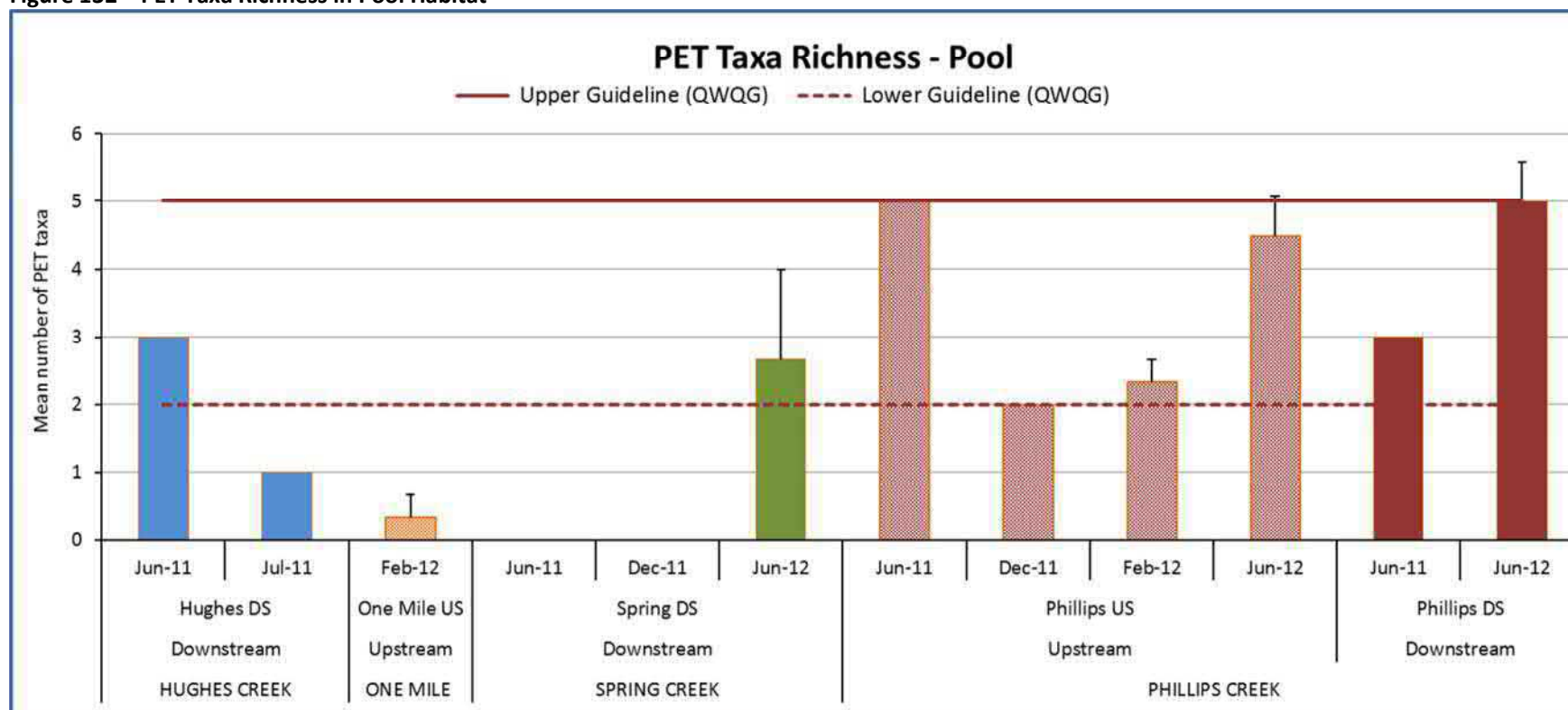
PET taxa richness was highly variable between surveys at the same site (Figure 132 and Figure 133). For example, in the pool habitat, the Hughes Creek downstream site was within guidelines during the 29th June 2011 survey (PET score of 3), and then below guidelines (PET score of 1) just two days later (1st July 2011 survey). Similarly the Spring Creek downstream site recorded a PET score of zero in successive surveys, and was then within guidelines six months later. This variability highlights the need for caution when interpreting single results or small data sets for this indicator.

In the pool habitat, there was no notable difference between upstream and downstream sites on Phillips Creek; with each recording the higher score in the two surveys completed at the same time (June 2011 and June 2012). There were no upstream sites for Hughes and Spring creeks, or downstream site for One-Mile Creek, with which to make comparisons.

In the edge habitat during 2013, the downstream results were generally lower than Phillips Creek upstream, although this is based on a very limited data set of 1-2 surveys.

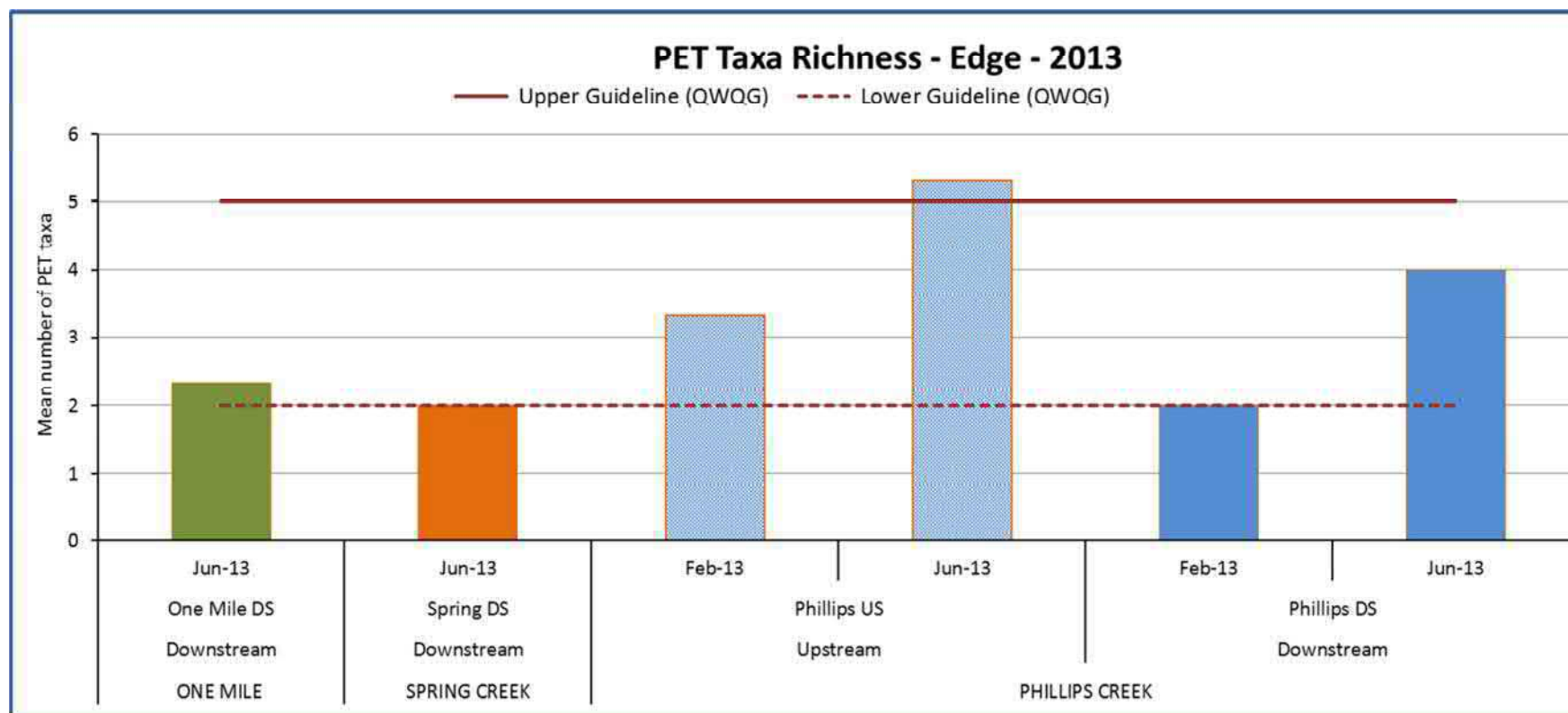
Overall, assessment was limited to a preliminary finding that PET taxa richness in the pool habitat in Phillips Creek does not appear to be notably affected downstream of mining. Further monitoring would be required for confirmation and assessment of the other streams and the edge habitat.

Figure 132 – PET Taxa Richness in Pool Habitat



* In the graph, zero values are those actually recorded (i.e. not due to a survey not being completed)

Figure 133 – PET Taxa Richness in Edge Habitat



8.4.2.3 SIGNAL-2

The SIGNAL index (stream invertebrate grade number – average level) was developed for bio-assessment in Australia as an indication of water quality. The updated version of this methodology is referred to as SIGNAL-2. Each macroinvertebrate group or family is assigned a sensitivity grade number range from 1 (most tolerant of pollution) to 10 (most sensitive to pollution). The SIGNAL score is the average sensitivity grade for the site. Higher scores (maximum of 10) generally indicate healthier waterways; whereas lower scores (minimum of 1) indicate a stressed waterway. In order to compensate for the relative abundance of taxa at a site, a weighted average method is used to produce a *SIGNAL-2: abundance weighted* score (Chessman, 2003).

SIGNAL-2 scores were usually poorer than the Queensland guidelines for the pool habitat, with the occasional site meeting or exceeding the guideline at times (Figure 134). There was no notable or consistent difference between upstream and downstream sites on Phillips Creek; with each recording the higher score in the two surveys completed at the same time (June 2011 and June 2012). There were no upstream sites for Hughes and Spring creeks, or downstream site for One-Mile Creek, with which to make comparisons.

In the edge habitat, SIGNAL-2 score were usually within the Queensland guidelines no notable or consistent difference between upstream Phillips Creek and downstream Phillips, One-Mile and Spring creeks.

Overall, assessment was limited to a preliminary finding that SIGNAL-2 scores in Phillips Creek does not appear to be notably affected downstream of mining. Further monitoring would be required for confirmation and assessment of the other streams and the edge habitat.

Figure 134 – SIGNAL-2 Score in Pool Habitat

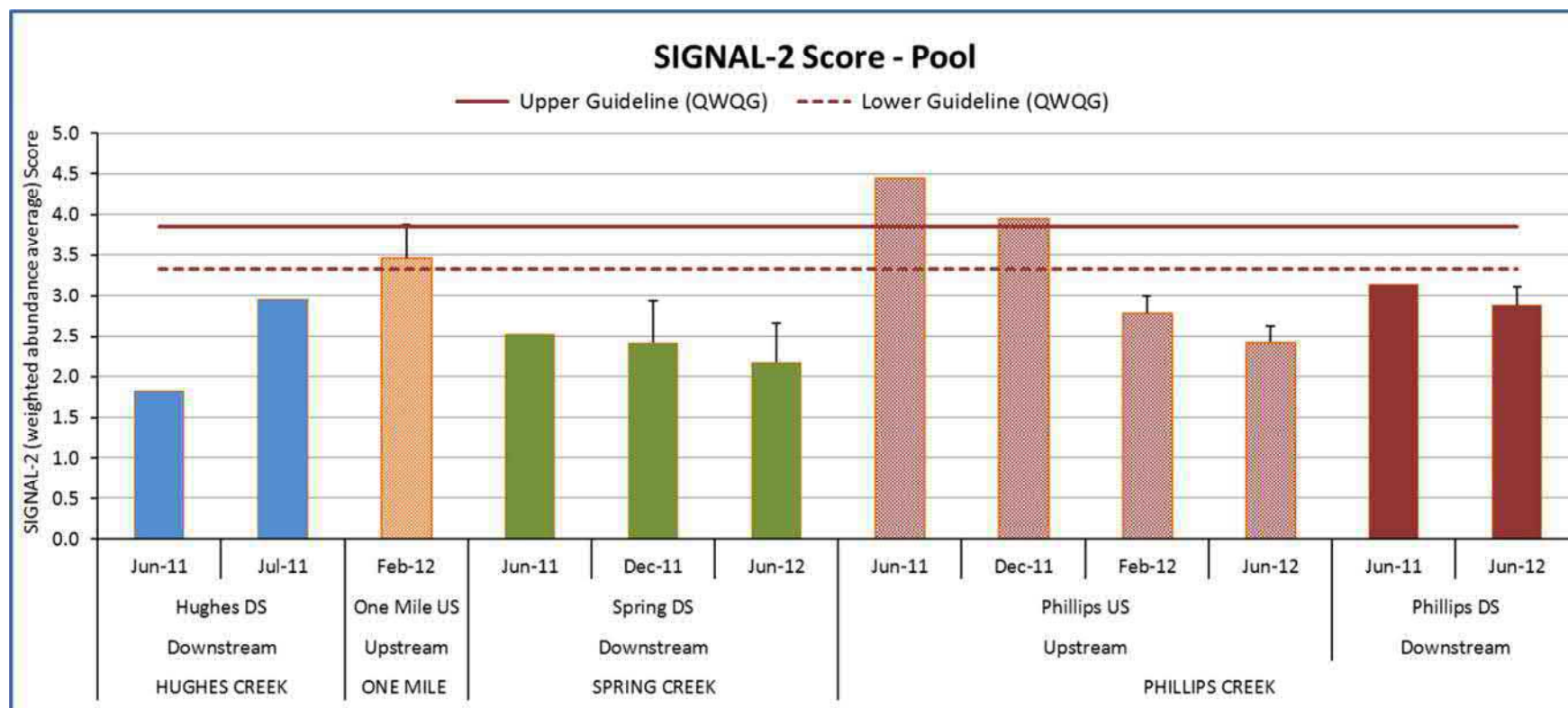
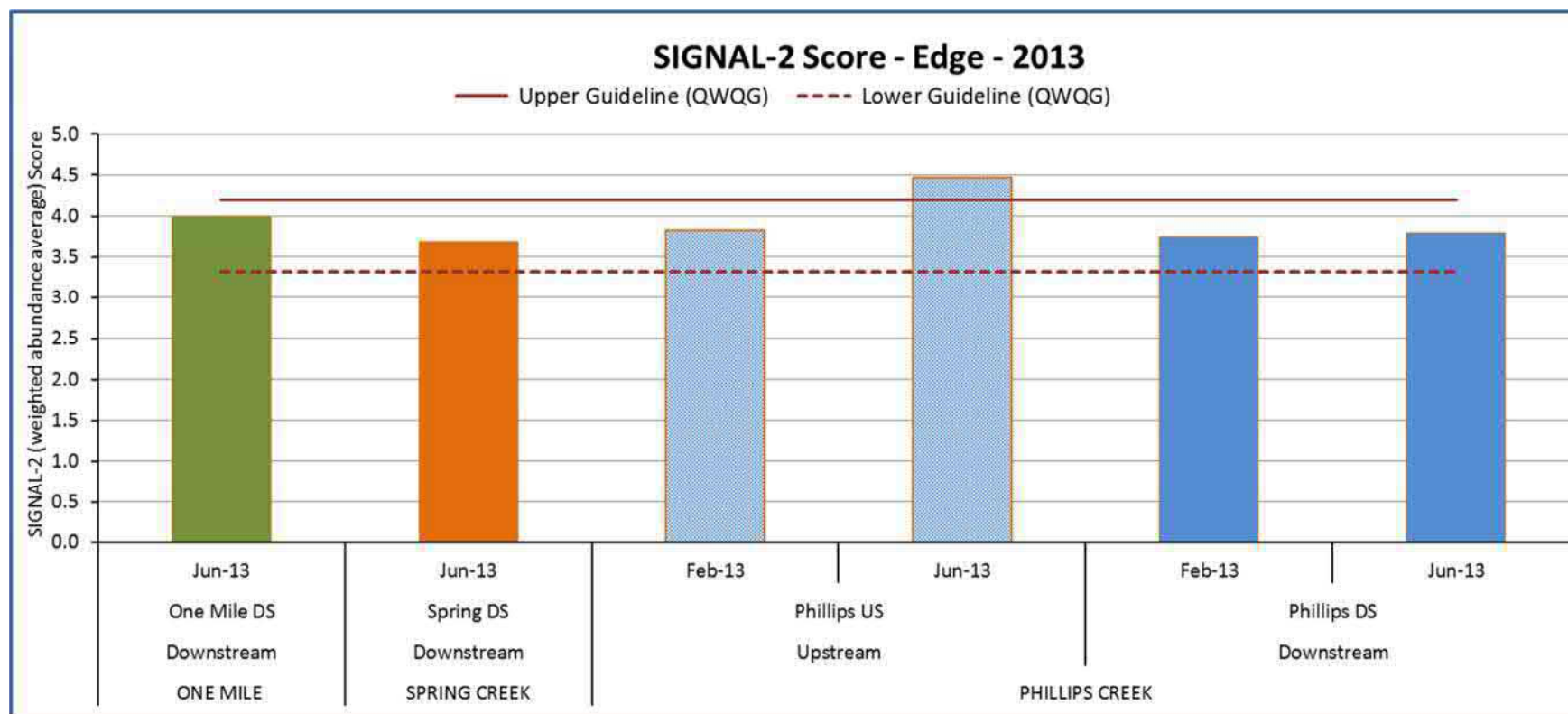


Figure 135 – SIGNAL-2 Score in Edge Habitat



8.4.2.4 Percentage Tolerant Taxa

The Percentage Tolerant Taxa score further analyses the SIGNAL data to express the percentage of SIGNAL taxa recorded which are tolerant to pollution (i.e. have a SIGNAL-2 score less than 4). Higher percentages potentially indicate a more degraded waterway.

In the pool habitat, the percentage of tolerant taxa was within or above (worse than) the Queensland guidelines at all sites (Figure 136). There was no notable difference between upstream and downstream sites on Phillips Creek. There were no upstream sites for Hughes and Spring creeks, or downstream site for One-Mile Creek, with which to make comparisons.

In the edge habitat, the percentage of tolerant taxa were within the Queensland guidelines for downstream One-Mile and Spring creeks, and below (better than) guidelines for both upstream and downstream Phillips Creek.

Overall, assessment was limited to a preliminary finding that Percentage Tolerant Taxa scores in Phillips Creek were not notably affected downstream of mining, and downstream One-Mile and Spring creeks were within guidelines. Further monitoring would be required for confirmation and assessment of the other streams in the study area.

Figure 136 – Percentage Tolerant Taxa in Pool Habitat

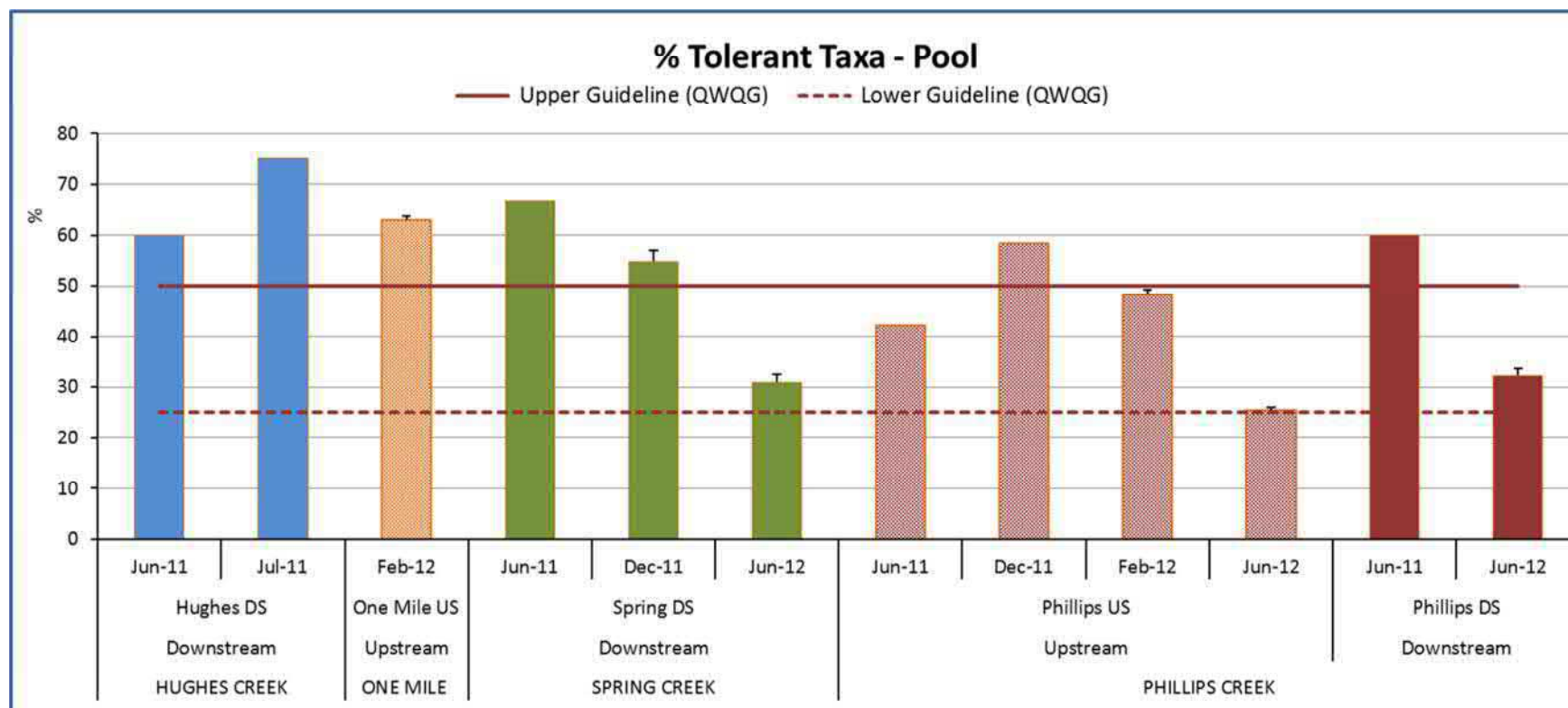
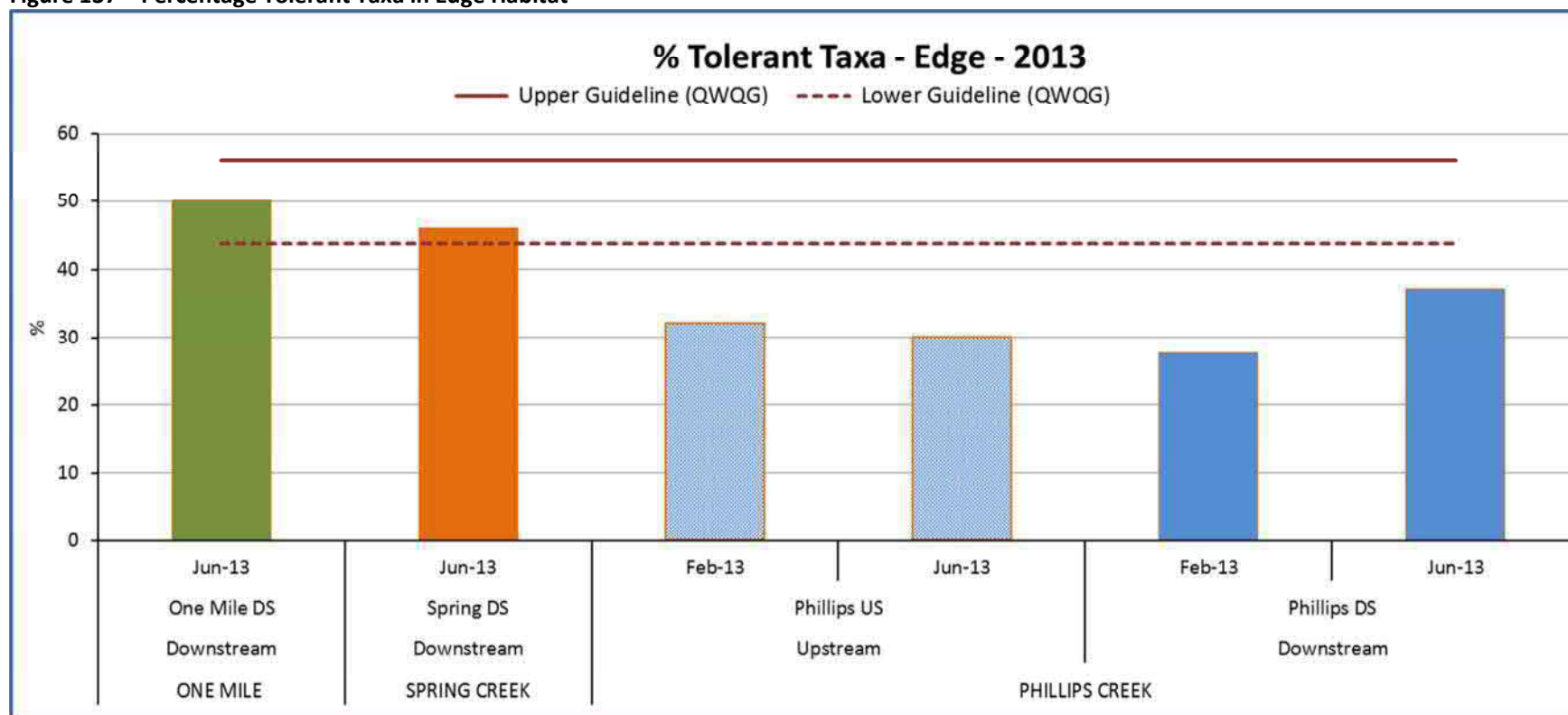


Figure 137 – Percentage Tolerant Taxa in Edge Habitat



8.4.2.5 Shannon Diversity Index

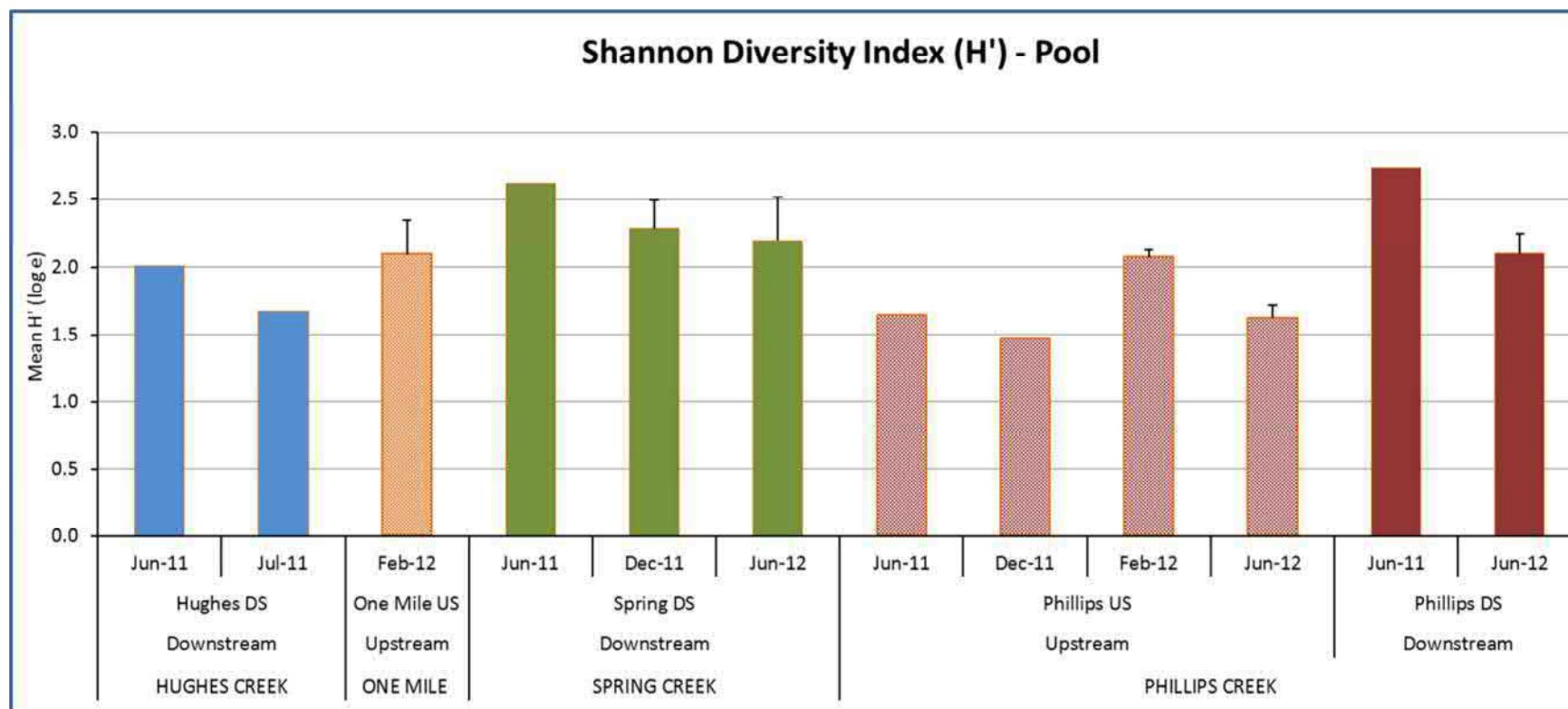
The Shannon Diversity Index (H') is a measure of diversity in terms of species richness and evenness. Higher scores are produced by higher numbers of different taxa, in combination with an even spread of numbers across taxa (1.5 = low richness/evenness, 3.5 = high richness/evenness). There are no Queensland guidelines for this index.

This index was not analysed in the 2013 surveys (pers.comm. CQU, 2014).

Species richness and evenness was generally low to moderate (Figure 138). Phillips Creek showed an improvement downstream in the two surveys conducted at the same time (June 2011 and June 2012). There were no comparative upstream sites for Hughes and Spring creeks, however the downstream sites were on a par or better than upstream Phillips and One Mile creeks.

From the preliminary data available, the Shannon Diversity Index does not appear to be impeded downstream of mining, although further monitoring is required to confidently establish a trend.

Figure 138 – Shannon Diversity Index for the Pool Habitat



8.4.2.6 Observed to Expected (O/E) Families Ratio (AUSRIVAS)

The O/E Families score is the ratio of the number of families of macroinvertebrates recorded in a sample to the number of families expected in that sample according to the predictions of the AUSRIVAS model for least-disturbed conditions. Ratios are categorised into bands describing the relative condition of the site, using the Queensland Coastal Pool model for autumn and spring (Table 18).

Table 18 – AUSRIVAS O/E Families Banding Description

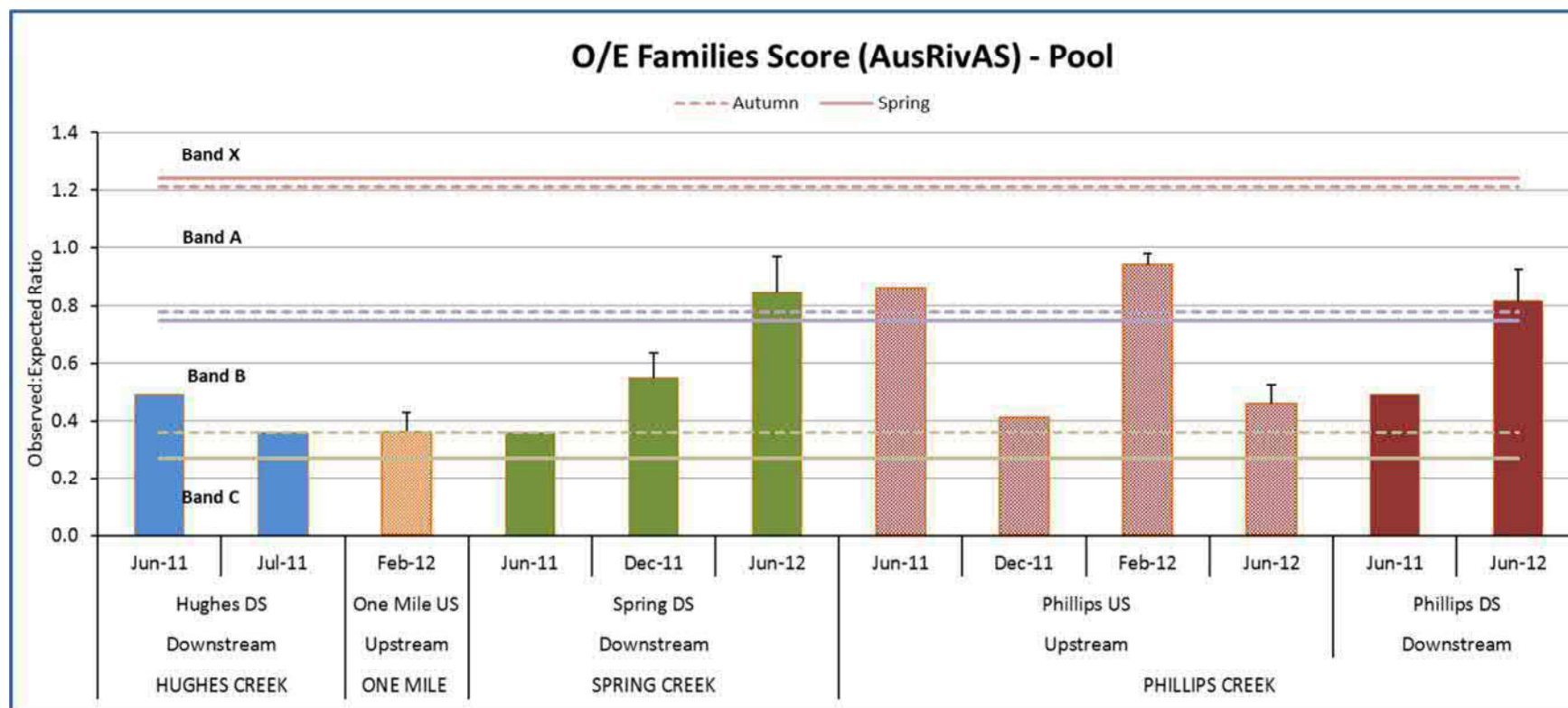
Band	Description	O/E Taxa Interpretations*
X	MORE BIOLOGICALLY DIVERSE THAN REFERENCE SITES	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
A	REFERENCE CONDITION	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
B	SIGNIFICANTLY IMPAIRED	Fewer families than expected. Potential impact either on water quality or habitat quality, or both, resulting in loss of taxa.
C	SEVERELY IMPAIRED	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
D	EXTREMELY IMPAIRED	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

Caution is advised in the interpretation of results as the AUSRIVAS model was developed using the “live pick” technique, whereas the Dec 2011 and the 2012 surveys were done using the laboratory sorting practice (Jones, *et al*, 2012). The AUSRIVAS scoring system was not continued into the 2013 surveys.

Most sites recorded O/E Families ratios in the “significantly impaired” Band B or “severely impaired” Band C, with occasional surveys registering sites in the Band A “reference condition” (Figure 139). There was significant variability between surveys at the same site. For example, Hughes Creek downstream rated a Band B (June 2011), and then two days (July 2012) rated as Band C. Upstream and downstream sites on Phillips Creek alternated from “reference condition” to “significantly impaired” between surveys. This variability highlights the need for caution when interpreting single results or small data sets for this indicator.

In general, the results indicate the streams in the study area are usually below reference condition. Phillips Creek does not appear to be notably impeded downstream, although further monitoring would be required for confirmation and an initial assessment of the other streams.

Figure 139 – AUSRIVAS Scores – O/E Families – Pool Habitat



* Bandings are based on the Queensland Coastal model. Solids lines represent the “Autumn” model and dashed lines are the “Spring” model.

8.4.2.7 Observed to Expected (O/E) SIGNAL Ratio (AUSRIVAS)

The Observed to Expected SIGNAL Ratio is a modelled output which gives the ratio of the observed SIGNAL value for a sample to the expected SIGNAL value in that sample according to the predictions of the model for least-disturbed conditions.

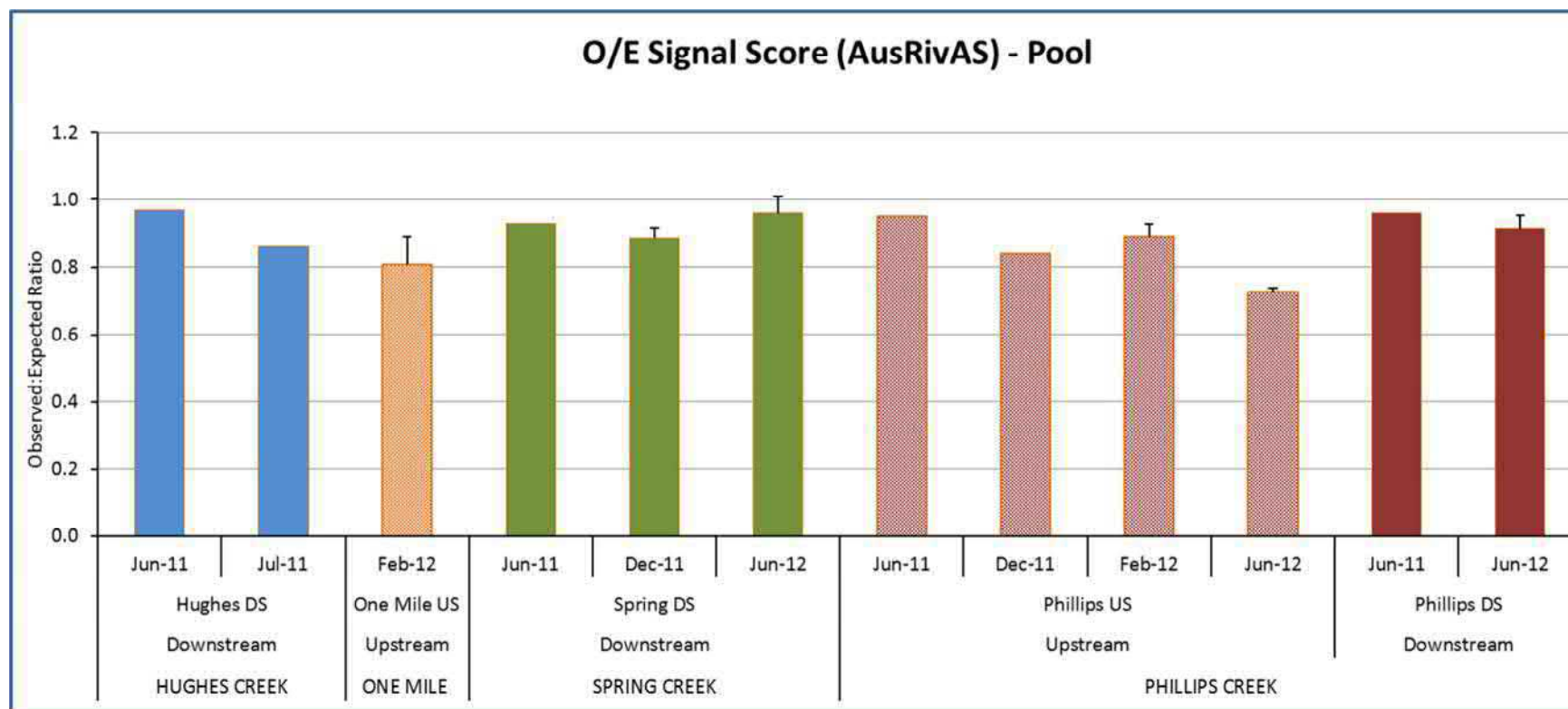
No banding categories are applicable for O/E SIGNAL scores.

Caution is advised in the interpretation of results as the AUSRIVAS model was developed using the “live pick” technique, whereas the 2012 surveys were done using the laboratory sorting practice (Jones, *et al*, 2012). The AUSRIVAS scoring system was not continued into the 2013 surveys.

Upstream and downstream sites recorded similar O/E SIGNAL scores, usually between 0.8 and 1.0, slightly below the expected reference value of 1.0 (Figure 140).

In general, the results indicate the streams in the study area are slightly below reference condition. Phillips Creek is similar, or slightly improved, downstream of mining. Further monitoring would be required for confirmation and an initial assessment of the other streams.

Figure 140 – AUSRIVAS Scores – O/E SIGNAL – Pool Habitat



9. REFERENCES

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APPENDIX A– WATER QUALITY STATISTICAL ANALYSIS



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Hughes US													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.25	7.95	7.67	7.63	7.37	6.2	0.1566	0.0376	-1.208	0%	111
	EC	µS/cm	1511	510	257	325.82	145	53	54981	22.2558	2.164	0%	111
	Turbidity	NTU	1730	331.2	180	254.08	25.6	3.5	129858	66.9169	2.619	0%	29
	DO	mg/L	8.28	7.968	7.59	7.19	6.746	4.21	1.44	0.3798	-1.434	0%	10
	Temp	°C	35.8	29.78	27.7	27.95	25.44	22.3	8.45	0.4486	0.592	0%	42
Organics	SS	mg/L	4640	318	67	319.20	19.8	2.5	507013	67.8911	3.783	6%	110
	Hardness	mg/L	220	53	50	73.00	41	21	4197	19.5	1.407	0%	11
	SO4	mg/L	117	34.8	17	21.82	8	3	330.8	1.7584	1.866	0%	107
	Fluoride	µg/L	300	140	100	116.52	50	50	5250.99	15.11	1.309	30%	23
	Ammonia	µg/L	370	40	20	39.69	5	2.5	5510	15.2	3.641	25%	24
	Nitrate	µg/L	920	182	40	169.89	10	2.5	86951	61.5	1.674	17%	23
TPH	C6-C9	µg/L	10	10	10	8.80	5	5	4.7500	0.4359	-1.145	100%	25
	C10-C36	µg/L	500	50	25	50.00	25	25	8906.3	18.8746	4.323	96%	25
Dissolved Metals	Al	µg/L	5600	760	185	755.85	40	5	2228993.7	292.8	2.584	8%	26
	As	µg/L	2	0.5	0.5	0.66	0.5	0.5	0.1817	0.0852	2.482	84%	25
	B	µg/L	100	62	60	51.66	25	2.5	573.35	4.7889	-0.074	32%	25
	Cd	µg/L	0.1	0.05	0.025	0.03	0.025	0.025	0.0003	0.0036	2.382	100%	24
	Cr	µg/L	1.8	0.68	0.5	0.52	0.18	0.1	0.1779	0.0844	1.313	32%	25
	Co	µg/L	20	0.6	0.5	1.92	0.5	0.5	17.5	0.8375	3.331	80%	25
	Cu	µg/L	7	2	2	1.90	1	0.5	2.8804	0.3328	2.006	19%	26
	Fe	µg/L	1720	1100	420	574.50	120	25	242086	96	0.717	4%	26
	Pb	µg/L	12	0.6	0.5	1.68	0.5	0.5	10.5183	0.6486	2.582	80%	25
	Mn	µg/L	3970	28.8	2.5	193.84	0.9	0.5	626854.9	158.3483	4.329	32%	25
	Hg	µg/L	0.05	0.05	0.05	0.04	0.04	0.025	0.0001	0.0021	-1.348	100%	24
	Mo	µg/L	1	0.5	0.5	0.56	0.5	0.5	0.0275	0.0332	2.200	88%	25
	Ni	µg/L	9	3.2	2	2.98	2	0.5	3.2600	0.3611	1.733	4%	25
	Se	µg/L	1	0.4	0.3	0.38	0.3	0.2	0.0289	0.0347	2.104	8%	24
	Ag	µg/L	0.5	0.05	0.05	0.08	0.05	0.05	0.0097	0.0201	3.299	92%	24
	U	µg/L	0.9	0.37	0.2	0.28	0.118	0.05	0.0533	0.0462	1.295	16%	25
	V	µg/L	4	1.88	1.05	1.38	0.62	0.25	1.0691	0.2111	1.380	8%	24
	Zn	µg/L	32	2.5	2.5	3.92	2.5	0.5	36.5738	1.1860	3.840	85%	26
Total Metals	Al	µg/L	38300	8722	3830	7243.80	698	30	89374165	1891	1.895	0%	25
	As	µg/L	4	3	1.5	1.81	0.5	0.5	1.69	0.2655	0.538	29%	24
	B	µg/L	100	80	68	64.25	56	25	469.15	4.4213	-0.530	17%	24
	Cd	µg/L	0.1	0.05	0.025	0.04	0.025	0.025	0.0007	0.0052	1.759	92%	24
	Cr	µg/L	14	2.44	0.5	2.21	0.29	0.1	15.2403	0.7808	2.195	20%	25
	Co	µg/L	39	8	2.5	5.75	0.5	0.5	76.5652	1.7861	2.463	25%	24
	Cu	µg/L	47	9	4	7.32	2	0.5	96.0183	1.9598	2.686	16%	25
	Fe	µg/L	50400	12300	4580	9397.60	1728	530	134707227	2321	2.004	0%	25
	Pb	µg/L	67	11.4	3	10.25	1	0.5	240.5000	3.1656	2.248	17%	24
	Mn	µg/L	4260	233.2	89	338.04	44	11	755344.0	177.4	3.840	0%	24
	Hg	µg/L	0.07	0.05	0.05	0.05	0.05	0.025	0.0001	0.0022	-0.661	92%	24
	Mo	µg/L	1	0.5	0.5	0.52	0.5	0.5	0	0	4.304	96%	24
	Ni	µg/L	59	11.8	7	9.52	4	0.5	134	2.36	3.221	4%	24
	Se	µg/L	1.2	0.54	0.4	0.46	0.3	0.3	0.0504	0.0458	1.985	8%	24
	Ag	µg/L	0.5	0.1	0.05	0.10	0.05	0.05	0.0122	0.0225	2.420	71%	24
	U	µg/L	3.4	0.736	0.44	0.65	0.258	0.19	0.4	0.1313	2.957	4%	25
	V	µg/L	52.6	13.28	5.9	10.18	2.92	0.5	136.7	2.3863	2.120	4%	24
	Zn	µg/L	96	22.4	13	17.44	2.5	2	467.9	4.3260	2.165	24%	25



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Hughes DS													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	9.35	8.22	7.91	7.90	7.552	6.67	0.1506	0.0325	0.057	0%	143
	EC	µS/cm	7830	746.6	439	736.88	268.8	94.4	1134676	89.0775	4.114	0%	143
	Turbidity	NTU	1640	350	52	219.33	3.1	0.3	128921	52.9399	2.292	0%	46
	DO	mg/L	8.45	8.058	7.57	7.09	6.602	2.63	2.54	0.4418	-1.661	0%	13
	Temp	°C	33.2	30.58	27.65	27.2	24.6	12.9	17.65	0.4952	-1.333	0%	72
Organics	SS	mg/L	2580	352	109	299.98	34	2.5	248175	41.9536	2.813	5%	141
	Hardness	mg/L	2420	350.8	63	339.93	45	44	396352	162.6	2.403	0%	15
	SO4	mg/L	1200	87.2	42.5	89.89	25	5	27436.4	13.9991	4.261	0%	140
	Fluoride	µg/L	500	300	200	212.81	60	50	19291.83	24.55	0.545	22%	32
	Ammonia	µg/L	90	44	20	28.15	6.2	2.5	450	3.6	1.001	15%	34
	Nitrate	µg/L	2990	460	70	397.12	20	5	532827	127.1	2.446	15%	33
TPH	C6-C9	µg/L	10	10	10	9.14	10	5	3.6555	0.3232	-1.669	100%	35
	C10-C36	µg/L	490	50	25	45.29	25	25	6311.7	13.4288	5.022	94%	35
Dissolved Metals	Al	µg/L	4500	360	90	499.69	16	5	1211256.3	183.4	2.844	14%	36
	As	µg/L	3	0.5	0.5	0.61	0.5	0.5	0.1924	0.0741	4.638	89%	35
	B	µg/L	270	112	61	75.30	25	2.5	2524.06	8.4921	1.642	23%	35
	Cd	µg/L	0.1	0.025	0.025	0.03	0.025	0.025	0.0002	0.0026	3.041	100%	34
	Cr	µg/L	1.3	0.52	0.3	0.41	0.1	0.1	0.1241	0.0596	1.211	37%	35
	Co	µg/L	20	0.5	0.5	1.13	0.5	0.5	11.0	0.5596	5.290	94%	35
	Cu	µg/L	12	2	2	2.04	1	0.5	3.4339	0.3088	4.248	14%	36
	Fe	µg/L	4580	600	210	519.94	25	5	784551	148	3.076	22%	36
	Pb	µg/L	13	0.5	0.5	1.04	0.5	0.5	4.9613	0.3765	4.570	89%	35
	Mn	µg/L	571	18.6	2	28.10	0.5	0.5	9509.2	16.4831	4.940	37%	35
	Hg	µg/L	0.5	0.05	0.05	0.06	0.05	0.025	0.0061	0.0134	5.213	100%	34
	Mo	µg/L	22	2	0.5	2.34	0.5	0.5	20.9672	0.7740	3.063	57%	35
	Ni	µg/L	19	3	2	3.01	2	0.5	8.6248	0.4964	4.601	3%	35
	Se	µg/L	10.4	1.38	0.5	1.52	0.4	0.3	5.9594	0.4187	2.351	3%	34
	Ag	µg/L	0.5	0.1	0.05	0.08	0.05	0.05	0.0070	0.0143	3.892	79%	34
	U	µg/L	6	1.648	0.35	1.13	0.174	0.05	3.1651	0.3007	1.780	9%	35
	V	µg/L	2.5	1.5	1	1.15	0.8	0.5	0.2808	0.0909	1.008	3%	34
	Zn	µg/L	31	2.5	2.5	3.24	2.5	0.5	24.4498	0.8241	4.921	86%	36
Total Metals	Al	µg/L	42600	15000	2780	6987.14	130	10	88857003	1593	1.809	0%	35
	As	µg/L	6	3.4	1	1.94	0.5	0.5	3.06	0.2999	1.086	35%	34
	B	µg/L	250	110	80	86.00	56	25	1931.94	7.5380	1.397	12%	34
	Cd	µg/L	0.1	0.025	0.025	0.03	0.025	0.025	0.0002	0.0026	3.041	100%	34
	Cr	µg/L	25	1.2	0.3	3.44	0.1	0.1	61.6871	1.3276	2.173	34%	35
	Co	µg/L	39	8.6	2	5.32	0.5	0.5	70.1952	1.4369	2.443	35%	34
	Cu	µg/L	49	11	4	7.33	2	0.5	86.7050	1.5739	2.747	9%	35
	Fe	µg/L	59400	17080	3310	9547.49	334	12	179607183	2265	1.875	11%	35
	Pb	µg/L	67	13.4	2.5	8.21	0.5	0.5	178.0472	2.2884	2.776	24%	34
	Mn	µg/L	1120	215.6	51	145.94	20.6	8	53678.5	39.7	2.645	0%	34
	Hg	µg/L	0.5	0.05	0.05	0.06	0.05	0.025	0.0061	0.0134	5.240	94%	34
	Mo	µg/L	23	1.4	0.5	2.44	0.5	0.5	26	1	2.952	65%	34
	Ni	µg/L	63	17.4	6	10.93	3	0.5	160	2.17	2.384	3%	34
	Se	µg/L	9.7	1.58	0.6	1.59	0.4	0.3	5.3459	0.3965	2.261	3%	34
	Ag	µg/L	0.5	0.1	0.05	0.09	0.05	0.05	0.0093	0.0165	2.801	71%	34
	U	µg/L	7.09	2.344	0.8	1.74	0.514	0.26	3.6	0.3194	1.575	0%	35
	V	µg/L	55.6	26.92	6.85	13.02	1.36	0.6	221.4	2.5520	1.346	0%	34
	Zn	µg/L	101	32.4	10	17.60	2.5	1	473.0	3.6761	1.915	40%	35



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One Mile US													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.15	7.49	7.26	7.23	6.944	6.11	0.1206	0.0311	-0.157	0%	125
	EC	µS/cm	491	234.68	149	164.87	104.8	50	5210	6.4561	0.876	0%	125
	Turbidity	NTU	2563	256.6	119.8	266.07	26.2	10.1	259523	96.2739	3.454	0%	28
	DO	mg/L	8.16	7.582	7.135	7.28	6.95	6.75	0.22	0.1649	0.670	0%	8
	Temp	°C	35.2	30.46	28.5	27.98	26.18	16.2	15.37	0.6446	-1.013	0%	37
Organics	SS	mg/L	300	36	17	28.58	7.6	2.5	1713	3.7172	4.416	3%	124
	Hardness	mg/L	120	120	120	120.00	120	120	NA	NA	NA	0%	1
	SO4	mg/L	70	6	2	4.71	0.5	0.5	63.6	0.7162	5.092	24%	124
	Fluoride	µg/L	200	144	50	89.00	50	50	3735.79	13.67	1.045	65%	20
	Ammonia	µg/L	160	50	30	36.75	18	5	1140	7.6	2.307	10%	20
	Nitrate	µg/L	64	40	25	25.20	9	5	342	4.1	0.598	20%	20
TPH	C6-C9	µg/L	10	10	10	9.75	10	5	1.2500	0.2500	-3.824	100%	20
	C10-C36	µg/L	50	25	25	26.25	25	25	31.3	1.2500	3.824	100%	20
Dissolved Metals	Al	µg/L	1170	450	230	341.19	40	5	129759.8	78.6	1.167	5%	21
	As	µg/L	3	1	0.5	0.90	0.5	0.5	0.4405	0.1448	1.798	57%	21
	B	µg/L	90	50	25	33.79	25	2.5	435.71	4.5550	1.382	76%	21
	Cd	µg/L	0.05	0.025	0.025	0.03	0.025	0.025	0.0000	0.0013	3.824	100%	20
	Cr	µg/L	2	1.22	0.5	0.65	0.1	0.1	0.3416	0.1307	0.864	35%	20
	Co	µg/L	2	0.5	0.5	0.71	0.5	0.5	0.3	0.1174	1.897	86%	21
	Cu	µg/L	2	2	0.5	0.98	0.5	0.5	0.4619	0.1483	0.764	62%	21
	Fe	µg/L	4580	1330	960	1171.90	720	310	899916	207	2.340	0%	21
	Pb	µg/L	2	0.5	0.5	0.57	0.5	0.5	0.1071	0.0714	3.949	95%	21
	Mn	µg/L	204	76	13	36.10	2	0.5	3118.5	12.1860	1.706	10%	21
	Hg	µg/L	0.5	0.05	0.05	0.07	0.05	0.025	0.0102	0.0226	3.804	100%	20
	Mo	µg/L	0.5	0.5	0.5	0.50	0.5	0.5	0.0000	0.0000	NA	100%	21
	Ni	µg/L	5	4	2	2.14	0.5	0.5	2.6286	0.3538	0.284	38%	21
	Se	µg/L	0.5	0.4	0.25	0.26	0.1	0.1	0.0226	0.0336	0.218	45%	20
	Ag	µg/L	0.5	0.2	0.05	0.12	0.05	0.05	0.0135	0.0260	1.808	60%	20
	U	µg/L	0.25	0.182	0.025	0.09	0.025	0.025	0.0066	0.0182	0.521	60%	20
	V	µg/L	2.9	1.82	0.7	0.99	0.2	0.1	0.8304	0.2038	0.825	15%	20
	Zn	µg/L	12	2.5	2.5	3.07	2.5	0.5	5.3821	0.5063	2.868	90%	21
Total Metals	Al	µg/L	4710	1826	475	1017.35	73.4	20	1494936	273	1.390	0%	20
	As	µg/L	2	1.2	1	1.03	0.5	0.5	0.30	0.1229	0.812	35%	20
	B	µg/L	90	56.8	25	38.55	25	25	433.63	4.6563	1.125	65%	20
	Cd	µg/L	0.05	0.025	0.025	0.03	0.025	0.025	0.0000	0.0013	3.824	100%	20
	Cr	µg/L	2	1.22	0.5	0.65	0.1	0.1	0.3416	0.1307	0.864	35%	20
	Co	µg/L	2	1.2	0.5	0.88	0.5	0.5	0.3651	0.1351	1.137	65%	20
	Cu	µg/L	4	2	0.5	1.28	0.5	0.5	1.0651	0.2308	1.024	55%	20
	Fe	µg/L	4540	3294	2265	2315.50	990	120	1649331	287	0.133	0%	20
	Pb	µg/L	5	2	0.5	1.40	0.5	0.5	1.9895	0.3154	1.316	60%	20
	Mn	µg/L	328	123.4	74.5	95.50	24.4	12	8651.7	20.8	1.442	0%	20
	Hg	µg/L	0.5	0.05	0.05	0.07	0.05	0.025	0.0102	0.0226	3.804	100%	20
	Mo	µg/L	0.5	0.5	0.5	0.50	0.5	0.5	0	0	NA	100%	20
	Ni	µg/L	6	5	2	2.68	0.5	0.5	4	0.46	0.165	35%	20
	Se	µg/L	0.5	0.4	0.35	0.28	0.1	0.1	0.0251	0.0354	-0.061	45%	20
	Ag	µg/L	0.5	0.05	0.05	0.08	0.05	0.05	0.0101	0.0225	3.685	90%	20
	U	µg/L	0.37	0.222	0.025	0.11	0.025	0.025	0.0	0.0247	0.685	60%	20
	V	µg/L	6	2.26	1.35	1.72	0.48	0.3	2.2	0.3312	1.387	0%	20
	Zn	µg/L	12	8	2.5	4.50	2.5	2	9.7	0.6959	1.030	60%	20



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

One Mile DS													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.66	8.318	7.93	7.91	7.534	6.85	0.1894	0.0385	-0.403	0%	128
	EC	µS/cm	2022	800.6	569	585.48	219	140	146110	33.7859	1.537	0%	128
	Turbidity	NTU	1320	476	136.6	257.23	19.6	2.3	100231	58.7897	1.574	0%	29
	DO	mg/L	8.39	7.934	7.68	7.65	7.382	6.85	0.22	0.1645	-0.119	0%	8
	Temp	°C	34.9	31.9	27.6	28.03	25.3	15.6	18.07	0.7084	-0.738	0%	36
Organics	SS	mg/L	5020	353.2	134	366.87	48.6	5	630676	70.4695	4.357	0%	127
	Hardness	mg/L	120	118	115	115.00	112	110	50	5.0	0.000	0%	2
	SO4	mg/L	446	88.8	42	69.57	20.2	5	6889.0	7.3651	2.771	0%	127
	Fluoride	µg/L	400	200	200	174.19	50	8	11268.76	23.16	0.303	19%	21
	Ammonia	µg/L	1200	50	30	91.57	30	5	64875	55.6	3.912	5%	21
	Nitrate	µg/L	970	270	40	184.05	5	5	69819	57.7	1.548	24%	21
TPH	C6-C9	µg/L	50	10	10	11.67	10	5	78.3333	1.9314	3.843	100%	21
	C10-C36	µg/L	50	25	25	26.19	25	25	29.8	1.1905	3.949	100%	21
Dissolved Metals	Al	µg/L	9360	616	195	974.32	32	5	4736026.9	464.0	2.782	14%	22
	As	µg/L	4	1	0.75	0.93	0.5	0.5	0.6023	0.1655	2.842	50%	22
	B	µg/L	80	68	37.5	42.91	25	0.5	602.92	5.2350	-0.030	50%	22
	Cd	µg/L	0.05	0.025	0.025	0.03	0.025	0.025	0.0001	0.0016	2.563	100%	21
	Cr	µg/L	1.6	0.6	0.3	0.48	0.1	0.05	0.2406	0.1070	1.252	38%	21
	Co	µg/L	43	0.5	0.5	2.52	0.5	0.5	81.8	1.9288	4.061	86%	22
	Cu	µg/L	22	2	1	2.75	0.6	0.5	22.8988	1.0202	3.080	23%	22
	Fe	µg/L	6790	1138	355	925.25	80	0.5	2297293	323	2.722	18%	22
	Pb	µg/L	20	0.5	0.5	1.68	0.5	0.5	17.7273	0.8977	3.747	86%	22
	Mn	µg/L	800	17.2	2.5	44.48	0.6	0.5	28623.3	36.0702	4.036	23%	22
	Hg	µg/L	0.5	0.05	0.05	0.07	0.05	0.025	0.0102	0.0226	3.804	100%	20
	Mo	µg/L	29	2	0.75	2.39	0.5	0.5	36.4031	1.2863	3.887	50%	22
	Ni	µg/L	50	3.8	2	6.11	2	0.5	151.6174	2.6252	2.744	5%	22
	Se	µg/L	4.6	1.9	0.8	1.15	0.3	0.1	1.2566	0.2446	1.518	5%	21
	Ag	µg/L	0.5	0.1	0.05	0.10	0.05	0.05	0.0113	0.0231	2.604	76%	21
	U	µg/L	3	0.31	0.21	0.36	0.16	0.1	0.3726	0.1332	3.845	5%	21
	V	µg/L	2.9	1.7	0.8	1.08	0.5	0.05	0.5473	0.1614	0.908	10%	21
	Zn	µg/L	55	2.5	2.5	4.98	2.5	2	131.3869	2.5013	3.948	90%	21
Total Metals	Al	µg/L	75100	4370	1500	6291.52	620	2	260742405	3524	3.666	0%	21
	As	µg/L	76	2	2	5.26	1	0.5	263.32	3.5410	3.934	14%	21
	B	µg/L	120	70	50	49.90	25	7	813.49	6.2240	0.576	38%	21
	Cd	µg/L	0.2	0.025	0.025	0.03	0.025	0.025	0.0015	0.0084	3.828	95%	21
	Cr	µg/L	2	0.8	0.3	0.56	0.1	0.1	0.3415	0.1275	1.188	29%	21
	Co	µg/L	85	5	2	8.64	0.5	0.5	428.1786	4.5155	2.798	24%	21
	Cu	µg/L	31	5	4	5.12	2	0.5	45.8476	1.4776	2.758	5%	21
	Fe	µg/L	22600	6950	2910	4758.86	840	76	34159781	1275	1.797	0%	21
	Pb	µg/L	36	5	2.5	5.10	2	0.5	60.0405	1.6909	3.028	19%	21
	Mn	µg/L	864	89	44	89.71	22	4	32505.1	39.3	3.745	0%	21
	Hg	µg/L	0.5	0.05	0.05	0.07	0.05	0.025	0.0102	0.0226	3.804	100%	20
	Mo	µg/L	49	1	0.5	4.19	0.5	0.5	134	3	3.028	67%	21
	Ni	µg/L	5700	10	5	279.71	3	2	1542563	271.03	3.948	0%	21
	Se	µg/L	9	2.7	0.9	1.79	0.4	0.3	4.4979	0.4628	1.997	0%	21
	Ag	µg/L	13	0.1	0.05	0.70	0.05	0.05	7.9530	0.6154	3.940	81%	21
	U	µg/L	300	0.59	0.42	14.90	0.27	0.2	4268.0	14.2562	3.948	5%	21
	V	µg/L	72.5	15.9	6.2	11.30	4.3	1.8	232.7	3.3287	3.041	0%	21
	Zn	µg/L	66	19.6	8.5	15.55	2.5	2.5	361.4	4.2511	1.575	30%	20



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Phillips US													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.73	8.346	8.005	7.99	7.742	6.4	0.1445	0.0344	-1.028	0%	122
	EC	µS/cm	1636	690	418	461.97	234.68	94	73794	24.5940	1.299	0%	122
	Turbidity	NTU	1450	573.2	169	312.84	26.8	1	119758	56.8920	1.329	0%	37
	DO	mg/L	8.16	8.002	7.8	7.78	7.548	7.28	0.09	0.1148	-0.359	0%	7
	Temp	°C	36.5	31.6	27.95	28.22	25.18	18.9	14.31	0.5459	0.019	0%	48
Organics	SS	mg/L	3460	484.8	82	356.80	20.6	2.5	432881	60.3129	2.980	3%	119
	Hardness	mg/L	480	208	110	173.82	62	54	22363	45.1	1.134	0%	11
	SO4	mg/L	196	19	13	15.83	7	1	472.0	1.9751	6.091	0%	121
	Fluoride	µg/L	230	200	100	126.62	80	32.1	3501.93	10.99	0.126	17%	29
	Ammonia	µg/L	200	40	20	37.29	7	2.5	2262	8.8	2.044	14%	29
	Nitrate	µg/L	400	148	70	93.16	11.2	2.5	9740	18.3	1.315	14%	29
TPH	C6-C9	µg/L	10	10	10	8.44	5	5	5.5444	0.4162	-0.771	100%	32
	C10-C36	µg/L	1680	50	25	84.84	25	25	84879.8	51.5024	5.123	94%	32
Dissolved Metals	Al	µg/L	3210	288	95	353.28	10.2	5	539338.3	129.8	2.852	16%	32
	As	µg/L	5	1	0.5	0.82	0.5	0.5	0.8532	0.1686	3.507	80%	30
	B	µg/L	120	60	36.5	41.32	25	0.5	708.58	4.8600	0.857	50%	30
	Cd	µg/L	0.2	0.05	0.025	0.04	0.025	0.025	0.0011	0.0062	4.001	97%	29
	Cr	µg/L	1	0.7	0.5	0.43	0.2	0.025	0.0809	0.0511	0.423	35%	31
	Co	µg/L	42	0.5	0.5	2.98	0.5	0.5	67.0	1.4949	3.770	83%	30
	Cu	µg/L	12	2	2	2.25	1	0.5	5.9516	0.4313	2.923	19%	32
	Fe	µg/L	2910	482	190	389.17	38	0.5	406119	113	2.866	19%	32
	Pb	µg/L	9	0.5	0.5	1.17	0.5	0.5	3.3678	0.3351	2.995	87%	30
	Mn	µg/L	675	11.6	2	51.32	1	0.5	23048.9	27.7181	3.160	37%	30
	Hg	µg/L	0.5	0.05	0.05	0.06	0.025	0.025	0.0076	0.0165	4.606	100%	28
	Mo	µg/L	2.5	0.5	0.5	0.66	0.5	0.5	0.2161	0.0863	2.985	90%	29
	Ni	µg/L	33	3.2	2	4.75	2	0.5	52.0302	1.3169	2.725	10%	30
	Se	µg/L	0.5	0.3	0.3	0.27	0.2	0.05	0.0142	0.0221	0.164	28%	29
	Ag	µg/L	1.5	0.1	0.05	0.16	0.05	0.05	0.0860	0.0545	3.441	83%	29
	U	µg/L	1.47	0.64	0.36	0.45	0.2	0.05	0.0943	0.0551	1.287	16%	31
	V	µg/L	11.9	7	4	5.13	2.6	0.45	10.5717	0.6038	0.714	0%	29
	Zn	µg/L	25	2.5	2.5	3.33	0.5	0.5	24.0421	0.8668	3.136	84%	32
Total Metals	Al	µg/L	170000	20400	4485	18686.43	476	18	1201640915	6329	2.978	3%	30
	As	µg/L	20	3	2	2.61	0.7	0.5	13.30	0.6893	3.837	21%	28
	B	µg/L	500	78.2	60	70.96	25	7	7751.07	16.6380	4.088	29%	28
	Cd	µg/L	0.2	0.05	0.025	0.05	0.025	0.025	0.0023	0.0091	2.379	86%	28
	Cr	µg/L	110	23.6	0.7	14.41	0.3	0.1	882.4765	5.4236	2.258	17%	30
	Co	µg/L	137	18.2	4.5	16.75	0.5	0.5	924.2500	5.7453	2.591	36%	28
	Cu	µg/L	1050	18.8	8	47.58	2	0.5	36130.1221	34.7036	4.881	10%	30
	Fe	µg/L	198000	25200	4420	22027.07	382	26	1685172630	7495	2.864	3%	30
	Pb	µg/L	590	21	3	31.63	0.5	0.5	12301.0301	20.9600	4.549	25%	28
	Mn	µg/L	4330	462.2	139	483.04	29.4	16	827985.0	172.0	2.981	0%	28
	Hg	µg/L	0.5	0.05	0.05	0.07	0.035	0.025	0.0077	0.0166	4.360	96%	28
	Mo	µg/L	5	1	0.5	0.89	0.5	0.5	1	0	2.987	78%	27
	Ni	µg/L	21000	47.6	8.5	792.48	3	0.5	15690976	748.59	4.735	11%	28
	Se	µg/L	1.2	0.5	0.4	0.41	0.3	0.1	0.0514	0.0428	1.897	18%	28
	Ag	µg/L	0.6	0.22	0.05	0.15	0.05	0.05	0.0313	0.0334	1.480	75%	28
	U	µg/L	1.88	1.1	0.805	0.90	0.642	0.25	0.1	0.0690	0.868	7%	30
	V	µg/L	120	45.96	19.15	31.30	7.02	2	1108.2	6.2913	1.528	0%	28
	Zn	µg/L	290	38.6	13.5	34.65	2.5	0.5	3296.7	10.4828	3.045	23%	30



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Phillips DS													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.92	8.402	8.135	8.096	7.864	6.78	0.1154	0.0313	-0.936	0%	118
	EC	µS/cm	1151	727	436	482.66	257.6	114	59321	22.3269	0.605	0%	119
	Turbidity	NTU	1500	741.6	257.5	404.59	53	2.9	185144	69.8013	1.040	0%	38
	DO	mg/L	8.33	7.9	7.7	7.690	7.4	7.08	0.16	0.1530	0.023	0%	7
	Temp	°C	37.8	30.9	26.85	27.6	25.8	14.2	16.06	0.5908	-0.237	0%	46
Organics	SS	mg/L	4000	644	119	458.9	27.2	2.5	613533	72.4146	2.579	1%	117
	Hardness	mg/L	199	158	150	118	60	57	3202	18.9	0.005	0%	9
	SO4	mg/L	291	30.8	19	29.504	12.6	1	1707.9	3.7885	4.549	0%	119
	Fluoride	µg/L	300	194	100	124.333	60	37	4068.54	12.28	0.702	19%	27
	Ammonia	µg/L	150	50	30	35.130	8	2.5	1093	6.4	1.675	15%	27
	Nitrate	µg/L	710	240	100	150.741	22	5	26596	31.4	1.642	15%	27
TPH	C6-C9	µg/L	10	10	10	8.667	5	5	5.0575	0.4106	-1.003	100%	30
	C10-C36	µg/L	1140	50	25	68.000	25	25	41107.9	37.0171	4.920	97%	30
Dissolved Metals	Al	µg/L	14400	344	75	981.900	14.8	5	8426503.8	530.0	3.636	13%	30
	As	µg/L	10	1	0.5	1.179	0.5	0.5	3.5225	0.3547	3.746	71%	28
	B	µg/L	72	62.4	36	41.429	25	0.5	481.94	4.1487	-0.102	50%	28
	Cd	µg/L	0.3	0.05	0.025	0.041	0.025	0.025	0.0028	0.0102	4.348	96%	27
	Cr	µg/L	1	0.64	0.4	0.415	0.2	0.025	0.0727	0.0501	0.566	24%	29
	Co	µg/L	47	1.4	0.5	3.000	0.5	0.5	79.1	1.6811	4.324	79%	28
	Cu	µg/L	10	3	2	2.233	1	0.5	4.5644	0.3901	2.223	13%	30
	Fe	µg/L	9670	444	175	717.9	25	0.5	3495100	341	3.841	23%	30
	Pb	µg/L	7	1.6	0.5	1.179	0.5	0.5	2.6151	0.3056	2.591	79%	28
	Mn	µg/L	351	15.6	2	32.071	0.5	0.5	6400.8	15.1195	2.769	43%	28
	Hg	µg/L	0.5	0.05	0.05	0.062	0.025	0.025	0.0081	0.0177	4.421	100%	26
	Mo	µg/L	2.5	1	0.5	0.833	0.5	0.5	0.3462	0.1132	1.591	70%	27
	Ni	µg/L	21	7.4	3	5.018	2	0.5	26.6386	0.9754	1.668	4%	28
	Se	µg/L	1.5	0.5	0.4	0.402	0.22	0.05	0.0693	0.0507	2.543	11%	27
	Ag	µg/L	0.5	0.09	0.05	0.083	0.05	0.05	0.0094	0.0187	3.310	81%	27
	U	µg/L	1.62	0.73	0.42	0.487	0.246	0.05	0.1192	0.0641	1.211	10%	29
	V	µg/L	11	6.38	2.8	3.939	1.72	1	8.6905	0.5673	1.053	0%	27
	Zn	µg/L	19	2.5	2.5	3.700	0.5	0.5	24.6310	0.9061	2.201	80%	30
Total Metals	Al	µg/L	68200	29880	9315	15532	808	5	341416043	3492	1.282	7%	28
	As	µg/L	8	4	2	2.846	0.5	0.5	5.92	0.4770	1.004	23%	26
	B	µg/L	110	70	60	57.346	25	12	738.88	5.3309	0.239	27%	26
	Cd	µg/L	0.2	0.05	0.025	0.046	0.025	0.025	0.0025	0.0098	2.300	85%	26
	Cr	µg/L	66	32.4	0.65	13.296	0.24	0.1	532.6129	4.3614	1.338	7%	28
	Co	µg/L	71	26	7	15.192	2	0.5	352.2815	3.6809	1.594	15%	26
	Cu	µg/L	72	31	9.5	16.607	3	2	329.4325	3.4301	1.544	0%	28
	Fe	µg/L	86900	44400	9870	20330	810	46	644005291	4796	1.210	4%	28
	Pb	µg/L	820	36	7	44.385	2	0.5	25273.4062	31.1778	4.455	15%	26
	Mn	µg/L	2020	860	210.5	422.308	43	5	266849.4	101.3	1.487	0%	26
	Hg	µg/L	0.5	0.05	0.05	0.072	0.05	0.025	0.0087	0.0183	3.774	96%	26
	Mo	µg/L	2	1	0.5	0.740	0.5	0.5	0	0	1.826	76%	25
	Ni	µg/L	31000	55	18.5	1224.69	5	2	36883080	1191.04	4.525	0%	26
	Se	µg/L	1.5	0.7	0.4	0.538	0.3	0.1	0.1041	0.0633	1.350	8%	26
	Ag	µg/L	0.5	0.1	0.05	0.106	0.05	0.05	0.0167	0.0253	2.278	77%	26
	U	µg/L	2.36	1.628	0.97	1.077	0.612	0.36	0.3	0.1002	0.769	4%	28
	V	µg/L	97.9	60	26.5	34.923	8.5	4.4	876.8	5.8071	0.732	0%	26
	Zn	µg/L	150	61	27.5	36.304	2.5	0.5	1592.1	7.5406	1.345	25%	28



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Additional Combined Upstream Site Statistics						
Analyte		Units	80th Percentile of the 80th percentiles	plus one standard error	20th Percentile of the 20th percentiles	minus one standard error
Field Measurements	pH	pH unit	8.1876	8.20742	7.1144	7.094583
	EC	µS/cm	618	629.169	120.88	109.7107
	Turbidity	NTU	476.4	518.891	25.84	0
	DO	%	7.9884	8.14126	6.8276	6.674737
	Temp	°C	31.144	31.4604	25.284	24.96765
Organics	SS	mg/L	418.08	447.899	12.48	0
	SO ₄	mg/L	28.48	29.3858	3.1	2.194169
	Fluoride	µg/L	177.6	185.204	50	42.39618
	Ammonia	µg/L	46	52.3794	5.8	0
	Nitrate	µg/L	168.4	189.595	9.4	0
TPH	C6-C9	µg/L	10	10.2236	5	4.776448
	C10-C36	µg/L	50	70.1528	25	4.847195
Dissolved Metals	Al	µg/L	636	746.581	22.12	0
	As	µg/L	1	1.08044	0.5	0.41956
	B	µg/L	61.2	63.9447	25	22.25528
	Cd	µg/L	0.05	0.05256	0.025	0.022437
	Cr	µg/L	1.012	1.06332	0.132	0.080685
	Co	µg/L	0.56	1.1701	0.5	0
	Cu	µg/L	2	2.19803	0.7	0.501973
	Fe	µg/L	1238	1318.82	70.8	0
	Pb	µg/L	0.56	0.80774	0.5	0.252262
	Mn	µg/L	57.12	110.638	0.94	0
	Hg	µg/L	0.05	0.05911	0.031	0.02189
	Mo	µg/L	0.5	0.5403	0.5	0.459698
	Ni	µg/L	3.68	4.18401	1.1	0.595987
	Se	µg/L	0.4	0.41732	0.14	0.122677
	Ag	µg/L	0.16	0.18234	0.05	0.027659
	U	µg/L	0.532	0.558	0.0622	0.036196
	V	µg/L	4.952	5.19063	0.368	0.129366
	Zn	µg/L	2.5	3.02771	1.3	0.772295
Total Metals	Al	µg/L	15728.8	18125.6	234.44	0
	As	µg/L	3	3.26611	0.5	0.233885
	B	µg/L	79.28	85.6096	25	18.67038
	Cd	µg/L	0.05	0.05372	0.025	0.021283
	Cr	µg/L	15.136	17.1338	0.176	0
	Co	µg/L	14.12	16.2729	0.5	0
	Cu	µg/L	14.88	27.569	1.1	0
	Fe	µg/L	20040	22885.3	625.2	0
	Pb	µg/L	17.16	24.7805	0.5	0
	Mn	µg/L	370.6	456.45	26.4	0
	Hg	µg/L	0.05	0.05913	0.041	0.031871
	Mo	µg/L	0.8	0.88382	0.5	0.416183
	Ni	µg/L	33.28	302.806	1.5	0
	Se	µg/L	0.524	0.54823	0.18	0.155766
	Ag	µg/L	0.172	0.18775	0.05	0.03425
	U	µg/L	0.9544	1.00544	0.1182	0.067157
	V	µg/L	32.888	35.2908	1.456	0
	Zn	µg/L	32.12	36.2156	2.5	0



APPENDIX A – WATER QUALITY STATISTICAL ANALYSIS

Hughes DS – Natural Flows Only													
Analyte		Units	Max	80th Percentile	Median	Mean	20th Percentile	Min	Variance	Std Error	Skew	% LOR	Total Samples
Field Measurements	pH	pH unit	8.61	8.204	7.885	7.866	7.532	6.67	0.1343	0.0317	-0.247	0%	134
	EC	µS/cm	6130	688.4	418.5	521.95	266.6	94.4	302610	47.5214	7.962	0%	134
	Turbidity	NTU	1640	430.2	130	272.37	18.04	3.1	146374	62.8972	1.993	0%	37
	DO	mg/L	8.45	8.058	7.57	7.086	6.602	2.63	2.54	0.4418	-1.661	0%	13
	Temp	°C	33.2	30.86	28.6	28.3	25.88	23.7	7.01	0.3335	-0.045	0%	63
Organics	SS	mg/L	2580	369.2	129	315.4	50.4	2.5	256427	43.7451	2.738	5%	134
	Hardness	mg/L	2420	238.4	60.5	318	45	44	418711	172.9	2.459	0%	14
	SO4	mg/L	1200	74	39	57.863	24	5	11024.5	9.1737	9.830	0%	131
	Fluoride	µg/L	440	300	180	182.500	50	50	13508.33	21.96	0.594	25%	28
	Ammonia	µg/L	50	40	20	23.233	5	2.5	241	2.8	0.386	17%	30
	Nitrate	µg/L	890	318	60	168.448	16	5	46095	39.9	1.608	17%	29
TPH	C6-C9	µg/L	10	10	10	9.032	10	5	4.0323	0.3607	-1.477	113%	31
	C10-C36	µg/L	490	50	25	44.839	25	25	6925.8	14.9470	4.927	106%	31
Dissolved Metals	Al	µg/L	4500	368	130	560.281	22	5	1333430.3	204.1	2.627	16%	32
	As	µg/L	3	0.5	0.5	0.629	0.5	0.5	0.2161	0.0835	4.310	100%	31
	B	µg/L	270	90	60	68.242	25	2.5	2390.18	8.7808	2.225	26%	31
	Cd	µg/L	0.1	0.03	0.025	0.032	0.025	0.025	0.0003	0.0029	2.794	113%	30
	Cr	µg/L	1.3	0.6	0.3	0.447	0.2	0.1	0.1265	0.0639	1.088	42%	31
	Co	µg/L	20	0.5	0.5	1.210	0.5	0.5	12.4	0.6315	4.920	106%	31
	Cu	µg/L	12	2	2	2.156	2	0.5	3.6038	0.3356	4.315	16%	32
	Fe	µg/L	4580	632	260	581.8	99.2	5	850223	163	2.892	25%	32
	Pb	µg/L	13	0.5	0.5	1.113	0.5	0.5	5.5785	0.4242	4.243	100%	31
	Mn	µg/L	571	12	2	27.403	0.5	0.5	10647.6	18.5330	4.721	42%	31
	Hg	µg/L	0.5	0.05	0.05	0.061	0.05	0.025	0.0070	0.0152	4.838	113%	30
	Mo	µg/L	22	1	0.5	1.516	0.5	0.5	14.9581	0.6946	4.789	65%	31
	Ni	µg/L	19	3	2	3.113	2	0.5	9.6618	0.5583	4.292	3%	31
	Se	µg/L	6	0.92	0.5	0.800	0.4	0.3	1.1200	0.1932	3.968	3%	30
	Ag	µg/L	0.5	0.1	0.05	0.083	0.05	0.05	0.0078	0.0161	3.604	90%	30
	U	µg/L	4.8	0.52	0.25	0.606	0.15	0.05	0.9462	0.1747	2.934	10%	31
	V	µg/L	2.5	1.82	1.05	1.217	0.8	0.5	0.2787	0.0964	0.917	3%	30
	Zn	µg/L	31	2.5	2.5	3.328	2.5	0.5	27.5260	0.9275	4.583	97%	32
Total Metals	Al	µg/L	42600	15000	3340	7885	1000	30	93407812	1736	1.672	0%	31
	As	µg/L	6	4	1.5	2.133	0.5	0.5	3.15	0.3242	0.930	40%	30
	B	µg/L	250	100	80	80.467	50	25	1871.43	7.8982	1.821	13%	30
	Cd	µg/L	0.1	0.03	0.025	0.032	0.025	0.025	0.0003	0.0029	2.794	113%	30
	Cr	µg/L	25	1.2	0.4	3.869	0.2	0.1	68.2341	1.4836	1.966	39%	31
	Co	µg/L	39	11	2	5.967	0.5	0.5	76.2402	1.5942	2.255	40%	30
	Cu	µg/L	49	11	4	8.145	2	0.5	92.1866	1.7245	2.620	10%	31
	Fe	µg/L	59400	20600	3960	10764	1430	12	190172596	2477	1.727	13%	31
	Pb	µg/L	67	14	4	9.233	1	0.5	193.3230	2.5385	2.589	27%	30
	Mn	µg/L	1120	320	55	160.567	22.6	8	59077.5	44.4	2.436	0%	30
	Hg	µg/L	0.5	0.05	0.05	0.063	0.05	0.025	0.0069	0.0151	4.861	107%	30
	Mo	µg/L	23	1	0.5	1.433	0.5	0.5	17	1	4.867	73%	30
	Ni	µg/L	63	18.8	6.5	11.92	3	0.5	173	2.40	2.208	3%	30
	Se	µg/L	6	1.12	0.6	0.920	0.4	0.3	1.1520	0.1960	3.589	3%	30
	Ag	µg/L	0.5	0.1	0.05	0.098	0.05	0.05	0.0103	0.0185	2.571	80%	30
	U	µg/L	4.4	1.7	0.78	1.156	0.45	0.26	0.9	0.1748	1.625	0%	31
	V	µg/L	55.6	28	7.8	14.663	3.92	0.8	228.3	2.7583	1.214	0%	30
	Zn	µg/L	101	34	13	19.548	2.5	1	501.7	4.0229	1.765	45%	31



APPENDIX B – WATER QUALITY DATA



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes DS	13/10/10	8:40	7.82	431				1340		42		20			<20	490
Hughes DS	14/10/10	8:15	7.89	607				352		73						
Hughes DS	15/10/10	10:25	7.93	502	180	28.6		187		74						
Hughes DS	16/10/10	10:45	7.85	599				228		75						
Hughes DS	17/10/10	14:42	7.76	427		27.5		254		47						
Hughes DS	18/10/10	11:50	8.22	610		30.1		144		73						
Hughes DS	19/10/10	8:00	7.41	806		24.4		64		76	200	30	60		<20	<50
Hughes DS	20/10/10	9:55	8.28	655	280	29.8		72		86						
Hughes DS	21/10/10	11:36	7.52	701	210	31.2		90		88						
Hughes DS	22/10/10	10:15	8.08	707	130	30.9		100		88						
Hughes DS	23/10/10	11:40	7.95	734	8.7	32.8		74		86						
Hughes DS	24/10/10	6:15	8.05	94.4				19		104						
Hughes DS	25/10/10	9:00	8.30	884	35	26.9		26		100						
Hughes DS	26/10/10	9:15	7.92	772		28.4		66		99	400	<10	<10		<20	<50
Hughes DS	27/10/10	15:00	8.19	917				18		103						
Hughes DS	28/10/10	10:50	8.05	919	155	33.2		23		108						
Hughes DS	29/10/10	8:45	8.58	785	3.1	25.6		15		50						
Hughes DS	18/11/10	8:00	7.63	115				1920		11						
Hughes DS	19/11/10	7:00	7.41	313				424		36	200	50	60		<20	<50
Hughes DS	20/11/10	8:14	7.12	250				2190		29						
Hughes DS	21/11/10	15:42	7.87	297				123		152						
Hughes DS	22/11/10	8:47	7.47	228				138		26						
Hughes DS	23/11/10	11:55	7.64	268				100		12						
Hughes DS	24/11/10	6:00	7.69	289				284		28						
Hughes DS	25/11/10	11:30	8.08	307		28.8		225		31	<100	20	70		<20	<50
Hughes DS	26/11/10	13:30	7.67	325		31.5		155		35						
Hughes DS	27/11/10	6:15	7.82	343				72		37						
Hughes DS	28/11/10	7:48	8.11	368		24.3		78		39						
Hughes DS	29/11/10	11:35	7.62	345	187	28.6		192		39						
Hughes DS	30/11/10	7:55	7.27	266	23.5	26.2		1050		24						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes DS	1/12/10	8:45	7.50	178	30	26.2		740		26						
Hughes DS	2/12/10	13:15	7.35	236	4.1	26.8		420		26	100	40	160		<20	<50
Hughes DS	3/12/10	9:30	7.13	157				956		14						
Hughes DS	4/12/10	9:51	7.74	191				180		18						
Hughes DS	5/12/10	11:50	7.74	208.3				152		18						
Hughes DS	6/12/10	9:38	7.77	253				318		21						
Hughes DS	7/12/10	12:15	7.08	257				56		23						
Hughes DS	8/12/10	8:42	7.72	250				57		23						
Hughes DS	9/12/10	9:27	7.41	369				34		24	<100	20	50		<20	<50
Hughes DS	10/12/10	10:50	7.41	303				204		27						
Hughes DS	11/12/10	10:30	7.99	318				200		29						
Hughes DS	12/12/10	9:45	7.52	231				728		26						
Hughes DS	13/12/10	9:14	7.45	212				371		21						
Hughes DS	14/12/10	8:20	7.46	184				233		15						
Hughes DS	15/12/10	8:28	7.74	330				32		41						
Hughes DS	16/12/10	9:15	7.31	232	508.00		7.31	60		37	<100	50	190		<20	<50
Hughes DS	17/12/10	11:03	7.81	263		30.60		72		23						
Hughes DS	18/12/10	11:10	7.63	270		31.1		32		25						
Hughes DS	19/12/10	14:30	8.09	308		28.5		1640		34						
Hughes DS	20/12/10	11:25	7.65	203		30.5		310		5						
Hughes DS	21/12/10	11:25	7.94	194		326		149		14						
Hughes DS	22/12/10	3:00	8.13	245				79		20						
Hughes DS	23/12/10	10:30	7.46	361	1300	31.8	8.23	338		32	<100	40	250		<20	<50
Hughes DS	24/12/10	11:40	7.45	154.8				280		12						
Hughes DS	26/12/10	10:53	7.58	275				472		25						
Hughes DS	27/12/10	9:30	7.54	229				860		19						
Hughes DS	28/12/10	9:55	7.46	132.6				560		10						
Hughes DS	29/12/10	8:30	7.43	147.4				428		9						
Hughes DS	30/12/10	11:35	7.42	170			7.57	171		14	<100	<10	70		<20	<50
Hughes DS	31/12/10	8:15	7.79	230.4				368		21						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes DS	1/01/11	13:30	7.96	291	10			68		24						
Hughes DS	2/01/11	11:50	7.79	364				61		28						
Hughes DS	3/01/11	7:45	7.78	354				320		23						
Hughes DS	4/01/11	10:58	7.9	289				140		22						
Hughes DS	5/01/11	12:21	7.89	330				37		26						
Hughes DS	6/01/11	13:22	7.75	319			7.8	56		26	<100	20	<10		<20	<50
Hughes DS	7/01/11	9:55	7.39	267				218		26						
Hughes DS	8/01/11	5:40	7.61	322				172		34						
Hughes DS	9/01/11	11:21	7.83	371		28.6		<5		34						
Hughes DS	10/01/11	8:05	7.82	407		24.6		218		43						
Hughes DS	11/01/11	10:05	7.93	418	39	30.1		122		38						
Hughes DS	12/01/11	10:05	8.03	464		30.8		92		44						
Hughes DS	13/01/11	8:45	7.62	372			7.37	512		37	<100	20	<10		<20	<50
Hughes DS	14/01/11	13:00	7.96	415		32.2		268		30						
Hughes DS	15/01/11	11:45	7.96	415	6	32		126		47						
Hughes DS	16/01/11	10:05	8.07	498				75		39						
Hughes DS	17/01/11	11:32	8.18	494				48		35						
Hughes DS	18/01/11	9:22	8.32	520				104		44						
Hughes DS	19/01/11	8:40	7.87	377				228		44						
Hughes DS	20/01/11	9:52	8	562			7.65	169		50	100	40	50		<20	<50
Hughes DS	21/01/11	11:28	8.25	524				177		48						
Hughes DS	22/01/11	10:45	7.91	561				87		50						
Hughes DS	23/01/11	12:20	8.36	549				90		49						
Hughes DS	24/01/11	8:09	8.14	543				53		48						
Hughes DS	25/01/11	9:45	8.49	542	194			52		54						
Hughes DS	26/01/11	9:30	8.51	626				23		72						
Hughes DS	27/01/11	8:53	8.18	655	1640	26.3	7.75	61		60	200	50	<10		<20	<50
Hughes DS	28/01/11	9:45	8.44	680		27.1		75		62						
Hughes DS	29/01/11	9:35	8.42	860		27.1		204		48						
Hughes DS	30/01/11	12:35	8.54	889				72		108						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes DS	31/01/11	13:50	7.58	555		26.1		2580		65	200	50	270		<20	<50
Hughes DS	1/02/11	12:45	7.86	346	339	32.1		352		36						
Hughes DS	2/02/11		8.06	481				182		42						
Hughes DS	3/02/11	10:17	7.93	882	391	26.6		2510		137	200	20	890		<20	<50
Hughes DS	3/02/11	10:50			26.9	30.2										
Hughes DS	4/02/11	10:30	7.97	382	84	23.7		203		38						
Hughes DS	5/02/11	7:15	7.92	399				109		39						
Hughes DS	6/02/11	10:21	8.29	324				1010		36	200	20	110		<20	<50
Hughes DS	7/02/11	6:47	7.77	327				132		36						
Hughes DS	8/02/11	6:29	7.54	374				99		38						
Hughes DS	9/02/11	12:19	7.84	445				67		40						
Hughes DS	10/02/11	13:51	7.81	476			8.45	66		44	100	<10	20		<20	<50
Hughes DS	11/02/11	11:55	8.21	566				32		53						
Hughes DS	12/02/11	9:10	8.31	530				75		53						
Hughes DS	13/02/11	10:58	8.40	557				37		52						
Hughes DS	14/02/11	6:30	8.28	790				<5		66						
Hughes DS	15/02/11	12:15	8.43	589				55		52						
Hughes DS	16/02/11	12:20	8.26	659				57		57						
Hughes DS	17/02/11	5:15	8.2	900			7.49	15		73	300	20	<10		<20	<50
Hughes DS	18/02/11	11:36	8.32	1083		26.5		6		91						
Hughes DS	19/02/11	11:11	8.35	1215		29.5		6		88						
Hughes DS	20/02/11	5:45	8.13	1336				6		92						
Hughes DS	23/02/11	12:35	8.05	623		29.2		720		120						
Hughes DS	24/02/11	11:25	7.98	640	18	29	8.39	134		73	300	20	210		<20	<50
Hughes DS	25/02/11	6:40	8.23	751		23.7		71		81						
Hughes DS	26/02/11	13:00	8.44	639		30		155		74						
Hughes DS	27/02/11	14:00	8.57	708		29.1		209		87						
Hughes DS	28/02/11	17:45	8.11	1001		27.3		5		103						
Hughes DS	19/03/11	16:30	7.85	583		27.8		624		52						
Hughes DS	20/03/11	9:56	7.98	722		28.1		103		66						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes DS	21/03/11	6:40	7.57	419	18.2	24.4		1680		32						
Hughes DS	22/03/11	11:35	7.68	486				178	44							
Hughes DS	23/03/11	8:20	7.9	492	77	29.3		74	44							
Hughes DS	24/03/11	16:05	8.04	810			6.13	16	63	55	200	20	40		<20	<50
Hughes DS	25/03/11	10:54	8.21	705	65	24.6		16	63							
Hughes DS	6/04/11	10:50	8.22	740		30.1		34	152	66	300	20	20		<20	<50
Hughes DS	13/04/11	15:55	7.98	1360	15	31.2	5.35	<5	2420	108	300	40	30		<20	<50
Hughes DS	20/04/11	12:40	7.88	1060	3.5	31.1	2.63	14	214	96		20	10		<20	<50
Hughes DS	16/05/11	13:30			228	24		43	275	142	400	30	40		<20	<50
Hughes DS	30/06/11	15:20	8.58	4910	0.7	21.3		14	654	916	500	80	2990		<20	<50
Hughes DS	1/07/11	11:30	8.30	4230	0.5	22.0				702	500	90	2110		<20	<50
Hughes DS	1/07/11	9:30	8.11	1873	2.4	12.9		<5		764	400	40	2530		<20	<50
Hughes DS	3/07/11	16:00	9.35	7830	2.9	26.5		6		506						
Hughes DS	4/07/11	10:00	8.44	3510	0.8	17.8				408	300	50	590		<20	120
Hughes DS	5/07/11	12:10	8.42	3110	0.9	25.1		<5		382						
Hughes DS	6/07/11	7:50	8.08	3370	1.2	14.6		<5		467						
Hughes DS	7/07/11	10:30	7.97	3490	1.9	19.2		<5		398						
Hughes DS	8/07/11	8:10	7.98	3110	0.3	14.4		7		461						
Hughes DS	16/01/12	9:30	7.34	420	528	24.4		660	58	30	150	5	390		<10	<100
Hughes DS	30/01/12	10:45	7.78	332	975	29.2		1300	45	24	160	<5	460		<10	<100
Hughes DS	13/03/12							660	58	30	150	5	390		<10	<100
Hughes DS	21/03/12	13:00	7.2	310	985	25.0		1300	45	24	160	<5	460		<10	<100
Hughes DS	22/03/12	9:15	7.26	474	350	26.0										
Hughes DS	23/03/12	9:15	7.25	439	440	26.6										
Hughes US	13/10/10	8:05	6.91	321	496			168		4		<10			<20	500
Hughes US	14/10/10	9:00	7.62	179.5	289			116		6						
Hughes US	15/10/10	11:15	7.81	198		28.8		22		6						
Hughes US	16/10/10	10:45	7.96	179		28		352		6						
Hughes US	17/10/10	15:24	7.34	193		31.1		62		6						
Hughes US	21/10/10	4:00	6.72	291				84		6						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes US	18/11/10	8:46	7.90	84				1860		3						
Hughes US	19/11/10	9:50	7.15	124				210		8	300	40	30		<20	<50
Hughes US	20/11/10	8:10	7.54	88.1	100.4			464		4						
Hughes US	21/11/10	6:55	8.07	121				236		59						
Hughes US	22/11/10	6:50	7.71	138				81		10						
Hughes US	23/11/10	9:20	7.62	166				61		9						
Hughes US	24/11/10	6:10	7.52	182.8				62		9						
Hughes US	25/11/10	6:25	7.24	183				49		12	<100	10	10		<20	<50
Hughes US	26/11/10	9:52	7.71	169.3		25.7		40		10						
Hughes US	27/11/10	8:19	7.26	175		24.7		25		8						
Hughes US	28/11/10	9:30	7.95	188.2	30	27.9		20		9						
Hughes US	29/11/10	15:20	7.80	165				99		8						
Hughes US	30/11/10	11:15	7.37	96.7		30.2		436		5						
Hughes US	1/12/10	8:00	7.51	68	195	25.1		374		4						
Hughes US	2/12/10	9:15	7.37	138	69	28		134		8	<100	40	250		<20	<50
Hughes US	3/12/10	11:00	7.22	104.2				556		6						
Hughes US	4/12/10	9:05	7.31	127				132		7						
Hughes US	5/12/10	11:45	7.51	159.6				67		10						
Hughes US	6/12/10	9:15	7.38	172				47		12						
Hughes US	7/12/10	9:49	7.48	222				84		14						
Hughes US	8/12/10	6:50	7.73	214				38		15						
Hughes US	9/12/10	13:45	7.6	332				20		17	<100	20	50		<20	<50
Hughes US	10/12/10	10:50	7.21	276				8		19						
Hughes US	11/12/10	10:29	7.93	277				18		16						
Hughes US	12/12/10	11:40	7.48	117				1020		8						
Hughes US	13/12/10	13:00	7.62	145	322.00			179		6						
Hughes US	14/12/10	13:10	7.43	167				101		9						
Hughes US	15/12/10	8:11	7.59	174				54		11						
Hughes US	16/12/10	10:10	7.78	222			7.68	30		13	<100	10	20		<20	<50
Hughes US	17/12/10	15:10	7.69	257				23		15						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes US	18/12/10	11:00	7.94	256		29.7		14		12						
Hughes US	19/12/10	14:10	7.7	240		33.4		1130		18						
Hughes US	20/12/10	7:15	7.67	117				391		20						
Hughes US	21/12/10	10:40	7.35	149.1				93		8						
Hughes US	22/12/10	12:45	7.95	207	238	25.4		61		12						
Hughes US	23/12/10	14:40	7.53	201	1002	34.8	8.28	104		12	100	20	50		<20	<50
Hughes US	24/12/10	12:00	7.6	123.6	34.7	32.2		148		5						
Hughes US	26/12/10	11:30	7.56	118.4				193		5						
Hughes US	27/12/10	8:01	7.56	137.2				122		7						
Hughes US	28/12/10	13:30	7.39	82.7				418		3						
Hughes US	29/12/10	11:50	7.59	111				270		4						
Hughes US	30/12/10	8:47	7.62	154			7.96	108		9	<100	<10	40		<20	<50
Hughes US	31/12/10	7:45	7.76	180.3				58		10						
Hughes US	1/01/11	14:53	7.95	206				42		14						
Hughes US	2/01/11	12:40	7.94	275				39		17						
Hughes US	3/01/11	11:00	7.84	211				186		10						
Hughes US	4/01/11	7:50	7.75	279				8		18						
Hughes US	5/01/11	13:51	7.91	349				8		24						
Hughes US	6/01/11	8:15	7.72	332			7.7	280		21	100	90	10		<20	<50
Hughes US	7/01/11	7:15	7.49	284				180		23						
Hughes US	8/01/11	12:50	7.67	357				52		25						
Hughes US	9/01/11	11:54	7.86	391		30.5		19		26						
Hughes US	10/01/11	11:45	7.84	451	38	29.5		42		36						
Hughes US	11/01/11	12:40	7.97	515		29.8		24		40						
Hughes US	12/01/11	14:45	8.19	470				48		32						
Hughes US	13/01/11	8:45	8.06	460	19	25.7	7.48	81		36	<100	70	<10		<20	<50
Hughes US	14/01/11	9:02	8.00	419	16	27.1		224		27						
Hughes US	15/01/11	13:40	8.00	419	6.8	35.8		43		44						
Hughes US	16/01/11	10:15	8.25	486				16		29						
Hughes US	17/01/11	10:25	8.23	514				8		29						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes US	18/01/11	9:28	8.21	512				315		36						
Hughes US	19/01/11	11:44	8.25	579				130		35						
Hughes US	20/01/11	13:45	7.88	684			7.50	45		49	100	30	40		<20	<50
Hughes US	21/01/11	12:50	8.18	601				16		44						
Hughes US	22/01/11	8:15	7.96	562				8		36						
Hughes US	23/01/11	10:00	8.09	519				<5		31						
Hughes US	24/01/11	9:30	8.00	503				<5		29						
Hughes US	25/01/11	7:52	7.92	526				<5		28						
Hughes US	26/01/11	11:55	8.13	575	186.7			8		30						
Hughes US	27/01/11	10:20	7.62	805		28.9	4.21	20		20	<100	370	10		<20	<50
Hughes US	28/01/11	9:45	7.21	1511				20		117						
Hughes US	31/01/11	14:52	7.75	252		29.9		4640		14	200	30	50		<20	<50
Hughes US	1/02/11	12:20	8.01	402		27.6		79		32						
Hughes US	2/02/11	14:15	8.11	531				51		42						
Hughes US	3/02/11	14:00	7.78	356				356		34	100	10	<10		<20	<50
Hughes US	3/02/11	17:15				29.6										
Hughes US	4/02/11	6:50	7.89	374	3.5	23.7		105		31						
Hughes US	5/02/11	7:10	7.89	391				41		32						
Hughes US	6/02/11	9:05	8.1	314				742		26	100	40	<10		<20	<50
Hughes US	7/02/11	6:38	7.64	286				99		22						
Hughes US	8/02/11	8:18	7.64	396				46		31						
Hughes US	9/02/11	9:08	7.92	462				33		37						
Hughes US	10/02/11	7:00	7.50	510			8	13		39	200	40	80		<20	<50
Hughes US	11/02/11	5:45	7.82	535				12		47						
Hughes US	12/02/11	10:25	7.79	564				<5		52						
Hughes US	13/02/11	6:30	6.90	1408				<5		73						
Hughes US	23/02/11	12:06	7.84	632		27.7		925		47						
Hughes US	24/02/11	8:25	7.57	490			6.25	67		56	100	60	80		<20	<50
Hughes US	25/02/11	6:40	7.33	536		23.7		59		56						
Hughes US	20/03/11	9:45	7.71	481	42	29.7		2640		32						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Hughes US	21/03/11	10:00	7.52	306		26.8		1520		20						
Hughes US	22/03/11		7.59	431				70	34							
Hughes US	23/03/11	9:15	7.83	492	345	27.7		32	41							
Hughes US	24/03/11	16:05	7.95	510	1730	25.3	6.87	<5	49	47	100	<10	40		<20	<50
Hughes US	25/03/11	6:50	7.55	633	285	24.9		<5	49							
Hughes US	6/04/11	8:00	7.74	700	36	26.5		8	183	61	300	40	30		<20	<50
Hughes US	13/04/11	8:20			18.8	29.4										
Hughes US	20/04/11	8:05			14	27.5										
Hughes US	16/01/12	13:30	7.31	246	190.3	26.1		280	53	17	110	5	920		<10	<100
Hughes US	30/01/12	7:30	7.25	178	627	27.4		1200	50	9	140	<5	630		<10	<100
Hughes US	22/02/12		7.48	53				3200		3						
Hughes US	23/02/12		7.45	84.5				3250		5.5						
Hughes US	13/03/12							280	53	17	110	5	920		<10	<100
Hughes US	21/03/12	14:10	6.2	98.1	320	29.0		1200	50	9	140	<5	630		<10	<100
Hughes US	22/03/12	6:40	6.7	159	170	25.6										
Hughes US	23/03/12	7:25	7.01	152	180	26.0										
Hughes US	23/04/12		6.44	131				330		8						
OMC DS	30/09/10	8:39	7.77	1020				184		228	200	70	970		<20	<50
OMC DS	1/10/10	10:16	8.29	1180				236		147						
OMC DS	2/10/10	13:55	8.08	1049				204		93						
OMC DS	3/10/10	10:15	8.29	968				52		81						
OMC DS	4/10/10	9:15	8.26	924				148		75						
OMC DS	5/10/10	8:54	7.73	847				110		67	200	30	50		<20	<50
OMC DS	6/10/10	9:05	8.52	801				92		62						
OMC DS	7/10/10	13:25	8.40	800				100		60						
OMC DS	8/10/10	9:06	8.42	808												
OMC DS	9/10/10	13:30	8.30	803	172.4			116		55						
OMC DS	10/10/10	10:40	8.12	849				293		72						
OMC DS	11/10/10	9:22	7.35	625.6				105		51						
OMC DS	12/10/10	9:54	6.85	739				79		45	200	30	<10		<20	<50



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC DS	13/10/10	7:57	8.12	652				215		42						
OMC DS	14/10/10	12:50	8.24	736				186		46						
OMC DS	15/10/10	7:00	7.87	691				132		44						
OMC DS	16/10/10	7:30	7.48	633				132		37						
OMC DS	17/10/10	9:42	7.22	596		27		76		34						
OMC DS	18/10/10	8:30	8.36	619		25.3		70		36						
OMC DS	19/10/10	12:28	8.29	778		33.7		55		32	200	20	20		<20	<50
OMC DS	20/10/10	15:30	8.17	601				44		35						
OMC DS	21/10/10	11:28	7.79	601	426	28.1		72		35						
OMC DS	22/10/10	9:25	8.35	602	136.6	29.1		134		36						
OMC DS	23/10/10	10:55	8.33	577	29	29.8		46		31						
OMC DS	24/10/10	12:52	8.18	568		34		43		29						
OMC DS	25/10/10	10:57	8.21	595	230	31.7		39		32						
OMC DS	26/10/10	9:10	8.4	581	45	27.5		63		28	200	30	20		<20	<50
OMC DS	27/10/10	7:45	8.44	577	2.3	24.1		44		31						
OMC DS	28/10/10	13:40	8.3	570	122	34.9		64		30						
OMC DS	29/10/10	13:45	8.38	595	24	26.4		35		26						
OMC DS	30/10/10	8:45	7.07	426	4.8	17.2		42		28						
OMC DS	31/10/10	14:00	8.19	532				71		29						
OMC DS	1/11/10	8:25	8.14	654				75		29						
OMC DS	2/11/10	11:02	7.82	615				71		28	200	90	<10		<20	<50
OMC DS	3/11/10	15:10	8.29	691				109		30						
OMC DS	4/11/10	14:15	8.14	713				170		32						
OMC DS	5/11/10	6:30	7.58	2022				216		446						
OMC DS	6/11/10	9:30	8.10	1828				112		396						
OMC DS	7/11/10	15:00	7.98	1958				198		401						
OMC DS	8/11/10	9:09	8.11	1912				143		418						
OMC DS	18/11/10	8:39	7.58	1027				1320		185						
OMC DS	19/11/10	9:20	7.54	1520				174		306	300	40	160		<20	<50
OMC DS	20/11/10	15:47	7.53	1556				308		310						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC DS	21/11/10	9:23	8.15	913				370		8						
OMC DS	22/11/10	11:55	8.39	604				66		51						
OMC DS	23/11/10	7:00	8.28	604				51		39						
OMC DS	24/11/10	11:15	8.35	520	440	27.1		180		27						
OMC DS	25/11/10	9:30	8.2	439				398		18	200	20	30		<20	<50
OMC DS	26/11/10	14:40	8.25	404		27.7		82		16						
OMC DS	27/11/10	10:20	8.33	396		28.5		98		14						
OMC DS	28/11/10	9:00	8.4	389	260	27.2		44		13						
OMC DS	29/11/10	4:45	8.66	298				60		13						
OMC DS	30/11/10	10:00	7.53	410	9	29.8		780		33						
OMC DS	1/12/10	11:15	7.35	151				740		12						
OMC DS	2/12/10		6.98	310				932		39	100	60	270		<20	<50
OMC DS	3/12/10	10:05	6.94	151				68		12						
OMC DS	4/12/10	12:35	7.83	200				598		21						
OMC DS	5/12/10	10:38	7.47	209.9				583		23						
OMC DS	6/12/10	10:25	7.69	464				26		5						
OMC DS	7/12/10	9:10	7.36	493				257		74						
OMC DS	8/12/10	10:30	7.97	592				254		92						
OMC DS	9/12/10	13:20	7.48	745				288		90	100	30	630		<20	<50
OMC DS	10/12/10	13:15	7.72	603				222		94						
OMC DS	11/12/10	9:21	7.93	691				1770		107						
OMC DS	12/12/10	13:10	7.68	481				4210		67						
OMC DS	13/12/10	15:14	7.13	213				418		20						
OMC DS	14/12/10	10:00	7.65	217				267		22						
OMC DS	15/12/10	9:00	7.53	335				48		32						
OMC DS	16/12/10	17:20	7.38	310			7.56	252		44	<100	30	270		<20	<50
OMC DS	17/12/10	8:22	7.76	388		27.00		322		59						
OMC DS	18/12/10	8:35	7.87	147.7	71	26.7		176		10						
OMC DS	19/12/10	13:10	7.97	385		34.9		995		57						
OMC DS	20/12/10	12:15	7.92	568	725	32.8		271		82						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC DS	21/12/10	12:40	7.64	351		27.2		128		48						
OMC DS	22/12/10	9:32	7.38	169	288	26.7		285		14						
OMC DS	23/12/10	12:55	7.53	182	33		8.39	254		14	<100	30	40		<20	<50
OMC DS	24/12/10	8:30	7.03	152.5				464		10						
OMC DS	27/12/10	8:09	7.04	192.1				392		20						
OMC DS	28/12/10	11:09	6.98	274				565		38						
OMC DS	29/12/10	13:21	7.12	172.9				424		31						
OMC DS	30/12/10	9:35	7.35	201			7.35	528		25	<100	40	160		<20	<50
OMC DS	31/12/10	9:50	7.7	202.7				358		34						
OMC DS	1/01/11	9:00	7.91	355				72		54						
OMC DS	2/01/11	11:28	7.75	153				138		11						
OMC DS	3/01/11	12:34	7.63	155				110		10						
OMC DS	4/01/11	15:30	7.68	140	168.1			284		11						
OMC DS	5/01/11	7:45	7.76	143				16		12						
OMC DS	6/01/11	6:45	7.83	333			7.8	186		47	100	30	30		<20	<50
OMC DS	7/01/11	12:25	7.49	380				98		59						
OMC DS	8/01/11	5:45	7.48	235				52		32						
OMC DS	9/01/11	12:17	7.81	226		32.4		30		26						
OMC DS	10/01/11	13:15	7.93	207		31.9		124		29						
OMC DS	11/01/11	8:30	8.22	222				94		30						
OMC DS	12/01/11	12:20	7.71	187				40		24						
OMC DS	13/01/11	12:02	7.61	174	19	25.3	8.01	34		18	<100	50	<10		<20	<50
OMC DS	14/01/11	9:30	8.00	178	20	29.6		260		13						
OMC DS	15/01/11	13:05	8.00	178	9.4	33.1		30		16						
OMC DS	16/01/11	7:50	8.49	172.3				22		13						
OMC DS	17/01/11	12:30	8.49	181.1				34		14						
OMC DS	18/01/11	10:00	8.59	189.5				23		18						
OMC DS	19/01/11	14:25	7.78	756	775			3600		18						
OMC DS	20/01/11	11:05	8.19	931			7.43	76		158	200	40	120		<20	<50
OMC DS	21/01/11	11:15	8.25	693				136		106						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC DS	22/01/11	10:16	7.92	613				219		90						
OMC DS	23/01/11	10:32	8.53	564				102		77						
OMC DS	24/01/11	14:35	8.38	542				5		78						
OMC DS	25/01/11	12:50	8.56	571				476		80						
OMC DS	26/01/11	8:45	8.17	616				24		47						
OMC DS	27/01/11	12:47				24.7										
OMC DS	31/01/11	8:20	7.73	898		25.3		5020		161						
OMC DS	1/02/11	9:30	8.01	1119				1560		192						
OMC DS	2/02/11	10:55	8.37	1147	545	29.3		232		194						
OMC DS	3/02/11	0:15	7.8	861				4680		126	400	40	530		<20	<50
OMC DS	3/02/11	8:35			19	28.1										
OMC DS	4/02/11	17:45	8.04	862	530	15.6		334		132						
OMC DS	5/02/11	10:40	8.3	671				75		107						
OMC DS	6/02/11	6:40	8.56	685				68		90						
OMC DS	7/02/11	13:10	7.6	423				1510		60						
OMC DS	8/02/11	10:05	7.74	430	745			141		58						
OMC DS	9/02/11	6:55	7.68	443				149		55						
OMC DS	10/02/11	7:22	7.57	438			7.82	40		54	200	<10	20		<20	<50
OMC DS	11/02/11	10:46	8.65	446				672		60						
OMC DS	12/02/11	12:10	8.38	386				880		61						
OMC DS	13/02/11	13:05	8.66	462				22		59						
OMC DS	14/02/11	6:20	8.15	537				20		67						
OMC DS	15/02/11	6:40	8.44	339				30		73						
OMC DS	16/02/11	5:30	7.89	647				26		76						
OMC DS	17/02/11	12:15	8.12	690	1320	26.9	6.85	17		84	300	30	<10		<20	<50
OMC DS	29/12/11	8:20	7.59	1142	160.5	22.6		220	110	160	8	1200	<10		<100	<50
OMC US	30/09/10	9:41	7.38	239				13		<1	<100	30	10		<20	<50
OMC US	1/10/10	12:45	7.23	235				10		<1						
OMC US	2/10/10	12:55	7.29	253				6		<1						
OMC US	3/10/10	10:28	7.81	238				6		<1						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC US	4/10/10	10:00	7.44	245				4		1						
OMC US	5/10/10	9:08	6.88	242				5		1	100	20	60		<20	<50
OMC US	6/10/10	10:15	7.51	240				4		<1						
OMC US	7/10/10	12:55	7.40	256				7		<1						
OMC US	8/10/10	9:40	7.48	251												
OMC US	9/10/10	8:24	7.28	222				8		<1						
OMC US	10/10/10	15:27	7.28	219				7		<1						
OMC US	11/10/10	9:56	6.97	340.1				21		<1						
OMC US	12/10/10	9:40	6.71	252				8		<1	200	<10	10		<20	<50
OMC US	13/10/10	8:40	7.56	135.2				10		<1						
OMC US	14/10/10	9:50	7.39	234.6				6		<1						
OMC US	15/10/10	14:28	7.29	227				13		<1						
OMC US	16/10/10	11:10	7.50	184		29.1		13		<1						
OMC US	17/10/10	14:55	7.23	197		32.4		11		<1						
OMC US	18/10/10	7:30	7.20	235				12		<1						
OMC US	19/10/10	11:20	7.06	287	132	32.9		10		<1	200	40	<10		<20	<50
OMC US	20/10/10	15:25	7.59	221		31.3		11		<1						
OMC US	21/10/10	13:02	7.23	242	261	26.1		18		32						
OMC US	22/10/10	9:00	7.04	221	92	28.8		13		2						
OMC US	23/10/10	10:15	7.30	210		29.2		9		<1						
OMC US	24/10/10	7:45	7.41	214				8		<1						
OMC US	25/10/10	3:36	7.42	243	445	21.4		8		<1						
OMC US	26/10/10	11:25	7.3	217	71	32.8		4		1	200	20	10		<20	<50
OMC US	27/10/10	9:00	7.44	215				6		<1						
OMC US	28/10/10	8:55	7.47	216	69	28.4		17		2						
OMC US	29/10/10	10:20	7.84	234	95.6	17.7		11		<1						
OMC US	30/10/10		7.6	242				5		2						
OMC US	31/10/10	8:35	7.67	245				5		3						
OMC US	1/11/10	12:34	7.49	250				5		3						
OMC US	2/11/10	7:45	7.28	321				23		3	200	160	40		<20	<50



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC US	3/11/10	9:35	7.46	251	472			4		4						
OMC US	6/11/10	11:49	8.12	196.8				6		8						
OMC US	7/11/10	7:20	7.87	228.6				6		8						
OMC US	18/11/10	13:39	7.39	128				25		6						
OMC US	19/11/10	11:15	8.15	184				13		2	100	60	30		<20	<50
OMC US	20/11/10	9:35	7.22	196.9				12		1						
OMC US	21/11/10	8:30	7.54	211				56		20						
OMC US	22/11/10	11:10	7.32	172	207.3			15		<1						
OMC US	23/11/10	7:15	7.41	199	158.9			26		2						
OMC US	24/11/10	11:40	7.11	192.6		29.9		23		2						
OMC US	25/11/10	10:20	7.20	186		27.4		27		2	<100	20	30		<20	<50
OMC US	26/11/10	13:45	7.00	162.9		30.6		33		2						
OMC US	27/11/10	11:05	7.10	167		29.8		19		2						
OMC US	28/11/10	11:55	7.18	176				16		2						
OMC US	29/11/10	13:20	7.29	176	114	25.5		36		1						
OMC US	30/11/10	10:29	6.87	50.3	28	28.5		300		2						
OMC US	1/12/10	11:00	7.08	50	10.1	26.5		111		3						
OMC US	2/12/10	9:45	6.92	116	16	16.2		117		4	<100	50	50		<20	<50
OMC US	3/12/10	8:30	7.02	77.6				109		3						
OMC US	4/12/10	2:23	7.21	82				42		4						
OMC US	5/12/10	10:00	6.37	89.2				37		5						
OMC US	6/12/10	9:30	7.02	86				118		70						
OMC US	7/12/10	9:20	7.58	107				17		5						
OMC US	8/12/10	8:45	7.24	97				43		6						
OMC US	9/12/10	8:56	7.03	162				18		6	<100	40	20		<20	<50
OMC US	10/12/10	8:48	7.54	106				26		5						
OMC US	11/12/10	10:00	6.79	117.8				18		6						
OMC US	12/12/10	13:45	6.95	82				116		3						
OMC US	13/12/10	11:00	6.97	71				72		3						
OMC US	14/12/10	9:34	6.8	75				32		3						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC US	15/12/10	8:40	6.81	72	245.00			13		4						
OMC US	16/12/10	8:45	6.53	90			7.14	25		5	<100	30	20		<20	<50
OMC US	17/12/10	10:05	7.57	114	1200.00	29.40		20		6						
OMC US	18/12/10	11:05	6.81	118.8				10		6						
OMC US	19/12/10	14:30	7.81	106		29.2		279		4						
OMC US	20/12/10	8:15	7.71	90		22.6		49		3						
OMC US	21/12/10	10:15	6.84	97.1	420	29.4		19		<1						
OMC US	22/12/10	11:21	7.3	108	2563	29.2		43		5						
OMC US	23/12/10	14:10	6.59	100	19	35.2	8.16	36		4	<100	20	30		<20	<50
OMC US	24/12/10	8:00	6.76	85.4				60		3						
OMC US	27/12/10	7:35	6.72	89.6				28		4						
OMC US	28/12/10	12:20	6.74	68.5				92		3						
OMC US	29/12/10	10:45	6.75	73.8				60		2						
OMC US	30/12/10	8:10	7.27	83			7.73	32		4	<100	<10	40		<20	<50
OMC US	31/12/10	7:45	6.76	93.5				30		4						
OMC US	1/01/11	13:10	7.46	125				20		6						
OMC US	2/01/11	12:41	7.31	128				28		6						
OMC US	3/01/11	14:40	7.45	145	250			34		7						
OMC US	4/01/11	8:17	7.31	155				37		8						
OMC US	5/01/11	8:41	7.37	171				26		10						
OMC US	6/01/11	7:15	7.26	126			7.1	12		5	<100	10	<10		<20	<50
OMC US	7/01/11	9:10	7.08	140				6		6						
OMC US	8/01/11	5:50	6.78	149				<5		9						
OMC US	9/01/11	6:05	7.72	197				<5		11						
OMC US	10/01/11	8:05	7.18	190		24.6		24		16						
OMC US	11/01/11	10:08	7.22	185		27.9		17		17						
OMC US	12/01/11	12:30	6.91	79				30		<1						
OMC US	13/01/11	10:35	7.49	208	23	26.7	7.13	<5		18	<100	20	<10		<20	<50
OMC US	14/01/11	10:15	6.69	227	16.6	31.6		16		1						
OMC US	15/01/11	9:30	6.69	227		27.2		12		15						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC US	16/01/11	9:15	6.97	233.2				12		14						
OMC US	17/01/11	8:30	7.12	259				43		15						
OMC US	18/01/11	11:35	7.44	109				37		2						
OMC US	19/01/11	15:45	7.13	96.1				25		2						
OMC US	20/01/11	11:55	7.45	250			6.85	9		22	<100	50	30		<20	<50
OMC US	21/01/11	9:55	7.55	252				<5		22						
OMC US	22/01/11	14:30	7.13	107				28		<1						
OMC US	23/01/11	14:42	6.88	79.6				23		<1						
OMC US	24/01/11	10:50	6.84	106.3				59		<1						
OMC US	25/01/11	9:40	7.61	113				24		2						
OMC US	26/01/11	16:10	7.71	118.5				17		<1						
OMC US	27/01/11	7:10				26.9										
OMC US	31/01/11	10:10	7.79	116	25	29.4		22		3						
OMC US	1/02/11	9:30	7.08	121.7		27.4		14		2						
OMC US	2/02/11	11:30	7.23	127.9				7		2						
OMC US	3/02/11	11:40	6.81	115.4	126	25.3		16		1	<100	60	10		<20	<50
OMC US	3/02/11	14:15			28	33.5										
OMC US	4/02/11		7.22	120				9		2						
OMC US	5/02/11	6:40	7.37	122				7		2						
OMC US	6/02/11	9:15	7.86	114				39		1						
OMC US	7/02/11	6:40	7.3	112				15		2						
OMC US	8/02/11	14:45	7.48	128				13		2						
OMC US	9/02/11	15:05	7.25	108.6				5		1						
OMC US	10/02/11	6:44	7	115			7.36	16		1	<100	10	30		<20	<50
OMC US	11/02/11	9:00	6.96	118.4				17		1						
OMC US	12/02/11	13:36	7.04	118.6				20		1						
OMC US	13/02/11	8:00	7.24	111.3				23		2						
OMC US	14/02/11	6:15	7.41	107.9	125.6			11		2						
OMC US	15/02/11	7:35	7.45	75	157.2			20		2						
OMC US	16/02/11	5:15	7.3	119.3				56		2						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
OMC US	17/02/11	12:11	7.68	130		28.5	6.75	7		3	<100	40	<10		<20	<50
OMC US	23/03/12		6.11	252				44		9						
Phillips DS	27/09/10	11:05						380		6						
Phillips DS	28/09/10	8:10	8.46	152				3080		4	100	70	130		<20	<50
Phillips DS	29/09/10	12:38	8.22	225				666		5						
Phillips DS	30/09/10	10:40	8.21	258				226		7						
Phillips DS	1/10/10	7:35	8.15	272				121		9						
Phillips DS	2/10/10	8:50	7.65	337				83		11						
Phillips DS	3/10/10	10:40	8.21	394				36		18						
Phillips DS	4/10/10	13:40	7.94	470				444		24						
Phillips DS	5/10/10	9:20	7.19	540				6		33	100	40	90		<20	<50
Phillips DS	6/10/10	10:40	8.29	526	520			16		33						
Phillips DS	12/10/10	7:55	6.78	206				518		5	100	<10	180		<20	<50
Phillips DS	13/10/10	9:45	8.01	161				332		10					<20	<50
Phillips DS	14/10/10	11:20	8.17	297				182		16						
Phillips DS	15/10/10	7:00	8.12	323				163		18						
Phillips DS	16/10/10	11:43	7.89	290		28.4		112		16						
Phillips DS	17/10/10	9:42	6.97	343		27		141		30						
Phillips DS	18/10/10	11:20	8.18	435	275	33.1		94		30						
Phillips DS	19/10/10	12:35	8.02	937	96.1	34.1		13		50	200	40	<10		<20	<50
Phillips DS	20/10/10	15:33	7.94	527		29.7		30		34						
Phillips DS	21/10/10	11:30	7.73	506				8		32						
Phillips DS	22/10/10	12:35	8.22	553		32.1		4		35						
Phillips DS	23/10/10	12:25	8.09	633	2.9	37.8		6		38						
Phillips DS	18/11/10	15:20	8.45	115	250			2140		2						
Phillips DS	19/11/10	8:40	8.03	231				490		6	100	20	80		<20	<50
Phillips DS	20/11/10	9:39	8.12	121.6				1420		5						
Phillips DS	21/11/10	10:12	8.16	213				23		1						
Phillips DS	22/11/10	10:05	8.12	256				143		11						
Phillips DS	23/11/10	6:00	7.98	314				315		26						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips DS	24/11/10	11:35	8.01	336		29.4		252		12						
Phillips DS	25/11/10	9:52	8.17	338		25.7		68		13	<100	10	90		<20	<50
Phillips DS	26/11/10	8:45	7.96	400	45	26.6		77		17						
Phillips DS	27/11/10	13:04	8.15	407		33.5		40		17						
Phillips DS	28/11/10	15:20	8.39	430	490	27.1		27		17						
Phillips DS	29/11/10	10:07	8.10	323	105	27.1		228		16						
Phillips DS	30/11/10	10:07	8.06	173.4	210	26		1430		14						
Phillips DS	1/12/10	8:35	8.10	159	31	25.3		588		15						
Phillips DS	2/12/10	10:45	7.64	256				444		17	100	60	100		<20	<50
Phillips DS	3/12/10	12:09	7.6	212				348		14						
Phillips DS	4/12/10	8:00	7.45	277				184		14						
Phillips DS	5/12/10	12:14	8.05	205.0				34		10						
Phillips DS	6/12/10	8:30	8.15	393				61		18						
Phillips DS	7/12/10	10:30	8.07	451				54		17						
Phillips DS	8/12/10	8:50	8.09	243				536		9						
Phillips DS	9/12/10	11:10	7.66	426				125		14	<100	50	50		<20	<50
Phillips DS	10/12/10	10:25	7.88	430				46		18						
Phillips DS	11/12/10	11:00	8.25	523	1100.00			40		19						
Phillips DS	12/12/10	10:30	7.92	197				955		15						
Phillips DS	13/12/10	10:08	8.37	172				788		10						
Phillips DS	14/12/10	10:19	8.12	168				498		14						
Phillips DS	15/12/10	13:10	7.88	246				20		18						
Phillips DS	16/12/10	9:25	7.95	389			7.35	49		21	<100	30	30		<20	<50
Phillips DS	17/12/10	8:30	8.46	475				34		22						
Phillips DS	18/12/10	9:34	8.25	470		25.9		26		22						
Phillips DS	19/12/10	9:01	7.92	436		25.3		1260		9						
Phillips DS	20/12/10	10:50	8.33	231				461		11						
Phillips DS	21/12/10	11:12	7.72	296	684	28.6		136		14						
Phillips DS	22/12/10	9:45	8.15	375	118	31		37		16						
Phillips DS	23/12/10	8:20	7.74	321		26.4	8.33	129		37	<100	20	70		<20	<50



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips DS	24/12/10	8:50	8.12	221.5				1330		12						
Phillips DS	27/12/10	9:15	8.02	287				310		12						
Phillips DS	28/12/10	9:47														
Phillips DS	29/12/10	9:35		398.1												
Phillips DS	30/12/10	11:00	7.86	331			7.86	138		15	<100	<10	20		<20	<50
Phillips DS	31/12/10	10:05	8.23	438				90		18						
Phillips DS	1/01/11	9:15	8.27	613				47		25						
Phillips DS	2/01/11	10:47	8.28	706				41		28						
Phillips DS	3/01/11	11:00	8.22	571				102		19						
Phillips DS	4/01/11	9:25	8.21	647				67		23						
Phillips DS	5/01/11	11:10	8.37	766				<5		21						
Phillips DS	6/01/11	6:35	8.17	561	98.7		7.7	915		34	100	<10	<10		<20	<50
Phillips DS	7/01/11	8:50	8.2	569				196		19						
Phillips DS	8/01/11	12:35	7.88	460	292	30.9		35		29						
Phillips DS	9/01/11	12:05	8.33	791				24		24						
Phillips DS	10/01/11	14:20	8.3	836		27.7		40		25						
Phillips DS	11/01/11	9:15	8.45	882		26.1		30		21						
Phillips DS	12/01/11	10:50	8.48	904	18.5	30.9		28		26						
Phillips DS	13/01/11	10:44	8.46	866	16	27.7	7.60	24		23	100	30	20		<20	<50
Phillips DS	14/01/11	13:35	8.48	906	5	32.7		16		20						
Phillips DS	15/01/11	14:40	8.48	906				14		24						
Phillips DS	16/01/11	9:30	8.52	891				10		17						
Phillips DS	17/01/11	11:10	8.50	901				10		19						
Phillips DS	18/01/11	10:02	8.34	917				30		21						
Phillips DS	19/01/11	8:00	8.32	483				648		19						
Phillips DS	20/01/11	12:30	8.47	745			7.08	109		18	100	40	180		<20	<50
Phillips DS	21/01/11	11:20	8.55	682				64		20						
Phillips DS	22/01/11	11:05	8.51	797	265			47		22						
Phillips DS	23/01/11	14:20	8.50	866				33		26						
Phillips DS	24/01/11	8:55	8.51	929				18		21						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips DS	25/01/11	14:00	8.59	265				49		24						
Phillips DS	26/01/11	14:35														
Phillips DS	31/01/11	15:55	7.88	451		30.4		2000		35						
Phillips DS	1/02/11	9:40	8.22	440		27.8		242		18						
Phillips DS	2/02/11	14:00	8.33	545	1200	25.1		115		22						
Phillips DS	3/02/11	8:32	8.03	338	65	26.2		1020		27	100	20	100		<20	<50
Phillips DS	3/02/11	14:10			5.2	35.9										
Phillips DS	4/02/11	10:25	8.12	426				325		19						
Phillips DS	5/02/11	8:11	8.19	496				82		35						
Phillips DS	6/02/11	15:15	7.74	303				640		19	100	<10	30		<20	<50
Phillips DS	7/02/11	7:21	7.86	488				119		34						
Phillips DS	8/02/11	5:50	8.11	581				49		25						
Phillips DS	9/02/11	8:25	8.29	715				21		22						
Phillips DS	10/02/11	10:15	8.42	745			7.91	22		27	200	10	<10		<20	<50
Phillips DS	11/02/11	8:35	8.41	814	94.2			22		30						
Phillips DS	12/02/11	7:20	8.56	854				16		30						
Phillips DS	13/02/11	6:30	8.44	557				19		29						
Phillips DS	14/02/11	8:45	8.49	750				8		274						
Phillips DS	20/03/11	9:50	7.8	626		26.6		613	150	94	200	50	420		<20	<50
Phillips DS	2/04/11	9:30	8.46	984	94	26.5		258		124	200	30	710		<20	<50
Phillips DS	9/05/11	11:30			9.8	26.7		2030	199	55	300	40	350		<20	<50
Phillips DS	11/06/11	19:50	8.92	998	320	14.2		705		291	37	100	<10		<20	<50
Phillips DS	16/01/12	10:45	8.03	257	1160	24.6		1200	57	10	160	8	330		<10	<100
Phillips DS	22/01/12	9:45	7.78	872	1500	27.0		3100	150	120	140	50	240		<10	<100
Phillips DS	29/01/12	6:30	7.56	238	452			690	62	14	200	2.5	110		<10	1140
Phillips DS	30/01/12	9:15	7.94	461	1210	27.4				44						
Phillips DS	13/02/12		8.52	338.5				645		20						
Phillips DS	13/03/12							1200	57	10	160	8	330		<10	<100
Phillips DS	19/03/12	10:00	7.36	360	474	23.4		3100	150	120	140	50	240		<10	<100
Phillips DS	20/03/12	11:05	7.83	537	167	23.9										



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips DS	21/03/12									44						
Phillips DS	22/03/12	7:45	7.73	321	220	25.9										
Phillips DS	23/03/12	10:15	7.87	114	780	26.0		4000		5						
Phillips DS	24/03/12	10:20	7.51	535	1064	25.8										
Phillips DS	12/06/12		8.38	623				300		33						
Phillips US	27/09/10	11:10						472		4						
Phillips US	28/09/10	9:35	8.47	131				3460		1	100	140	160		<20	<50
Phillips US	29/09/10	8:00	8.14	205				646		3						
Phillips US	30/09/10	8:45	8.03	243				182		5						
Phillips US	1/10/10	7:32	7.84	279				152		7						
Phillips US	2/10/10	10:50	7.86	339				82		8						
Phillips US	3/10/10	11:45	7.97	360	604			51		10						
Phillips US	4/10/10	11:06	7.84	422				64		14						
Phillips US	5/10/10	9:48	7.57	480				16		19	100	20	120		<20	<50
Phillips US	6/10/10	9:21	8.01	492				16		24						
Phillips US	12/10/10	12:42	6.40	195				316		3	100	20	110		<20	<50
Phillips US	13/10/10	15:30	7.80	185				360		5					<20	<50
Phillips US	14/10/10	8:10	7.89	235				449		8						
Phillips US	15/10/10	14:15	7.78	289				354		9						
Phillips US	16/10/10	10:15	7.92	168.7		26.8		204		7						
Phillips US	17/10/10	8:15	7.77	246	850	27.2		346		7						
Phillips US	18/10/10	13:55	7.81	338		30.8		210		10						
Phillips US	19/10/10	7:55	8.27	481		22.6		102		12	200	30	10		<20	<50
Phillips US	20/10/10	9:20	7.68	412	102	28		78		15						
Phillips US	21/10/10	11:30	6.93	441		25.5		53		17						
Phillips US	22/10/10	9:43	7.65	429	169	28.1		61		19						
Phillips US	23/10/10	14:25	7.94	464	14	36.5		30		19						
Phillips US	18/11/10	8:00	8.25	94				2620		2						
Phillips US	19/11/10	11:24	7.73	226				408		5	100	20	80		<20	<50
Phillips US	20/11/10	8:58	8.24	135.5				948		3						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips US	21/11/10	8:03	8.19	206				208		6						
Phillips US	22/11/10	8:35	7.80	283				62		7						
Phillips US	23/11/10	13:10	7.72	293				80		11						
Phillips US	24/11/10	9:20	7.89	303		27.4		36		10						
Phillips US	25/11/10	12:05	7.78	331	55	28.9		40		11	<100	10	280		<20	<50
Phillips US	26/11/10	13:40	7.90	396		34.3		38		13						
Phillips US	27/11/10	6:55	8.05	430	1.6	20.7		25		15						
Phillips US	28/11/10	8:40	7.93	489	83	27.4		21		21						
Phillips US	29/11/10	11:58	8.09	295	120	28.6		244		8						
Phillips US	30/11/10	14:35	7.55	183	1	31.8		672		3						
Phillips US	1/12/10	14:10	8.27	133	68	33.7		636		3						
Phillips US	2/12/10		7.30	245				188		7	100	40	80		<20	<50
Phillips US	3/12/10	12:15	7.34	189				508		5						
Phillips US	4/12/10	9:20	7.14	278				82		7						
Phillips US	5/12/10	8:34	7.96	357.0				98		30						
Phillips US	6/12/10	8:10	7.96	411				35		12						
Phillips US	7/12/10	8:01	8.08	449				14		13						
Phillips US	8/12/10	8:10	7.88	380				117		10						
Phillips US	9/12/10	12:20	7.74	500	396			44		14	<100	100	70		<20	<50
Phillips US	10/12/10	9:50	7.96	484				20		17						
Phillips US	11/12/10	9:35	8.28	547				19		18						
Phillips US	12/12/10	9:23	8.11	177				67		4						
Phillips US	13/12/10	11:25	7.08	146				238		5						
Phillips US	14/12/10	15:19	7.37	141				213		4						
Phillips US	15/12/10	11:50	7.55	216				14		10						
Phillips US	16/12/10	9:25	7.95	380			7.28	78		13	<100	40	20		<20	<50
Phillips US	17/12/10	11:20	7.94	425		26.10		22		17						
Phillips US	18/12/10	9:34	8.08	472		25.9		10		20						
Phillips US	19/12/10	11:00	8.18	214	220	33.1		1100		5						
Phillips US	20/12/10	11:53	7.65	208		33.5		504		4						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips US	21/12/10	12:40	7.73	290				90		7						
Phillips US	22/12/10	14:35	8.42	396		33.7		24		12						
Phillips US	23/12/10	11:10	7.75	309	40	30.1	8.16	59		11	<100	30	30		<20	<50
Phillips US	24/12/10	7:10	8.08	234.6				1240		4						
Phillips US	27/12/10	9:50	8	285				84		7						
Phillips US	28/12/10	10:13	8.22	164.8				1420		3						
Phillips US	29/12/10	9:15	8.08	282				338		5						
Phillips US	30/12/10	9:10	8.01	300			8.03	104		8	<100	<10	20		<20	<50
Phillips US	31/12/10	12:42	8.25	440				50		10						
Phillips US	1/01/11	12:57	8.01	591				30		16						
Phillips US	2/01/11	12:10	8.1	670				23		20						
Phillips US	3/01/11	6:16	8.14	504				170		8						
Phillips US	4/01/11	10:37	8.11	647				37		13						
Phillips US	5/01/11	12:05	8.38	780				<5		16						
Phillips US	6/01/11	6:40	8.21	429			7.8	840		8	100	10	20		<20	<50
Phillips US	7/01/11	7:55	8	534	85.1			246		9						
Phillips US	8/01/11	12:23	7.96	574		33.2		15		17						
Phillips US	9/01/11	12:55	8.19	827		33.2		11		19						
Phillips US	10/01/11	14:15	8.37	860		30.1		23		19						
Phillips US	11/01/11	12:25	8.31	861		29.6		16		19						
Phillips US	12/01/11	10:25	8.43	875	23.5	31.3		24		20						
Phillips US	13/01/11	1:00	8.46	858			7.78	15		19	100	30	<10		<20	<50
Phillips US	14/01/11	9:05	8.36	831	23	29		6		16						
Phillips US	15/01/11		8.36	831				5		20						
Phillips US	16/01/11	8:05	8.47	895				<5		16						
Phillips US	17/01/11	12:35	8.52	892				<5		16						
Phillips US	18/01/11	9:05	8.49	895				345		18						
Phillips US	19/01/11	12:00	8.46	811				154		10						
Phillips US	20/01/11	12:06	8.4	669			7.49	83		15	100	40	70		<20	<50
Phillips US	21/01/11	14:15	8.50	765	450			27		17						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips US	22/01/11	11:10	8.39	879				24		22						
Phillips US	23/01/11	10:54	8.37	918				20		21						
Phillips US	24/01/11	11:20	8.44	936				31		25						
Phillips US	25/01/11		8.57	786				21		20						
Phillips US	26/01/11	8:50														
Phillips US	31/01/11	8:20	8.1	285		25.3		1300		16						
Phillips US	1/02/11	10:15	8.28	431		27.9		208		14						
Phillips US	2/02/11	11:25	8.33	612	140	30		57		19						
Phillips US	3/02/11	9:53	7.93	267	154	26.8		1890		15	100	30	90		<20	<50
Phillips US	3/02/11	13:05			5	34.4										
Phillips US	4/02/11		8.29	414				217		132						
Phillips US	5/02/11	6:15	8.35	527				47		16						
Phillips US	6/02/11	10:30	8.20	250				336		7	100	20	10		<20	<50
Phillips US	7/02/11	8:19	7.54	451				64		15						
Phillips US	8/02/11	14:35	8.04	560				34		19						
Phillips US	9/02/11	8:47	7.98	695				26		22						
Phillips US	10/02/11	12:55	8.35	783	275		7.89	17		25	200	<10	<10		<20	<50
Phillips US	11/02/11	7:54	8.48	844				18		27						
Phillips US	12/02/11	8:29	8.45	863				14		27						
Phillips US	13/02/11	7:00	8.40	767				7		25						
Phillips US	14/02/11	9:40	8.44	947				6		26						
Phillips US	20/03/11	5:45	7.98	549				648	174	24	200	40	80		<20	60
Phillips US	2/04/11	5:30	7.90	557				546		9	200	10	60		<20	<50
Phillips US	9/05/11	6:45			2.5	28.2		890	208	13	200	40	400		<20	<50
Phillips US	11/06/11		8.73	556				391		196	32.1	200	<10		<20	<50
Phillips US	16/01/12	14:00	8.09	438	434	24.6		620	110	9	170	7	240		<10	<100
Phillips US	22/01/12	12:10	7.82	207.3	1450	27.6		3200	62	7	140	20	140		<10	<100
Phillips US	29/01/12	4:30	7.42	351	323			130	82	18	200	2.5	190		<10	1680
Phillips US	30/01/12	8:15	7.97	201	915	27.1				3						



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Field Measurements					SS	Total Hardness	SO ₄	Fluoride	Nitrogen		TOC	TPH	
			pH	EC	Turbidity	Temp	DO					Ammonia	Nitrate		C6-C9	C10-C36(sum)
			pH unit	µS/cm	NTU	°C	mg/L					µg/L	µg/L		µg/L	µg/L
Phillips US	13/03/12							620	110	9	170	7	240		<10	<100
Phillips US	18/03/12		7.69	360				270		15						
Phillips US	19/03/12	8:30	7.51	247	285	23.2		3200	62	7	140	20	140		<10	<100
Phillips US	20/03/12	9:25	7.84	272	206	24.1										
Phillips US	21/03/12	10:00	7.85	126	760	24.1				3						
Phillips US	22/03/12	13:30	7.67	301	110	27.1										
Phillips US	23/03/12	7:00	7.77	160	900	25.6										
Phillips US	24/03/12	9:00	7.53	433	743	25.1										
Phillips US	15/07/12	12:15	7.39	468	815.0	18.9		1900	130	11	140	140	12		<10	<100
Phillips DS	15/07/12	13:45	7.73	690	1135.0	18.9		3400	170	57	170	150	150		<10	<100
Hughes US	25/01/13	8:30	6.24	123.1	364	25.1		1500	21	6					<10	<100
Hughes DS	25/01/13	12:45	6.67	646	489	25.8		2200	54	73					<10	<100
Phillips US	25/01/13	9:45	6.91	202	383	25.0		2000	54	7					<10	<100
Phillips DS	25/01/13	15:15	7.68	298	494	26.0		2500	66	24					<10	<100
OMC DS	19/02/13	14:35	7.1	1252	130.7			210	120	190	350	8	520		<10	<100
OMC US	20/02/13	10:05	6.95	491	79.6	26.8		28	120	17	130	45	64		<10	<100
Phillips US	20/02/13	11:15	8.06	1636	21.2	28.4		<5	440	64	200	<5	12		<10	<100
Phillips US	2/03/13	11:45	7.82	497	348	29.5		1100		13					<10	<100
Phillips DS	2/03/13	8:30	7.67	1151	308	26.2		610		180					<10	<100
Hughes US	20/03/13	15:15	6.88	663		22.3		13	220	20	130	<5	<5		<10	<100
Hughes DS	20/03/13	14:00	8.61	6130	101.7	25.0		7	910	1200	440	7	560		<10	<100
Phillips US	20/03/13	16:00	8.18	1432		24.5		5	480	58	230	<5	<5		<10	<100



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Hughes DS	13/10/10	8:40	100	<1	60	<0.05	0.4	<1	2	340	<1	<1	<0.1	<1	2	0.5	<0.1	0.15	1.1	<5
Hughes DS	19/10/10	8:00	190	<1	60	<0.05	<0.2	<1	2	280	<1	<1	<1	1	3	0.5	<0.1	0.37	1.1	<5
Hughes DS	26/10/10	9:15	80	<1	110	<0.05	0.3	<1	2	190	<1	<1	<0.1	4	4	0.8	0.1	0.47	1.2	<5
Hughes DS	19/11/10	7:00	710	<1	60	<0.05	1	<1	2	780	<1	2	<0.1	<1	2	0.4	<0.1	0.18	2	<5
Hughes DS	25/11/10	11:30	1170	<1	60	<0.05	0.8	<1	2	1010	<1	2	<0.1	<1	3	0.4	<0.1	0.18	1.9	<5
Hughes DS	2/12/10	13:15	300	<1	<50	<0.05	1.3	<1	2	350	<1	1	<0.1	<1	3	1.3	0.2	0.2	2.3	<5
Hughes DS	9/12/10	9:27	280	<1	50	<0.05	1	<1	2	560	2	32	<0.1	<1	3	0.4	0.1	0.19	2	6
Hughes DS	16/12/10	9:15	240	<1	50	<0.05	0.4	<1	2	460	<1	2	<0.1	<1	4	1.5	<0.1	0.2	0.8	<5
Hughes DS	23/12/10	10:30	290	<1	<50	<0.05	1.2	<1	2	480	<1	2	<0.1	<1	3	1.2	<0.1	0.19	2.5	<5
Hughes DS	30/12/10	11:35	360	1	<5	<0.05	1.2	<1	2	640	1	12	<0.1	<1	4	0.4	0.2	0.21	2	<5
Hughes DS	6/01/11	13:22	250	1	60	<0.05	0.6	<1	2	600	<1	2	<0.1	<1	3	0.4	0.1	0.3	1.2	<5
Hughes DS	13/01/11	8:45	1020	3	70	<0.05	0.3	3	4	1190	5	111	<0.1	<1	6	0.4	<0.1	0.38	0.9	8
Hughes DS	20/01/11	9:52	40	<1	80	<0.05	0.2	<1	1	200	<1	2	<0.1	<1	2	0.4	0.1	0.52	0.9	<5
Hughes DS	27/01/11	8:53	370	<1	80	<0.2	<0.5	<1	2	370	<1	26	<0.1	<1	3	<2	<0.1	0.7	1.8	<5
Hughes DS	31/01/11	13:50	40	<1	<50	<0.05	0.2	<1	1	220	<1	<1	<0.1	1	2	0.7	<0.1	0.09	0.6	<5
Hughes DS	3/02/11	10:17	2670	1	<50	<0.05	0.3	20	12	4580	13	571	<0.1	<1	19	1.9	0.1	0.35	0.8	31
Hughes DS	3/02/11	10:50	20	<1	<50			<1	2	160	<1	<1		2	2					<5
Hughes DS	6/02/11	10:21	320	<1	<50	<0.05	0.5	<1	2	570	<1	2	<0.1	<1	3	0.5	<0.1	0.14	1.3	<5
Hughes DS	10/02/11	13:51	120	<1	<50	<0.05	0.3	<1	2	240	<1	1	<0.1	<1	3	0.3	<0.1	0.18	0.9	<5
Hughes DS	17/02/11	5:15	<10	<1	140	<0.05	<0.2	<1	1	<50	<1	<1	<0.1	1	2	0.4	<0.1	1.05	1.3	<5
Hughes DS	24/02/11	11:25	30	<1	60	<0.05	<0.2	<1	2	100	<1	<1	<0.1	2	2	0.9	<0.1	0.41	0.8	<5
Hughes DS	24/03/11	16:05	60	<1	70	<0.05	0.4	<1	2	100	<1	1	<0.1	<1	2	0.3	<0.1	0.35	1.2	<5
Hughes DS	6/04/11	10:50	40	<1	90	<0.05	0.2	<1	2	80	<1	2	<0.1	<1	2	0.4	<0.1	0.45	0.9	<5
Hughes DS	13/04/11	15:55	<10	<1	130	<0.05	<0.2	<1	<1	<50	<1	<1	<0.1	1	2	0.5	<0.1	2.58	1.1	<5
Hughes DS	20/04/11	12:40	30	<1	90	<0.05	<0.2	<1	1	<50	<1	47	<0.1	1	2	0.3	<0.1	2.04	0.6	<5
Hughes DS	16/05/11	13:30	140	<1	90	<0.05	<0.2	<1	2	130	<1	15	<0.1	<1	2	0.6	<0.1	1.55	0.8	<5
Hughes DS	30/06/11	15:20	<10	<1	150	<0.05	<0.2	<1	<1	<50	<1	9	<0.1	16	3	10.4	<0.1	5.59	0.8	<5
Hughes DS	1/07/11	11:30	20	<1	130	<0.05	<0.2	<1	<1	<50	<1	21	<0.1	7	2	6.9	<0.1	5.76	0.7	<5
Hughes DS	1/07/11	9:30	<10	<1	120	<0.05	<0.2	<1	<1	<50	<1	18	<0.1	8	2	7.8	<0.1	6	0.6	<5
Hughes DS	4/07/11	10:00	30	<1	120	<0.05	<0.2	<1	3	<50	<1	86	<0.1	4	2	2.7	<0.1	3.51	0.5	<5



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Hughes DS	16/01/12	9:30	14	<1	61	<0.1	0.2	<1	2	99	<1	<5	<0.05	1	2	0.5	<0.1	0.1	1	<1
Hughes DS	30/01/12	10:45	4500	<1	68	<0.1	0.5	<1	2	2300	<1	<5	<0.05	<1	2	0.3	<0.1	<0.1	1	1
Hughes DS	13/03/12		14	<1	61	<0.1	0.2	<1	2	99	<1	<5	<0.05	1	2	0.5	<0.1	0.1	1	<1
Hughes DS	21/03/12	13:00	4500	<1	68	<0.1	0.5	<1	2	2300	<1	<5	<0.05	<1	2	0.3	<0.1	<0.1	1	1
Hughes US	13/10/10	8:05	760	<1	<50	<0.05	0.6	<1	2	760	<1	2	<0.1	<1	2	0.3	<0.1	0.14	1.3	<5
Hughes US	25/11/10	6:25	1620	<1	60	<0.05	1	<1	2	1260	<1	2	<0.1	<1	2	0.3	<0.1	0.15	1.8	<5
Hughes US	2/12/10	9:15	130	<1	50	<0.05	1.2	<1	2	180	<1	1	<0.1	<1	3	0.3	0.2	0.17	2.1	<5
Hughes US	9/12/10	13:45	200	<1	60	<0.05	0.6	<1	2	310	<1	4	<0.1	<1	2	0.3	<0.1	0.22	1.3	<5
Hughes US	16/12/10	10:10	370	<1	60	<0.05	0.3	<1	2	660	<1	2	<0.1	<1	3	0.4	<0.1	0.12	0.7	<5
Hughes US	23/12/10	14:40	540	1	<50	<0.05	1	<1	2	660	<1	2	<0.1	<1	3	0.4	<0.1	0.13	1.8	<5
Hughes US	30/12/10	8:47	360	2	<5	<0.05	1.2	<1	2	690	1	24	<0.1	<1	4	0.4	0.2	0.21	2	<5
Hughes US	6/01/11	8:15	190	<1	60	<0.05	0.5	<1	1	420	<1	1	<0.1	<1	2	0.3	<0.1	0.32	1	<5
Hughes US	13/01/11	8:45	400	2	80	<0.05	0.3	1	2	830	2	48	<0.1	<1	3	0.4	<0.1	0.6	1.1	<5
Hughes US	20/01/11	13:45	20	<1	80	<0.05	<0.2	<1	<1	<50	<1	3	<0.1	<1	2	0.3	<0.1	0.57	0.9	<5
Hughes US	27/01/11	10:20	<10	<1	90	<0.2	<0.5	20	<1	1720	<1	3970	<0.1	<1	9	<2	<0.1	0.9	<0.5	7
Hughes US	31/01/11	14:52	110	<1	<50	<0.05	0.3	<1	1	300	<1	<1	<0.1	<1	2	0.2	<0.1	0.07	0.7	<5
Hughes US	3/02/11	14:00	940	<1	<50	<0.05	0.5	3	4	1550	5	123	<0.1	<1	5	0.4	<0.1	0.13	1.3	32
Hughes US	3/02/11	17:15	180	<1	<50			<1	<1	410	<1	<1		<1	2					<5
Hughes US	6/02/11	9:05	150	<1	<50	<0.05	0.4	<1	1	420	<1	2	<0.1	<1	3	0.3	<0.1	0.11	0.9	<5
Hughes US	10/02/11	7:00	40	<1	70	<0.05	<0.2	<1	<1	60	<1	<1	<0.1	<1	2	0.3	<0.1	0.31	0.9	<5
Hughes US	24/02/11	8:25	40	<1	<50	<0.05	0.2	<1	1	120	<1	<1	<0.1	1	2	0.4	<0.1	0.2	0.8	<5
Hughes US	24/03/11	16:05	80	1	60	<0.05	0.4	<1	1	140	<1	<1	<0.1	<1	2	0.3	<0.1	0.24	1.1	<5
Hughes US	6/04/11	8:00	40	<1	60	<0.05	<0.2	<1	2	90	<1	9	<0.1	<1	2	0.3	<0.1	0.11	0.5	<5
Hughes US	16/01/12	13:30	21	<1	57	<0.1	<0.2	<1	1	120	<1	<5	<0.05	1	2	0.6	<0.1	<0.1	0.5	<1
Hughes US	30/01/12	7:30	5600	<1	60	<0.1	0.5	7	7	1100	12	320	<0.05	<1	6	0.2	<0.1	0.7	4	8
Hughes US	13/03/12		21	<1	57	<0.1	<0.2	<1	1	120	<1	<5	<0.05	1	2	0.6	<0.1	<0.1	0.5	<1
Hughes US	21/03/12	14:10	5600	<1	60	<0.1	0.5	7	7	1100	12	320	<0.05	<1	6	0.2	<0.1	0.7	4	8
OMC DS	30/09/10	8:39	<10	<1	70	<0.05	<0.2	<1	2	<50	<1	1	<0.1	2	2	4.6	<0.1	0.1	0.3	<5
OMC DS	5/10/10	8:54	80	<1	80	<0.05	<0.2	<1	<1	180	<1	<1	<0.1	1	1	0.4	<0.1	0.36	0.8	<5
OMC DS	12/10/10	9:54	40	1	60	<0.05	0.3	<1	<1	280	<1	<1	<0.1	1	1	0.3	<0.1	0.26	0.6	<5



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
OMC DS	19/10/10	12:28	50	1	50	<0.05	<0.2	<1	<1	280	<1	<1	<1	<1	1	0.2	<0.1	0.17	0.5	<5
OMC DS	26/10/10	9:10	3840	<1	60	<0.05	<0.2	<1	2	1480	<1	6	<0.1	2	3	0.3	<0.1	0.23	0.8	<5
OMC DS	2/11/10	11:02	9360	1	70	<0.05	<0.2	<1	2	3240	<1	14	<0.1	<1	2	0.4	<0.1	0.42	0.7	<5
OMC DS	19/11/10	9:20	30	<1	80	<0.05	0.2	<1	<1	<50	<1	<1	<0.1	2	2	2.4	<0.1	0.21	0.4	<5
OMC DS	25/11/10	9:30	520	<1	60	<0.05	0.6	<1	1	430	<1	1	<0.1	<1	2	0.3	<0.1	0.33	1.8	<5
OMC DS	2/12/10		120	<1	<50	<0.05	0.6	<1	2	240	<1	1	<0.1	<1	2	0.8	<0.1	0.16	1.4	<5
OMC DS	9/12/10	13:20	330	<1	<50	<0.05	0.6	1	2	1150	2	37	<0.1	2	3	2	<0.1	0.21	1.2	<5
OMC DS	16/12/10	17:20	460	<1	<50	<0.05	0.4	<1	1	570	<1	2	<0.1	<1	2	1.3	<0.1	0.19	0.8	<5
OMC DS	23/12/10	12:55	770	1	<50	<0.05	1.6	<1	1	1060	<1	3	<0.1	<1	3	0.4	<0.1	0.16	2.9	<5
OMC DS	30/12/10	9:35	390	1	<5	<0.05	1.5	<1	3	1090	1	22	<0.1	<1	5	1	0.2	0.25	2.2	<5
OMC DS	6/01/11	6:45	640	1	<50	<0.05	0.8	<1	1	880	<1	3	<0.1	<1	4	0.9	0.1	0.16	1.2	<5
OMC DS	13/01/11	12:02	360	4	<50	<0.05	1.5	<1	1	1620	<1	18	<0.1	<1	3	0.6	0.1	0.2	2.4	<5
OMC DS	20/01/11	11:05	100	1	60	<0.05	0.2	<1	<1	180	<1	2	<0.1	1	3	1.9	0.2	0.21	0.9	<5
OMC DS	3/02/11	8:35	20	<1	<50			<1	1	80	<1	<1		1	2					<5
OMC DS	10/02/11	7:22	270	1	<50	<0.05	0.4	<1	1	670	<1	6	<0.1	<1	2	0.7	<0.1	0.2	1.7	<5
OMC DS	17/02/11	12:15	40	1	70	<0.05	<0.2	<1	1	80	<1	44	<0.1	1	4	0.9	<0.1	0.31	0.8	<5
OMC DS	29/12/11	8:20	<10	<1	<1	<0.1	<0.1	2	10	<1	<10	2		5	50	<0.2	<0.2	3	<0.1	
OMC US	30/09/10	9:41	10	<1	<50	<0.05	<0.2	<1	<1	320	<1	<1	<0.1	<1	<1	<0.2	<0.1	<0.05	<0.2	<5
OMC US	5/10/10	9:08	40	<1	<50	<0.05	<0.2	<1	<1	430	<1	<1	<0.1	<1	<1	<0.2	<0.1	<0.05	0.2	<5
OMC US	12/10/10	9:40	60	<1	<50	<0.05	0.2	<1	<1	430	<1	13	<0.1	<1	<1	<0.2	<0.1	<0.05	0.2	<5
OMC US	19/10/10	11:20	170	<1	<50	<0.05	<0.2	<1	<1	960	<1	2	<1	<1	<1	<0.2	<0.1	<0.05	0.2	<5
OMC US	26/10/10	11:25	90	<1	<50	<0.05	<0.2	<1	<1	970	<1	1	<0.1	<1	<1	<0.2	<0.1	<0.05	0.3	<5
OMC US	2/11/10	7:45	10	1	<50	<0.05	<0.2	<1	<1	720	<1	204	<0.1	<1	1	<0.2	<0.1	<0.05	<0.2	12
OMC US	19/11/10	11:15	30	1	<50	<0.05	<0.2	<1	<1	880	<1	3	<0.1	<1	<1	<0.2	<0.1	<0.05	0.2	<5
OMC US	25/11/10	10:20	600	<1	<50	<0.05	0.3	<1	<1	1300	<1	3	<0.1	<1	<1	<0.2	<0.1	<0.05	0.7	<5
OMC US	2/12/10	9:45	230	<1	<50	<0.05	2	<1	2	310	<1	17	<0.1	<1	3	0.3	0.2	0.19	2.8	<5
OMC US	9/12/10	8:56	340	<1	60	<0.05	1.3	<1	2	810	2	25	<0.1	<1	4	0.3	0.2	0.18	2.3	7
OMC US	16/12/10	8:45	1170	<1	50	<0.05	0.6	<1	2	1000	<1	6	<0.1	<1	4	0.4	0.1	0.13	0.4	<5
OMC US	23/12/10	14:10	1170	1	<50	<0.05	1.7	<1	2	1130	<1	5	<0.1	<1	4	0.4	0.1	0.19	2.9	<5
OMC US	30/12/10	8:10	420	<1	<5	<0.05	1.4	<1	2	1020	<1	14	<0.1	<1	4	0.5	0.3	0.21	1.8	<5



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
OMC US	6/01/11	7:15	940	<1	<50	<0.05	1.2	<1	2	1360	<1	4	<0.1	<1	4	0.4	0.2	0.16	1.9	<5
OMC US	13/01/11	10:35	390	3	80	<0.05	0.9	2	1	1550	<1	76	<0.1	<1	5	0.4	0.1	0.16	1.5	<5
OMC US	20/01/11	11:55	450	<1	90	<0.05	0.5	2	1	920	<1	88	<0.1	<1	4	0.4	0.2	0.09	1	<5
OMC US	3/02/11	11:40	110	2	<50	<0.05	0.6	<1	<1	2840	<1	98	<0.1	<1	2	0.2	<0.1	<0.05	0.7	<5
OMC US	3/02/11	14:15	350	1	<50			<1	<1	950	<1	1		<1	2					<5
OMC US	10/02/11	6:44	370	1	<50	<0.05	0.6	<1	<1	1330	<1	22	<0.1	<1	2	0.2	<0.1	<0.05	0.8	<5
OMC US	17/02/11	12:11	210	2	<50	<0.05	0.5	<1	<1	4580	<1	25	<0.1	<1	2	0.3	<0.1	<0.05	1.2	<5
Phillips DS	28/09/10	8:10	150	<1	<50	<0.05	0.9	<1	3	200	<1	2	<0.1	<1	3	0.2	<0.1	0.16	9.6	<5
Phillips DS	5/10/10	9:20	10	<1	60	<0.05	0.2	<1	2	<50	<1	<1	<0.1	2	2	0.3	<0.1	0.76	4.4	<5
Phillips DS	12/10/10	7:55	170	<1	<50	<0.05	0.7	<1	2	290	<1	<1	<0.1	<1	2	0.4	<0.1	0.24	2.8	<5
Phillips DS	19/10/10	12:35	40	<1	<50	<0.05	0.2	<1	1	<50	<1	2	<1	2	2	0.3	<0.1	1.02	2.8	<5
Phillips DS	19/11/10	8:40	320	1	<50	<0.05	0.9	<1	2	520	<1	3	<0.1	<1	3	0.3	<0.1	0.31	6.5	<5
Phillips DS	25/11/10	9:52	300	<1	60	<0.05	0.7	<1	2	430	<1	1	<0.1	<1	3	0.3	<0.1	0.56	3.6	<5
Phillips DS	2/12/10	10:45	180	<1	<50	<0.05	0.6	<1	2	390	<1	1	<0.1	<1	4	0.4	0.1	0.34	2.7	<5
Phillips DS	9/12/10	11:10	440	<1	<50	<0.05	0.5	2	3	500	2	70	<0.1	<1	5	0.4	<0.1	0.42	2.2	<5
Phillips DS	16/12/10	9:25	90	<1	50	<0.05	0.4	<1	2	290	<1	1	<0.1	<1	4	0.4	<0.1	0.7	3	<5
Phillips DS	23/12/10	8:20	160	1	<50	<0.05	0.8	<1	2	410	<1	2	<0.1	<1	9	0.5	<0.1	0.26	2.5	<5
Phillips DS	30/12/10	11:00	7420	2	60	<0.05	1	5	5	4070	2	164	<0.1	<1	13	0.4	<0.1	0.45	3.9	13
Phillips DS	6/01/11	6:35	10	<1	<50	<0.05	0.2	<1	1	<50	<1	<1	<0.1	<1	4	0.4	<0.1	0.86	2.5	<5
Phillips DS	13/01/11	10:44	140	3	70	<0.05	0.3	<1	1	140	<1	24	<0.1	<1	2	0.2	<0.1	1.62	11	<5
Phillips DS	20/01/11	12:30	<10	1	60	<0.05	0.2	<1	1	<50	<1	<1	<0.1	<1	2	<0.2	<0.1	0.88	9.7	<5
Phillips DS	3/02/11	8:32	2080	<1	<50	<0.05	0.4	10	8	2130	7	351	<0.1	<1	17	0.4	0.1	0.34	2.4	19
Phillips DS	3/02/11	14:10	50	<1	<50			<1	2	180	<1	<1		<1	3					<5
Phillips DS	6/02/11	15:15	140	<1	<50	<0.05	0.4	<1	1	350	<1	1	<0.1	<1	4	0.3	<0.1	0.26	2.5	<5
Phillips DS	10/02/11	10:15	<10	<1	<50	<0.05	0.3	<1	1	<50	<1	<1	<0.1	<1	2	0.2	<0.1	0.71	6.5	<5
Phillips DS	20/03/11	9:50	840	2	50	<0.05	0.3	6	4	760	2	209	<0.1	<1	11	0.7	<0.1	0.32	2.2	11
Phillips DS	2/04/11	9:30	60	<1	60	<0.05	0.2	<1	1	120	<1	<1	<0.1	2	4	1.5	<0.1	0.87	5.9	<5
Phillips DS	9/05/11	11:30	14400	3	70	<0.05	<0.2	3	10	9670	6	48	<0.1	1	12	0.6	<0.1	0.59	1.6	19
Phillips DS	11/06/11	19:50	23	10	<1	0.3	<0.05	<1	<1	<50	1	1		<5	<1	<0.1	0.3	<0.1	1.06	<1
Phillips DS	16/01/12	10:45	22	<1	72	<0.1	0.2	<1	2	170	<1	<5	<0.05	1	2	0.5	<0.1	0.1	1	<1



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Phillips DS	22/01/12	9:45	<10	<1	64	<0.1	<0.2	<1	<1	19	<1	<5	<0.05	1	1	0.4	0.1	0.5	1	<1
Phillips DS	29/01/12	6:30	2300	<1	47	<0.1	0.6	<1	1	350	<1	<5	<0.05	<1	2	0.2	<0.1	0.1	4	<1
Phillips DS	13/03/12		22	<1	72	<0.1	0.2	<1	2	170	<1	<5	<0.05	1	2	0.5	<0.1	0.1	1	<1
Phillips DS	19/03/12	10:00	<10	<1	64	<0.1	<0.2	<1	<1	19	<1	<5	<0.05	1	1	0.4	0.1	0.5	1	<1
Phillips US	28/09/10	9:35	160	1	<50	<0.05	1	<1	2	190	<1	1	<0.1	<1	2	0.2	<0.1	0.18	10.6	<5
Phillips US	5/10/10	9:48	160	<1	50	<0.05	0.2	<1	2	190	<1	2	<0.1	1	2	0.3	<0.1	0.7	3.4	<5
Phillips US	12/10/10	12:42	420	<1	<50	<0.05	0.7	<1	2	490	<1	1	<0.1	<1	2	0.3	<0.1	0.2	2.6	<5
Phillips US	19/10/10	7:55	230	<1	<50	<0.05	0.3	<1	2	340	<1	2	<1	<1	2	0.3	<0.1	0.62	1.8	<5
Phillips US	19/11/10	11:24	260	<1	<50	<0.05	1	<1	2	450	<1	2	<0.1	<1	3	0.2	<0.1	0.31	7	<5
Phillips US	25/11/10	12:05	70	<1	60	<0.05	0.7	<1	2	170	<1	<1	<0.1	<1	2	0.3	<0.1	0.53	3.3	<5
Phillips US	2/12/10		180	<1	50	<0.05	0.9	<1	3	340	<1	2	<0.1	<1	3	0.3	<0.1	0.36	3.1	<5
Phillips US	9/12/10	12:20	220	<1	50	<0.05	0.7	<1	2	300	<1	30	<0.1	<1	3	0.3	<0.1	0.59	3.4	<5
Phillips US	16/12/10	9:25	150	<1	60	<0.05	0.5	<1	1	310	<1	<1	<0.1	<1	3	0.3	<0.1	0.69	3	<5
Phillips US	23/12/10	11:10	280	<1	<50	<0.05	0.8	<1	1	510	<1	2	<0.1	<1	4	0.4	<0.1	0.36	2.6	<5
Phillips US	30/12/10	9:10	500	<1	<5	<0.05	0.8	2	2	680	<1	63	<0.1	<1	6	0.4	0.1	0.45	4.3	<5
Phillips US	6/01/11	6:40	20	<1	<50	<0.05	0.3	<1	2	80	<1	<1	<0.1	<1	2	0.3	<0.1	0.75	4.2	<5
Phillips US	13/01/11	1:00	100	3	70	<0.05	0.3	<1	<1	140	<1	34	<0.1	<1	2	0.2	<0.1	1.47	11.6	<5
Phillips US	20/01/11	12:06	<10	1	50	<0.05	<0.2	<1	1	<50	<1	<1	<0.1	<1	2	<0.2	<0.1	0.75	10.5	<5
Phillips US	3/02/11	9:53	3210	<1	<50	<0.05	0.5	14	10	2910	9	498	<0.1	<1	20	0.3	<0.1	0.32	2.9	25
Phillips US	3/02/11	13:05	90	<1	<50			<1	2	340	<1	<1		<1	2					<5
Phillips US	6/02/11	10:30	290	<1	<50	<0.05	0.5	<1	2	600	<1	1	<0.1	<1	3	0.3	<0.1	0.13	1.2	<5
Phillips US	10/02/11	12:55	10	1	<50	<0.05	0.2	<1	<1	<50	<1	3	<0.1	<1	2	0.3	<0.1	0.64	5.5	<5
Phillips US	20/03/11	5:45	1340	1	50	<0.05	<0.2	4	4	900	4	194	<0.1	<1	6	<0.2	<0.1	0.4	2.6	12
Phillips US	2/04/11	5:30	40	<1	<50	<0.05	0.4	<1	2	140	<1	1	<0.1	<1	2	<0.2	<0.1	0.44	11.9	<5
Phillips US	9/05/11	6:45	2670	1	<50	<0.05	0.2	15	12	2400	5	675	<0.1	<1	22	0.2	<0.1	0.36	5.8	14
Phillips US	11/06/11		11	<10	<1	0.2	<0.05	<1	<1	<50	2	2		<5	<1	<0.1	1.5	<0.1	0.45	<1
Phillips US	16/01/12	14:00	<10	<1	61	<0.1	<0.2	<1	2	38	<1	<5	<0.05	<1	3	0.3	<0.1	0.6	7	<1
Phillips US	22/01/12	12:10	12	<1	48	<0.1	0.2	<1	2	85	<1	<5	<0.05	<1	2	0.2	0.1	0.1	7	<1
Phillips US	29/01/12	4:30	770	<1	60	<0.1	<0.2	<1	1	360	<1	<5	<0.05	<1	3	<0.2	0.2	0.2	4	<1
Phillips US	30/01/12	8:15																		



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Dissolved Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Phillips US	13/03/12		<10	<1	61	<0.1	<0.2	<1	2	38	<1	<5	<0.05	<1	3	0.3	<0.1	0.6	7	<1
Phillips US	19/03/12	8:30	12	<1	48	<0.1	0.2	<1	2	85	<1	<5	<0.05	<1	2	0.2	0.1	0.1	7	<1
Phillips US	15/07/12	12:15	39	<1	<1	<0.1	<1	42	<1	<1	<5	2	<0.05		33	<1	<1	<0.5	10	<1
Phillips DS	15/07/12	13:45	35	<1	<1	<0.1	<1	47	<1	<1	<5	2	<0.05		21	<1	<1	0.6	9	1
Hughes US	25/01/13	8:30	670				<1		2	700								<0.5		<1
Hughes DS	25/01/13	12:45	16				<1		2	110								<0.5		<1
Phillips US	25/01/13	9:45	26				<1		2	190								<0.5		<1
Phillips DS	25/01/13	15:15	19				<1		3	140								<0.5		<1
OMC DS	19/02/13	14:35	<10	<1	56	<0.1	<1	<1	5	<10	<1	14	<0.05	29	<1	3	<1	<0.5	<1	2
OMC US	20/02/13	10:05	<10	1	52	<0.1	<1	2	<1	800	<1	150	<0.05	<1	<1	<1	<1	<0.5	<1	<1
Phillips US	20/02/13	11:15	<10	<1	98	<0.1	<1	<1	<1	<10	<1	7	<0.05	2	<1	<1	<1	1.1	2	4
Phillips US	2/03/13	11:45	10				<1		2	92								<0.5		2
Phillips DS	2/03/13	8:30	16				<1		1	69								<0.5		2
Hughes US	20/03/13	15:15	<10	<1	100	<0.1	<1	<1	<1	32	<1	<5	<0.05	<1	<1	<1	<1	<0.5	<1	<1
Hughes DS	20/03/13	14:00	<10	<1	270	<0.1	<1	<1	<1	<10	<1	<5	<0.05	22	<1	6	<1	4.8	<1	<1
Phillips US	20/03/13	16:00	<10	<1	120	<0.1	<1	<1	<1	<10	<1	<5	<0.05	1	<1	<1	<1	<0.5	3	<1



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Hughes DS	13/10/10	8:40	10800	3	<50	<0.05	0.4	6	11	14400	14	97	<0.1	<1	12	1.5	<0.1	2.22	43.6	25
Hughes DS	19/10/10	8:00	3340	2	100	<0.05	<0.2	1	5	3960	4	17	<1	2	7	0.7	<0.1	0.53	8.6	11
Hughes DS	26/10/10	9:15	530	<1	120	<0.05	0.3	1	4	480	2	28	<0.1	2	6	0.9	0.1	0.64	7.3	5
Hughes DS	19/11/10	7:00	12100	3	80	<0.05	1	7	10	16000	10	145	<0.1	<1	17	0.6	<0.1	0.56	16.2	32
Hughes DS	25/11/10	11:30	7570	<1	60	<0.05	0.8	2	3	9270	2	55	<0.1	<1	3	0.6	<0.1	0.45	10.2	<5
Hughes DS	2/12/10	13:15	5740	2	60	<0.05	1.3	2	5	5860	5	36	<0.1	<1	8	1.4	<0.1	0.59	10.8	13
Hughes DS	9/12/10	9:27	370	<1	50	<0.05	1	<1	2	640	2	33	<0.1	<1	3	0.4	<0.1	0.26	4.9	<5
Hughes DS	16/12/10	9:15	2810	2	50	<0.05	0.4	2	4	3770	4	47	<0.1	<1	6	1.2	<0.1	0.39	5.6	10
Hughes DS	23/12/10	10:30	1000	1	<50	<0.05	1.2	6	4	1430	5	146	<0.1	<1	6	1.1	0.1	0.42	8.3	15
Hughes DS	30/12/10	11:35	2010	1	50	<0.05	1.2	<1	3	2270	2	12	<0.1	<1	5	0.4	0.1	0.33	5.7	7
Hughes DS	6/01/11	13:22	1680	1	60	<0.05	0.6	2	3	2780	2	55	<0.1	<1	5	0.4	<0.1	0.41	5.4	<5
Hughes DS	13/01/11	8:45	17200	4	80	<0.05	0.3	7	11	16200	13	135	<0.1	<1	18	0.5	<0.1	1.09	14.8	36
Hughes DS	20/01/11	9:52	4040	3	80	<0.05	0.2	2	4	4960	4	70	<0.1	<1	7	0.4	0.2	0.66	7	13
Hughes DS	27/01/11	8:53	1470	1	100	<0.2	<0.5	1	3	1930	1	32	<0.1	<1	5	<2	<0.1	0.7	4	<5
Hughes DS	31/01/11	13:50	42600	6	60	<0.05	0.2	39	49	59400	67	1120	<0.1	<1	63	1.7	0.1	3.3	55.6	101
Hughes DS	3/02/11	10:17	20400	4	70	<0.05	0.3	27	24	28800	29	713	<0.1	<1	40	2.4	0.1	2.05	45.6	58
Hughes DS	6/02/11	10:21	17100	2	<50	<0.05	0.5	11	9	20600	12	328	<0.1	<1	13	0.6	0.1	1.06	26.2	25
Hughes DS	10/02/11	13:51	1850	1	<50	<0.05	0.3	1	3	2900	2	42	<0.1	<1	5	0.4	<0.1	0.35	6	<5
Hughes DS	17/02/11	5:15	140	<1	110	<0.05	<0.2	<1	1	<50	<1	11	<0.1	1	2	0.4	<0.1	1.56	1.6	<5
Hughes DS	24/02/11	11:25	5130	2	110	<0.05	<0.2	4	7	7370	4	86	<0.1	1	11	0.8	<0.1	0.88	10.2	14
Hughes DS	24/03/11	16:05	2780	1	90	<0.05	0.4	2	6	3310	3	40	<0.1	<1	15	0.4	<0.1	0.56	6.7	21
Hughes DS	6/04/11	10:50	1050	<1	80	<0.05	0.2	<1	2	1460	1	23	<0.1	<1	3	0.3	0.1	0.78	3.6	<5
Hughes DS	13/04/11	15:55	30	<1	140	<0.05	<0.2	<1	2	<50	<1	10	<0.1	1	2	0.5	<0.1	2.84	1	<5
Hughes DS	20/04/11	12:40	90	<1	100	<0.05	<0.2	<1	1	190	<1	87	<0.1	<1	2	0.3	<0.1	1.92	0.8	<5
Hughes DS	16/05/11	13:30	1290	1	80	<0.05	<0.2	<1	2	1740	1	21	<0.1	<1	3	0.5	<0.1	1.7	3.2	<5
Hughes DS	30/06/11	15:20	40	<1	160	<0.05	<0.2	<1	2	370	<1	15	<0.1	19	6	9.7	<0.1	5.91	0.8	<5
Hughes DS	1/07/11	11:30	30	<1	130	<0.05	<0.2	<1	1	<50	<1	22	<0.1	8	3	6.8	<0.1	5.94	0.7	<5
Hughes DS	1/07/11	9:30	10	<1	110	<0.05	<0.2	<1	<1	<50	<1	20	<0.1	9	3	7.6	<0.1	6.07	0.6	<5
Hughes DS	4/07/11	10:00	20	<1	110	<0.05	<0.2	<1	<1	60	<1	88	<0.1	4	2	2.3	<0.1	7.09	0.7	<5
Hughes DS	16/01/12	9:30	15000	4	72	<0.1	25	11	13	22000	14	320	<0.05	1	22	0.5	<0.1	0.8	28	34



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Hughes DS	30/01/12	10:45	22000	6	95	<0.1	24	15	19	35000	29	390	0.06	<1	23	0.6	0.3	1.5	35	52
Hughes DS	13/03/12		15000	4	72	<0.1	25	11	13	22000	14	320	<0.05	1	22	0.5	<0.1	0.8	28	34
Hughes DS	21/03/12	13:00	22000	6	95	<0.1	24	15	19	35000	29	390	0.06	<1	23	0.6	0.3	1.5	35	52
Hughes US	13/10/10	8:05	8520	2	<50	<0.05	0.6	3	8	9150	1	51	<0.1	<1	7	0.5	<0.1	0.88	18.8	15
Hughes US	19/11/10	9:50	8180	2	60	<0.05	1.8	4	7	9510	10	116	<0.1	<1	9	0.5	<0.1	0.44	12.8	16
Hughes US	25/11/10	6:25	29100	4	80	<0.05	1.0	8	15	21300	33	137	<0.1	<1	16	0.4	<0.1	0.25	5.6	58
Hughes US	2/12/10	9:15	3830	2	60	<0.05	1.2	1	3	4080	4	26	<0.1	<1	5	0.4	<0.1	0.4	7.4	7
Hughes US	9/12/10	13:45	360	<1	50	<0.05	0.6	<1	2	560	2	20	<0.1	<1	3	0.3	<0.1	0.19	2.5	<5
Hughes US	16/12/10	10:10	1780	1	60	<0.05	0.3	1	2	2550	3	41	<0.1	<1	4	0.4	<0.1	0.23	4.1	<5
Hughes US	23/12/10	14:40	730	<1	<50	<0.05	1	1	2	1130	3	46	<0.1	<1	4	0.3	<0.1	0.26	5.2	6
Hughes US	30/12/10	8:47	1970	1	60	<0.05	1.2	<1	3	2650	3	24	<0.1	<1	5	0.3	0.1	0.26	3.2	6
Hughes US	6/01/11	8:15	6450	2	70	<0.05	0.5	4	6	8810	9	99	<0.1	<1	8	0.3	0.1	0.66	11.3	8
Hughes US	13/01/11	8:45	2810	1	80	<0.05	0.3	1	2	3580	3	52	<0.1	<1	5	0.3	<0.1	0.69	4	6
Hughes US	20/01/11	13:45	1490	1	80	<0.05	<0.2	<1	2	1860	1	48	<0.1	<1	4	0.3	0.1	0.69	3.3	<5
Hughes US	27/01/11	10:20	30	<1	100	<0.2	<0.5	21	<1	4580	<1	4260	<0.1	<1	9	<2	<0.1	1.1	0.8	<5
Hughes US	31/01/11	14:52	38300	4	60	<0.05	0.3	39	47	50400	67	1150	<0.1	<1	59	1.2	0.1	3.4	52.6	96
Hughes US	3/02/11	14:00	9530	3	<50	<0.05	0.5	5	7	13500	11	160	<0.1	<1	11	0.4	0.1	0.44	11.7	16
Hughes US	6/02/11	9:05	7590	2	<50	<0.05	0.4	8	8	12000	12	253	<0.1	<1	13	0.6	<0.1	0.52	14	18
Hughes US	10/02/11	7:00	570	<1	70	<0.05	<0.2	<1	<1	540	<1	11	<0.1	<1	3	0.3	<0.1	0.23	1.5	<5
Hughes US	24/02/11	8:25	2730	<1	70	<0.05	0.2	2	4	3760	2	79	<0.1	1	7	0.4	<0.1	0.44	6.2	24
Hughes US	24/03/11	16:05	1760	<1	80	<0.05	0.4	1	2	2250	2	48	<0.1	<1	4	0.3	<0.1	0.35	3.6	13
Hughes US	6/04/11	8:00	420	<1	60	<0.05	<0.2	<1	<1	530	<1	72	<0.1	<1	2	0.3	<0.1	0.4	1.3	<5
Hughes US	16/01/12	13:30	5600	3	68	<0.1	5	5	6	7700	9	160	<0.05	<1	7	0.4	<0.1	0.4	10	13
Hughes US	30/01/12	7:30	18000	4	84	0.1	14	13	18	28000	30	440	0.07	<1	18	0.6	0.3	1.3	27	41
Hughes US	13/03/12		5600	3	68	<0.1	5	5	6	7700	9	160	<0.05	<1	7	0.4	<0.1	0.4	10	13
Hughes US	21/03/12	14:10	18000	4	84	0.1	14	13	18	28000	30	440	0.07	<1	18	0.6	0.3	1.3	27	41
OMC DS	30/09/10	8:39	680	<1	60	<0.05	<0.2	2	4	630	2	44	<0.1	1	5	5	<0.1	0.59	16.4	12
OMC DS	5/10/10	8:54	2320	2	90	<0.05	<0.2	2	4	3370	2	44	<0.1	1	5	0.4	<0.1	0.48	5.4	10
OMC DS	12/10/10	9:54	240	1	70	<0.05	0.3	<1	1	730	<1	22	<0.1	<1	2	0.4	<0.1	0.4	5	<5
OMC DS	19/10/10	12:28	450	2	80	<0.05	<0.2	<1	<1	900	3	5	<1	<1	2	0.3	<0.1	0.25	2.3	<5



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
OMC DS	26/10/10	9:10	3820	1	70	<0.05	<0.2	2	2	4770	3	45	<0.1	<1	3	0.4	<0.1	0.34	5.2	<5
OMC DS	2/11/10	11:02	1060	<1	80	<0.05	<0.2	<1	2	2320	<1	10	<0.1	<1	3	0.4	<0.1	0.54	4.3	6
OMC DS	19/11/10	9:20	75100	<5	120	<0.05	0.2	10	15	22600	13	95	<0.1	<5	33	2.7	<0.1	0.56	14.4	49
OMC DS	25/11/10	9:30	770	2	60	<0.05	0.6	5	4	840	4	114	<0.1	<1	4	0.5	<0.1	0.91	15.9	<5
OMC DS	2/12/10		10900	2	50	<0.05	0.6	5	10	12100	9	68	<0.1	<1	14	1.2	<0.1	1.39	22.4	26
OMC DS	9/12/10	13:20	380	1	<50	<0.05	0.6	1	2	1180	2	38	<0.1	1	3	1.8	<0.1	0.42	6.2	<5
OMC DS	16/12/10	17:20	4370	2	<50	<0.05	0.4	3	4	7100	5	74	<0.1	<1	6	1.4	<0.1	0.5	9	9
OMC DS	23/12/10	12:55	650	2	<50	<0.05	1.6	1	1	2870	9	77	<0.1	<1	3	0.4	<0.1	0.23	4.6	7
OMC DS	30/12/10	9:35	3450	1	<50	<0.05	1.5	2	4	4010	3	23	<0.1	<1	7	0.8	0.1	0.42	8.5	9
OMC DS	6/01/11	6:45	4610	2	<50	<0.05	0.8	4	5	6950	4	89	<0.1	<1	10	1.1	0.2	0.3	6.8	18
OMC DS	13/01/11	12:02	2290	2	<50	<0.05	1.5	<1	2	3250	2	22	<0.1	<1	4	0.5	<0.1	0.2	2.4	7
OMC DS	20/01/11	11:05	3810	2	50	<0.05	0.2	2	3	3750	2	63	<0.1	1	7	2.1	<0.1	0.33	6.6	8
OMC DS	3/02/11	0:15	13700	4	50	<0.05	0.2	52	31	17300	36	864	<0.1	<1	51	3.5	0.1	4.05	72.5	56
OMC DS	10/02/11	7:22	1500	2	<50	<0.05	0.4	1	2	2910	2	37	<0.1	<1	5	0.8	<0.1	0.27	4.5	<5
OMC DS	17/02/11	12:15	620	1	<50	<0.05	<0.2	<1	2	780	<1	102	<0.1	1	5	0.9	<0.1	0.45	1.8	13
OMC DS	29/12/11	8:20	2	76	7	0.2	0.3	85	5	76	<5	4		49	5700	9	13	300	20	
OMC US	30/09/10	9:41	30	<1	<50	<0.05	<0.2	<1	<1	650	<1	60	<0.1	<1	<1	<0.2	<0.1	<0.05	0.4	<5
OMC US	5/10/10	9:08	20	<1	<50	<0.05	<0.2	<1	4	120	<1	328	<0.1	<1	6	<0.2	<0.1	<0.05	0.3	<5
OMC US	12/10/10	9:40	80	<1	<50	<0.05	0.2	<1	<1	870	<1	100	<0.1	<1	<1	<0.2	<0.1	<0.05	0.4	<5
OMC US	19/10/10	11:20	200	1	50	<0.05	<0.2	<1	<1	1780	<1	12	<1	<1	<1	<0.2	<0.1	<0.05	0.9	<5
OMC US	26/10/10	11:25	40	1	<50	<0.05	<0.2	<1	<1	1740	<1	76	<0.1	<1	<1	<0.2	<0.1	<0.05	0.5	<5
OMC US	2/11/10	7:45	1720	<1	60	<0.05	<0.2	<1	<1	850	<1	20	<0.1	<1	<1	<0.2	<0.1	<0.05	0.3	<5
OMC US	19/11/10	11:15	90	1	<50	<0.05	<0.2	<1	<1	2030	<1	80	<0.1	<1	1	<0.2	<0.1	<0.05	0.6	<5
OMC US	25/11/10	10:20	1040	1	<50	<0.05	0.3	<1	<1	3960	<1	326	<0.1	<1	<1	<0.2	<0.1	<0.05	1.5	<5
OMC US	2/12/10	9:45	4710	2	60	<0.05	2	2	3	4520	5	59	<0.1	<1	5	0.4	<0.1	0.37	6	10
OMC US	9/12/10	8:56	640	<1	<50	<0.05	1.3	<1	2	1020	2	25	<0.1	<1	4	0.4	<0.1	0.23	4.5	<5
OMC US	16/12/10	8:45	2320	1	<50	<0.05	0.6	1	2	3240	4	26	<0.1	<1	5	0.4	<0.1	0.24	2.9	8
OMC US	23/12/10	14:10	1450	1	<50	<0.05	1.7	<1	1	1510	4	22	<0.1	<1	4	0.4	<0.1	0.2	2.1	7
OMC US	30/12/10	8:10	1690	<1	50	<0.05	1.4	<1	2	2370	2	21	<0.1	<1	5	0.4	0.1	0.22	2	5
OMC US	6/01/11	7:15	820	1	<50	<0.05	1.2	1	2	2230	1	29	<0.1	<1	4	0.4	0.1	0.2	3.1	12



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
OMC US	13/01/11	10:35	2480	<1	80	<0.05	0.9	2	2	3240	2	74	<0.1	<1	5	0.5	<0.1	0.18	2	8
OMC US	20/01/11	11:55	2250	1	90	<0.05	0.5	2	2	2690	2	103	<0.1	<1	5	0.4	<0.1	0.1	1.7	8
OMC US	3/02/11	11:40	250	2	<50	<0.05	0.6	<1	<1	3510	<1	111	<0.1	<1	2	0.2	<0.1	<0.05	1.2	<5
OMC US	10/02/11	6:44	310	2	<50	<0.05	0.6	1	<1	3140	<1	173	<0.1	<1	2	0.3	<0.1	<0.05	1.2	<5
OMC US	17/02/11	12:11	160	2	<50	<0.05	0.5	<1	<1	4540	<1	75	<0.1	<1	2	0.4	<0.1	<0.05	1.7	<5
Phillips DS	28/09/10	8:10	68200	3	60	<0.05	0.9	71	72	86900	26	2020	<0.1	<1	198	1	<0.1	1.44	97.9	111
Phillips DS	5/10/10	9:20	<10	3	110	<0.05	0.2	<1	5	100	<1	19	<0.1	<1	4	0.3	<0.1	0.84	5.1	<5
Phillips DS	12/10/10	7:55	1460	<1	<50	<0.05	0.7	6	7	790	5	171	<0.1	<1	8	0.5	<0.1	0.97	34.4	7
Phillips DS	19/10/10	12:35	290	<1	70	<0.05	0.2	<1	2	280	<1	5	<1	2	2	0.3	<0.1	1.11	4.4	<5
Phillips DS	19/11/10	8:40	22200	2	60	<0.05	0.9	17	20	28500	8	489	<0.1	<1	54	0.4	<0.1	0.57	42.2	36
Phillips DS	25/11/10	9:52	410	<1	60	<0.05	0.7	1	3	280	1	43	<0.1	<1	4	0.4	<0.1	0.69	8.9	<5
Phillips DS	2/12/10	10:45	6930	2	60	<0.05	0.6	5	8	8740	6	130	<0.1	<1	17	0.5	<0.1	0.69	22.7	27
Phillips DS	9/12/10	11:10	530	<1	<50	<0.05	0.5	2	3	580	2	66	<0.1	<1	5	0.3	<0.1	0.57	7	<5
Phillips DS	16/12/10	9:25	1830	1	50	<0.05	0.4	2	3	2870	2	49	<0.1	<1	8	0.4	<0.1	0.89	6.6	10
Phillips DS	23/12/10	8:20	720	1	<50	<0.05	0.8	4	2	1300	2	124	<0.1	<1	12	0.4	<0.1	0.36	5.9	16
Phillips DS	30/12/10	11:00	5020	2	50	<0.05	1	5	6	6310	3	142	<0.1	<1	16	0.3	0.1	0.52	10.6	15
Phillips DS	6/01/11	6:35	11700	3	60	<0.05	0.2	16	14	17400	14	538	<0.1	<1	32	0.7	0.2	1.52	45.9	39
Phillips DS	13/01/11	10:44	940	<1	70	<0.05	0.3	<1	2	1050	<1	28	<0.1	<1	3	<0.2	<0.1	1.74	10.4	<5
Phillips DS	20/01/11	12:30	2640	2	50	<0.05	0.2	2	3	2870	2	55	<0.1	<1	6	0.3	0.1	1.05	14	7
Phillips DS	3/02/11	8:32	13600	2	<50	<0.05	0.4	15	15	20700	16	485	<0.1	<1	34	0.6	<0.1	0.98	31.3	37
Phillips DS	6/02/11	15:15	12300	3	50	<0.05	0.4	9	11	15100	12	250	<0.1	<1	24	0.4	0.1	0.63	24.2	28
Phillips DS	10/02/11	10:15	500	<1	<50	<0.05	0.3	<1	2	840	<1	26	<0.1	<1	3	0.2	<0.1	0.97	8.5	<5
Phillips DS	20/03/11	9:50	14000	3	<50	<0.05	0.3	12	12	19100	11	367	<0.1	<1	30	1	<0.1	0.77	28.8	36
Phillips DS	2/04/11	9:30	2630	1	70	<0.05	0.2	6	5	4380	3	319	<0.1	1	14	1.5	0.3	1.09	21.2	13
Phillips DS	9/05/11	11:30	55600	8	60	<0.05	<0.2	45	62	76100	61	1450	<0.1	<1	110	1.2	<0.1	2.36	60	127
Phillips DS	11/06/11	19:50	<50	4170	<1	0.3	<0.05	2	23	<50	33	17	<0.1	42	1010	5.4	16.2	<0.1	1.59	10
Phillips DS	16/01/12	10:45	42000	6	100	0.2	66	27	36	56000	36	860	<0.05	1	64	0.4	<0.1	1.7	86	74
Phillips DS	22/01/12	9:45	35000	8	96	0.1	51	26	31	55000	36	1100	0.16	2	55	0.7	<0.1	2	77	61
Phillips DS	29/01/12	6:30	15000	4	57	<0.1	21	8	11	21000	14	260	<0.05	<1	20	0.5	0.5	0.6	32	30
Phillips DS	13/03/12		42000	6	100	0.2	66	27	36	56000	36	860	<0.05	1	64	0.4	<0.1	1.7	86	74



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Phillips DS	19/03/12	10:00	35000	8	96	0.1	51	26	31	55000	36	1100	0.16	2	55	0.7	<0.1	2	77	61
Phillips US	28/09/10	9:35	77400	2	60	<0.05	1	83	82	94300	30	2350	<0.1	<1	225	1.2	<0.1	1.88	102	120
Phillips US	5/10/10	9:48	140	2	50	<0.05	0.2	<1	8	190	<1	381	<0.1	1	<1	0.3	<0.1	0.81	6.5	6
Phillips US	12/10/10	12:42	1120	<1	<50	<0.05	0.7	3	5	620	3	108	<0.1	<1	5	0.4	<0.1	0.7	22	6
Phillips US	19/10/10	7:55	2210	2	70	<0.05	0.3	<1	3	2530	2	19	<1	<1	4	0.4	<0.1	0.81	10.7	<5
Phillips US	19/11/10	11:24	18500	2	60	<0.05	1	14	16	22800	6	409	<0.1	<1	44	0.4	<0.1	0.53	36.6	26
Phillips US	25/11/10	12:05	380	<1	50	<0.05	0.7	<1	2	250	1	30	<0.1	<1	3	0.3	<0.1	0.65	7.8	<5
Phillips US	2/12/10		3390	1	60	<0.05	0.9	1	4	3570	3	42	<0.1	<1	6	0.4	<0.1	0.6	12.3	8
Phillips US	9/12/10	12:20	220	<1	<50	<0.05	0.7	<1	2	270	<1	27	<0.1	<1	3	0.3	<0.1	0.66	3.3	<5
Phillips US	16/12/10	9:25	860	1	50	<0.05	0.5	<1	2	1210	2	28	<0.1	<1	4	0.3	<0.1	0.76	4	30
Phillips US	23/12/10	11:10	580	<1	<50	<0.05	0.8	<1	1	880	1	33	<0.1	<1	5	0.3	<0.1	0.48	5.5	<5
Phillips US	30/12/10	9:10	2240	2	70	<0.05	0.8	2	3	2820	2	57	<0.1	<1	9	0.3	0.1	0.49	9.5	6
Phillips US	6/01/11	6:40	12400	2	90	<0.05	0.3	13	14	13800	11	414	<0.1	<1	25	0.5	0.3	1.5	43.6	28
Phillips US	13/01/11	1:00	500	1	60	<0.05	0.3	<1	1	650	<1	34	<0.1	<1	2	<0.2	<0.1	1.62	11.4	<5
Phillips US	20/01/11	12:06	2180	1	50	<0.05	<0.2	2	3	2520	<1	60	<0.1	<1	6	0.2	0.1	0.86	14.3	6
Phillips US	3/02/11	9:53	25300	4	<50	<0.05	0.5	21	22	33100	25	674	<0.1	<1	50	0.5	<0.1	1.04	36	53
Phillips US	6/02/11	10:30	1860	3	<50	<0.05	0.5	6	5	5270	5	242	<0.1	<1	8	0.4	<0.1	0.61	16.3	15
Phillips US	10/02/11	12:55	270	1	<50	<0.05	0.2	<1	<1	410	<1	22	<0.1	<1	2	<0.2	<0.1	0.86	9	<5
Phillips US	20/03/11	5:45	16600	3	50	<0.05	<0.2	8	12	20900	15	263	<0.1	<1	20	0.3	<0.1	0.94	24.5	35
Phillips US	2/04/11	5:30	5580	2	<50	<0.05	0.4	12	11	6630	2	477	<0.1	<1	28	0.3	0.4	0.73	44.4	12
Phillips US	9/05/11	6:45	2E+05	20	500	<0.05	0.2	137	1050	2E+05	89	4330	<0.1	<10	383	0.4	<0.1	1	48.6	290
Phillips US	11/06/11		<50	8060	<1	0.2	<0.05	1	14	<50	29	13	<0.1	21	566	10.6	16.6	<0.1	0.71	4
Phillips US	16/01/12	14:00	20000	3	65	0.1	39	14	18	25000	13	440	<0.05	1	40	0.3	<0.1	1.1	47	34
Phillips US	22/01/12	12:10	60000	5	79	0.2	110	37	41	73000	29	1200	0.11	<1	130	0.5	0.1	1.5	120	79
Phillips US	29/01/12	4:30	11000	3	77	<0.1	15	6	8	15000	11	170	<0.05	3	16	1	0.6	0.7	25	26
Phillips US	13/03/12		20000	3	65	0.1	39	14	18	25000	13	440	<0.05	1	40	0.3	<0.1	1.1	47	34
Phillips US	19/03/12	8:30	60000	5	79	0.2	110	37	41	73000	29	1200	0.11	<1	130	0.5	0.1	1.5	120	79
Phillips US	15/07/12	12:15	16000	2	7	<0.1	38	54	16	26	590	16	<0.05		21000	<1	<1	0.7	44	<1
Phillips DS	15/07/12	13:45	21000	3	12	<0.1	57	61	23	46	820	24	<0.05		31000	<1	<1	1.1	60	<1
Hughes US	25/01/13	8:30	7700				6		13	9600								0.7		22



APPENDIX B- WATER QUALITY DATA

Site	Date	Time	Total Metals																	
			Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Hughes DS	25/01/13	12:45	7300				10		10	9900								0.6		22
Phillips US	25/01/13	9:45	9800				20		14	13000								<0.5		25
Phillips DS	25/01/13	15:15	17000				40		32	21000								0.5		42
OMC DS	19/02/13	14:35	1400	2	61	<0.1	2	2	4	1500	2	44	<0.05	25	2	4	<1	<0.5	3	66
OMC US	20/02/13	10:05	47	1	56	<0.1	<1	2	<1	2300	<1	190	<0.05	<1	<1	<1	<1	<0.5	1	2
Phillips US	20/02/13	11:15	18	<1	110	<0.1	<1	<1	<1	33	<1	30	<0.05	2	<1	<1	<1	1.1	2	3
Phillips US	2/03/13	11:45	22000				50		24	26000								0.7		100
Phillips DS	2/03/13	8:30	6400				11		8	11000								0.8		150
Hughes US	20/03/13	15:15	45	1	98	<0.1	<1	<1	<1	1200	<1	220	<0.05	<1	<1	<1	<1	<0.5	<1	2
Hughes DS	20/03/13	14:00	30	<1	250	<0.1	<1	<1	<1	12	<1	8	<0.05	23	<1	6	<1	4.4	1	1
Phillips US	20/03/13	16:00	45	<1	110	<0.1	<1	<1	<1	33	<1	29	<0.05	1	<1	<1	<1	0.8	3	3



APPENDIX C – SEDIMENT QUALITY DATA

Table 19 – Particle Size Distribution of Sediments Data (%)

System	REMP Site Name	Survey	Clays (<2um)	Silts (2um-60um)	Sands (0.060-2mm)	Gravel (>2mm)
HUGHES	Hughes Creek US	Feb-13	2	<1	87	11
		Jun-13	1	<1	99	<1
	Hughes Creek DS	Feb-13	6	2	91	1
		Jun-13	5	2	92	1
ONE MILE	One Mile Creek US	Jun-13	1	<1	99	<1
	One Mile Creek DS	Feb-13	5	3	92	<1
		Jun-13	9	17	74	<1
SPRING	Spring Creek US	Jun-13	1	1	98	<1
	Spring Creek DS	Feb-13	10	6	84	<1
		Jun-13	14	11	75	<1
PHILLIPS	Phillips Creek US	Feb-13	<1	2	91	7
		Jun-13	3	2	95	<1
	Phillips Creek DS	Feb-13	2	2	96	<1
		Jun-13	3	<1	96	1



APPENDIX C - SEDIMENT QUALITY DATA

Table 20 – Total Metals and Metalloids in Sediments (mg/kg)

	Abbreviation	Al	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	U	V	Zn
	Units:	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
One Mile Creek US	Feb-12	12700	2	25	0.05	10.3	2.9	14.7	6960	12.4	76.2	0.05	1	10.7	0.5	0.05	0.8	23	32.6
	Jun-13	790	2.2	<50	<0.1	1.8	1	1.1	4670	3.1	28	<0.1	0.2	0.9	<1	<0.1	<0.1	3	4
One Mile Creek DS	Feb-13	1300	1.6	<50	<0.1	5.7	2	2.4	4860	1.9	39	<0.1	0.2	3.5	<1	<0.1	0.1	12	6.6
	Jun-13	6040	6.9	<50	<0.1	12.4	6.7	12.3	19100	12	128	<0.1	1.1	14.9	2	<0.1	0.4	20	30.6
Phillips Creek US	Dec-11	1280	2.5	25	0.5	11	4	2.5	8910	2.5	102	0.05	1	8	2.5	1	0.05	12	11
	Feb-12	4310	1.8	25	0.05	20.7	4.9	5.1	8980	4.5	116	0.05	1	12.9	0.5	0.05	0.2	18	14.4
	Jun-12	1170	3.9	25	0.05	15.2	4.7	2	13000	2.9	150	0.05	0.2	7.8	0.5	0.05	0.05	14	7.7
	Feb-13	1410	1.5	<50	<0.1	14.7	3.4	2.2	8550	2.8	106	<0.1	0.2	7.5	<1	<0.1	<0.1	13	9.9
	Jun-13	1600	1.2	<50	<0.1	10.8	2.9	1.9	7490	2.5	108	<0.1	0.2	6.6	<1	<0.1	<0.1	9	8.2
Phillips Creek DS	Dec-11	1370	2.5	25	0.5	8	4	2.5	6680	2.5	194	0.05	1	8	2.5	1	0.05	10	9
	Feb-12	1450	1.5	25	0.05	10.7	4	2.9	5590	2.7	117	0.05	1	9.4	0.5	0.05	0.05	11	10.8
	Jun-12	2090	2.1	25	0.05	13.7	8.2	4.9	13900	5.5	336	0.05	0.2	14.5	0.5	0.05	0.1	16	16
	Feb-13	2340	2.1	<50	<0.1	11.6	5.9	3.5	9810	4.6	205	<0.1	0.2	12.2	<1	<0.1	<0.1	14	12.8
	Jun-13	2160	1.6	<50	<0.1	10.7	4.7	3	9420	2.5	132	<0.1	0.2	10.8	<1	<0.1	<0.1	10	10.7
Hughes Creek US	Feb-13	810	3.6	<50	<0.1	5.3	2.8	2.2	8850	6.7	54.4	<0.1	0.4	3	<1	<0.1	0.2	7	18
	Jun-13	560	1.2	<50	<0.1	2.3	0.9	0.9	2690	2.3	30.2	<0.1	0.1	1	<1	<0.1	<0.1	3	3.1
Hughes Creek DS	Dec-11	1180	2.5	25	0.5	12	3	2.5	13100	2.5	92	0.05	1	6	2.5	1	0.2	24	6
	Feb-12	3080	3.4	25	0.05	33.4	5.1	6.1	30900	3.1	149	0.05	1	12	0.5	0.05	0.5	63	14.8
	Feb-13	1300	2.4	<50	<0.1	16.1	4.2	3.8	18600	1.6	83.6	<0.1	0.2	7.6	<1	<0.1	0.3	35	9.2
	Jun-13	2240	3.4	<50	<0.1	19.1	7.8	5.6	26800	2.8	197	<0.1	0.4	11.1	<1	<0.1	0.3	44	15.5
Spring Creek US	Jun-13	720	1.3	<50	<0.1	2.9	0.8	1.1	3120	2.5	18.6	<0.1	0.1	1.1	<1	<0.1	<0.1	5	3
Spring Creek DS	Dec-11	2880	2.5	25	0.5	6	5	2.5	5570	6	129	0.05	1	5	2.5	1	0.1	12	7
	Feb-12	8610	0.9	25	0.05	14.5	6.3	7.7	7070	7.5	132	0.05	1	8.2	0.5	0.05	0.2	19	11
	Jun-12	1390	1.4	25	0.05	8.2	2.1	2	4730	4.7	39.7	0.05	0.2	2.5	0.5	0.05	0.05	11	4
	Feb-13	8030	1.5	<50	<0.1	15.8	7.4	6.6	9730	8.8	245	<0.1	0.3	10.1	<1	<0.1	0.2	20	16.1
	Jun-13	4130	2	<50	<0.1	11.2	4.9	5	7840	6.3	96.3	<0.1	0.3	6.7	<1	<0.1	0.2	16	10.8

APPENDIX D – COMMUNICATION ON MINE WATER RELEASE TO HUGHES CREEK

From: Gooley, Ross [mailto:Ross.Gooley@bmacoal.com]
Sent: Friday, 2 September 2011 08:48 AM
To: Nielsen Tenille
Cc: Van Soest, Jacqueline; Hammond, Mark; Johnston, Steve SN; Brown, Damien; Roe, Peter PA @ Brisbane; Theil, Clinton
Subject: FW: SRM Tailings Pipeline Rupture-EAMIN100845908-Completion of Remediation Works

Tennille,

Further to below notification, please be advised that flushing operations have been completed. Flushed water captured at the Hughes Creek Diversion Back Access Road Levee has been reticulated to the internal mine water storage system. Water quality monitoring of captured flush water is as follows;

- Samples collected 31/8/11 for full suite analysis as per Tables W2 & W3 of EA MIN100845908;
- As at 8:00 AM 2/9/11, a limited amount of water remains with pH 7.55 and Electrical Conductivity 855uS/cm.

It is therefore advised that works will commence today with regard to removal of the Hughes Creek Diversion Back Access Road Levee to enable normalised flows to be reinstated for Hughes Creek. Remaining water released (i.e. pH 7.55, Electrical 855 uS/cm) through removal of the levee will not move beyond the mine lease.

If there are any further matters for clarification, please do not hesitate to contact me.

Regards



Ross Gooley
Principal Environment, Saraji Mine, Metallurgical Coal
BHP Billiton Mitsubishi Alliance, Dysart, Qld, 4745, Australia
T: +61 7 4968 9806 Mobile: +61418992312 F: +61 7 4968 9760
E: Ross.Gooley@bmacoal.com W: <http://www.bhpbilliton.com/>
Please consider the environment before printing this email.

From: Gooley, Ross
Sent: Thursday, 11 August 2011 11:32 AM
To: Nielsen Tenille
Cc: Van Soest, Jacqueline; Hammond, Mark; Johnston, Steve SN; Brown, Damien; Roe, Peter PA @ Brisbane; Theil, Clinton
Subject: FW: SRM Tailings Pipeline Rupture-EAMIN100845908-Condition A10-110811

Tennille,





Following below notification, please find attached water quality monitoring data as per requirements of Condition A10 of EAMIN100845908 pertaining to low flow samples collected as per attached location map. Please note possible sampling contamination with regard to single value anomalies for Dissolved Copper, Selenium and C10-C36 Hydrocarbon fraction concerning low flow Hughes Creek Downstream samples collected as related to Table W3 (Release Contaminant Trigger Investigation Levels) of EAMIN100845908.

Laboratory results of analyses from biological sampling conducted at Hughes Creek Downstream on 1/7/11 by the Central Queensland University is to be uploaded into the ACARP-CWiMI Research Project – *Discharged Mine Water Impacts on Aquatic Ecosystems*. An initial findings report is expected by November 2011.

Tailings excavation from the invert of Hughes Creek Diversion has been completed. Removal of established tailings cells via the excavation process is near complete. Batter restoration works is in progress. Please refer to attached images with regard to invert clean out and batter restoration works completed immediately downstream of Ramp 4.2.2. Work is currently in progress with regard to logistics concerning internal clean water flush of affected bed sections of Hughes Creek Diversion. Flushed water is to be captured and reticulated to internal mine water storage system.

If there are any further matters for clarification, please do not hesitate to contact me.

Regards



Ross Gooley

Principal Environment, Saraji Mine, Metallurgical Coal

BHP Billiton Mitsubishi Alliance, Dysart, Qld, 4745, Australia

T: +61 7 4968 9806 Mobile: +61418992312 F: +61 7 4968 9760



E: Ross.Gooley@bmacoal.com W: <http://www.bhpbilliton.com/>
Please consider the environment before printing this email.

From: Gooley, Ross
Sent: Thursday, 14 July 2011 6:14 AM
To: Nielsen Tenille; Blades Rebecca
Cc: Van Soest, Jacqueline; Hammond, Mark; Collier, Richard RW; Johnston, Steve SN; Roe, Peter PA @ Brisbane; Brown, Damien
Subject: SRM Tailings Pipeline Rupture-EAMIN100845908-Condition A9-300611

Rebecca/Tenille,

As per Condition A8 of EAMIN100845908, verbal notification was provided on 30/6/11 that at approximately 14:30 pm a tailings pipeline was found to have leaked tailings and tailings water into Hughes Creek Diversion. Field inspections confirmed that tailings sediment did not traverse off lease.

Written advice is hence as follows with regard to requirements of Condition A9 of EAMIN100845908;

a. **Proposed actions to prevent a recurrence of the emergency or incident;**

- Installation of new dual tailings pipeline;
 - New pipe work to replace existing worn pipeline;
 - Above-ground sections of pipeline contained within trench;
 - Double skinned pipelines around Hughes and Barrett's Creek crossings
 - Overflow points of double skinning outside of high banks of creeks;
 - Buried at least 500mm below creek bed and covered with suitable material to prevent scour of pipeline.
- Improve current monitoring programme;
 - Installation of pressure and flow meter alarm system on pipeline to detect any changes in pressure/flow between start and end of pipeline, allowing for early detection of any spills;
 - Mobile camera relocation to applicable Ramps 2-3 discharge spigots;
 - Camera installation at Ramp 3 Decant;
 - Inspection sheet to be simplified to a shift only format that clearly identifies the required checks that need to occur throughout each shift;
 - Weekly form to be restructured to include only those environmental components which require a weekly check, such as dam wall integrity and chemical lines;
 - Improve monitoring and signoff of shift and weekly checks, with an investigation to be instigated if the shift and weekly checks are not completed as required.

- Environmental training
 - Saraji Mine Environmental Training Package: *Water Management* to be rolled out to all CPP operators;

b & c) Outcomes of actions taken at the time to prevent or minimise environmental harm & Proposed actions to respond to information about circumstances which result or may result in environmental harm.

- Coal Processing Plan (CPP) stopped immediately once pipeline breach identified. This action prevented further movement of tailings through the pipeline;
- Area inspected by SRM Environment Section and key management representatives to determine extent and effects of incident;
- DERM notified of incident;
- Saraji Mine Incident Management Team (IMT) formed, to respond to the incident and drive the start of remediation works;
- Water sampling at Hughes Creek Downstream and other sites with the affected reaches of Hughes Creek Diversion commenced;
- Excavation of existing pipeline in vicinity of leak to identify cause and repair pipeline;
- Bund constructed at Back Access Road at Hughes Creek Diversion to restrict further tailings-affected water running off site and to contain all tailings fines.
- New pipeline construction works accelerated to prevent future tailings releases.
- Continuation of water sampling at Hughes Creek Downstream monitoring site and back access road at Hughes Creek Diversion;
- Central Queensland University researchers on site to conduct water quality and macro-invertebrate checks at Hughes Creek Downstream;
- Excavation of tailings from affected area of Hughes Creek Diversion bed commenced;
- Assessment commenced with regard to internal clean water flush of affected bed sections of Hughes Creek Diversion. Flushed water is to be captured and reticulated to internal mine water storage system.
- Pre Strip Fleet monitoring camera moved into place at the location of the pipeline breach, so that the area could be viewed remotely at all times.

If you have any queries regarding the above incident, or any other matters, please do not hesitate to contact me.

Regards



Ross Gooley
Principal Environment, Saraji Mine, Metallurgical Coal
BHP Billiton Mitsubishi Alliance, Dysart, Qld, 4745, Australia
T: +61 7 4968 9806 Mobile: +61418992312 F: +61 7 4968 9760
E: Ross.Gooley@bmacoal.com W: <http://www.bhpbilliton.com/>

Appendix B

Hydrobiology REMP Annual Report



BHP Billiton Mitsubishi Alliance



2014/2015 Receiving Environment Monitoring Program Annual Report

Saraji Mine

February 2016

ABN	26 096 574 659
GST	The company is registered for GST
Head Office	27 / 43 Lang Parade Auchenflower QLD 4066
Registered Office	c/- de Blonk Smith and Young Accountants GPO 119 Brisbane, QLD 4001
Postal Address	PO Box 2151 Toowong QLD 4066
Phone	61 (07) 3721 0100
Fax	61 (07) 3721 0151
Email Contact	info@hydrobiology.biz
Website	http://www.hydrobiology.biz

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2014/2015 Receiving Environment Monitoring Program Annual Report

Saraji Mine

February 2016

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EXECUTIVE SUMMARY

This report describes the results from the Receiving Environment Monitoring Program (REMP) sampling conducted for Saraji mine (SRM) during the 2014/2015 monitoring period. In 2014/2015, the REMP included the following monitoring aspects:

- Surface water flow monitoring at Phillips Creek DS, Hughes Creek US, Hughes Creek DS, One Mile Creek US, One Mile Creek DS, Spring Creek US and Spring Creek DS;
- Four sites were visited by Central Queensland University located upstream (Phillips Creek US and Hughes Creek DS) and downstream (Phillips Creek DS and Hughes Creek US) of SRM. Due to dry conditions only the following could be assessed:
 - Water quality at Phillips Creek US (March 2015);
 - Sediment quality at all sites (March and June 2015);
 - Macroinvertebrates at Phillips Creek US (March 2015); and
 - No downstream sites for Phillips Creek or any of the sites for Hughes Creek could be assessed and, thus, the receiving environment could only be assessed for sediment quality.
- Due to rainfall and associated stream flows, water quality sampling occurred in September and December 2014, and January 2015 at a range of downstream sites. Further, December and January were undertaken as part of the EA requirements for the release of mine-affected waters. This provides some assessment for the REMP.

Flow monitoring indicated ephemeral flow patterns throughout the local catchment, with extended period of nil flow intersperse with flow events. Peak discharges in the local catchment occurred between December 2014 and late January 2015, though flow events were noted as early as September 2014. Where upstream and downstream gauging stations were located within a single watercourse (i.e. One Mile, Hughes and Spring Creeks) no changes in flow volumes or patterns were evident. Further, the release of mine-affected water in December 2014 and January 2015 was in accordance condition Table W4 of the EA.

Surface water monitoring undertaken during high flow conditions (September and December 2014, and January 2015), resulted in reduced water clarity (turbidity), and elevated nutrients (ammonia and oxidised nitrogen) and metal (total aluminium, chromium and iron) concentrations. Noted elevated levels were likely attributed to rainfall and associated runoff and mobilisation of sediments from the local upstream catchment. Aluminium and iron are highly soil sorbed and are regularly above recommended guidelines (i.e. recreation and aesthetic guidelines). Further, dissolved concentrations for these metals were below the aquatic ecosystem protection guidelines and thus considered to be of low risk to aquatic ecosystems.

In December 2015, electrical conductivity levels at Phillips Creek DS was comparatively higher than other upstream sites surveyed in the same month, with concentrations also considerably above the historical upstream and site specific 80th percentiles. In January 2015,

electrical conductivity again was higher at Phillips Creek DS than other upstream sites, though One Mile Creek DS also exhibited similar elevated levels. These elevated levels are likely attributed the release of mine affected waters into Phillips Creek during December 2014 and January 2015 and runoff from the SRM.

Monitoring of the Phillips Creek US site was undertaken in baseflow conditions, during March 2015, resulted in analyte concentrations above Environmental Value (EV) protection guidelines concerning water chemistry (electrical conductivity, sulphate, sodium and total hardness of water). This is not within the receiving environment and sampling conducted in May 2015 was from small drying pools, which can naturally experience elevated salinities (i.e. evaporation and subsequent concentration of salts). Assessment of water quality in the receiving environment could not be undertaken for release events, as the downstream sites were dry at the time of the REMP sampling.

Metal and metalloids concentrations in sediments are of “low risk” to aquatic ecosystems (i.e. concentrations below Low-Interim Sediment Quality Guidelines (ISQGs) and did not increase significantly (two fold) above background (upstream of the mine) levels). No obvious temporal trends in metal and metalloid concentrations were evident in this monitoring period.

For Phillips Creek US, all calculated macroinvertebrate health indices (taxa richness, PET taxa richness, % tolerant taxa and SIGNAL 2) suggested suitable water quality and habitat conditions when compared to 20th and 80th percentiles of EHP (2009a). Macroinvertebrate assemblages were also assessed using the AUSRIVAS predictive modelling approach. Model fitness was considered good for sampled habitats. Predictive modelling results indicated that Phillips Creek US consists of water and habitat of equivalent quality to the AUSRIVAS database expected reference condition. Additionally, results from this round of monitoring indicate an improvement in water quality and habitat, when compared to historical observed/expected (OE50) values. Macroinvertebrate assessment of the receiving environment could not be undertaken as the downstream sites were dry at the time of sampling.

2014/2015 Receiving Environment Monitoring Program Annual Report

Saraji Mine

February 2016

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1 INTRODUCTION

1.1 Background

BHP Billiton Mitsubishi Alliance (BMA) is required to implement a Receiving Environment Monitoring Program (REMP) at its Saraji mine (SRM) in accordance with its Environmental Authority (EA) EPML00862313 (here on in referred to as the EA). The EA states that a REMP must be developed to monitor, identify and describe any impacts to the environmental values, water quality and flows of the receiving environment arising from the authorised mining activity and that an annual report must be prepared that outlines the findings of the REMP.

The EA defines the SRM receiving environment as those waters of the Hughes, One Mile and Phillips Creeks, including connected or surrounding waterways five kilometres downstream of the release of mine-affected water.

1.2 Objective and Scope

This report addresses Condition C21 of the EA, which includes the reporting of all monitoring results and interpretations in accordance with Condition W19 and W20 of the EA. Specific items of these conditions are detailed in Appendix 1.

The REMP design was developed by Gauge (Industrial and Environmental), with monitoring in the July 2014 – May 2015 (2014/2015) cycle undertaken by Central Queensland University (CQU). This report presents the findings of the 2014/2015 (July 2014 – June 2015) monitoring.

1.3 Location and History

SRM is located in central Queensland, approximately 10 km north (southern boundary of the mine footprint) of Dysart and 250 km north-west of Rockhampton. The site topography comprises gently undulating country descending to alluvial plains.

The mine commenced production in 1974, while prior to mining the predominant land use was agriculture. SRM shares a portion of the local catchment with Peak Downs Mine to the north and regionally is located downstream of a number of other coal mines.

1.4 Watercourse description

The mine is traversed by a number of watercourses that drain from west to east into the Isaac River. The major watercourses within the receiving environment include the upper to middle reaches of Hughes Creek, One Mile and Phillips Creeks.

The local streams (on site and within the receiving environment) are ephemeral, with no permanent or semi-permanent waterholes. Flow initiates after significant rainfall and for limited periods each year. Monitoring sites are located at approximately 180 to 360 m Australian Height Datum (AHD). Substrates are dominated by coarse sand throughout the river and creek systems.

SRM is located within the Isaac River catchment, with all mine-affected water released into Isaac western upland tributaries (EHP, 2013). These catchments form part of the larger Fitzroy Basin.

1.5 Landuse

There are no areas of high ecological value (HEV) within the receiving environment as defined by EHP (2013). Identification of relevant HEVs is pertinent to this assessment; as such areas require further development of water quality guidelines.

The catchment areas upstream of the mine footprint are predominantly rural grazing land and natural bushland. Downstream of the SRM is dominated by rural grazing, while cropping is evident further downstream and south of the mine.

1.6 Groundwater

None of the creeks in the receiving environment have permanent groundwater base flow that contributes to surface flows.

1.7 Local Climate

The climate for the area is typical of the region with high daytime summer temperatures, mild winters and low to moderate humidity. Rainfall is highly variable and seasonal with most rainfall occurring during the warmer months from December to March.

1.8 Environmental Values

Environmental values (EVs) relevant for the receiving environment are detailed in Appendix 2. This provides context for the REMP analysis presented in this report (i.e. identification of relevant EVs and associated guideline comparisons).

2 REMP DESIGN

2.1 Monitoring Aspects

The REMP design was developed by Gauge (Industrial and Environmental) and development of this monitoring program was based on the Monitoring and Sampling Manual (EHP, 2009b) and the specific requirements of each aspect of the program, which included:

- Habitat;
- Stream flow;
- Water quality (surface water);
- Sediment quality; and
- Bio indicators (macroinvertebrates).

2.2 Site Selection

As defined by Gauge (2014), sites were selected to avoid spatially confounding factors. They were selected to best represent the sum of stream influences prior to, and after, the mining operation. Where appropriate, the sites were aligned with historical or regulatory monitoring sites for the purposes of correlation with previous data and EA conditions, and the use of existing infrastructure. Figure 2-1 displays historical and current sampling site locations.

Sampling was undertaken by CQU for the 2014/2015 monitoring cycle. Table 2-1 details current monitoring sites and parameters that were assessed.



Figure 2-1 Location of current and historical monitoring sites

Table 2-1 Current and historic REMP survey design, monitoring sites and assessed parameters

Site name	REMP	Easting	Northing	Parameters historically assessed	September 2014	December 2014 ¹	January 2015 ¹	March 2015	June 2015
Hughes Creek US	Hughes Creek 1500 metres upstream of RP2, 4470 metres upstream of RP3, 4300 metres upstream of RP 6, 300 metres upstream of RP9	630293	7524061	f, w, s, m	-	w	w	f, s	f, s
One Mile Creek US	One Mile Creek 1600 metres upstream of RP5, 4300 metres upstream of RP 7	631096	7516901	f, w, s, m	-		w	f	f
Phillips Creek US	Phillips Creek 5500 metres upstream of RP1, 10,000 metres upstream of RP 4	634518	7515056	w, s, m	-	w	w	w, s, m	s
Hughes Creek DS	Hughes Creek 5400 metres downstream of RP2, 1930 metres downstream of RP3, 2100 metres downstream of RP6, 6900 metres downstream of RP9	634346	7525530	f, w, s, m	-	w	w	f, s	f, s
One Mile Creek DS	One Mile Creek 4300 metres downstream of RP5, 1600 metres downstream of RP 7	632488	7517976	f, w, s, m	w	-	w	f	f
Phillips Creek DS	Phillips Creek 6900 metres downstream of RP1, 700 metres downstream of RP4	639027	7513729	f, w, s, m	-	w	w	f, s	f, s
Spring Creek US	Spring Creek, 380 m upstream of the mine footprint	634410	7514683	f, s, m	-	-	-	f	f
Spring Creek DS	Spring Creek, 910 km upstream of the mine	637571	7518563	f, w, s, m	-	-	-	f	f

1: Monitoring undertaken during release event

Note: reference to upstream indicates monitoring sites upstream of SRM while reference downstream indicates sites downstream of SRM

f: flow; w: water quality; s: sediment quality; m: macroinvertebrates

2.3 Temporal Considerations

The timing for each aspect of the REMP is summarised in Table 2-2.

Table 2-2 Temporal design of monitoring program

Aspect	Temporal Design (Gauge, 2014)	2014/2015 Implementation
Stream Flow	On-line monitoring providing continuous data. Electrical conductivity and the pH of surface waters are also recorded.	Stream flow data were available for Phillips Creek DS, Hughes Creek US, Hughes Creek DS, One Mile Creek US, One Mile Creek DS, Spring Creek US and Spring Creek DS.
Water Quality	The ephemeral streams in the study area required a quick response to obtain grab samples after rain events. The accessibility, safety and staffing available at short notice often dictated the sampling times and locations possible, particularly for ephemeral sites.	Grab sampling occurred during the late-wet (March 2015) and dry (June 2015) seasons. Due to catchment discharges, water quality sampling occurred in September and December 2014, and January 2015 (wet season). The December and January sampling efforts were undertaken as part of the EA requirements for the release of mine-affected waters.
Sediments	Sampling during different seasons.	Sediment sampling occurred during the late-wet (March 2015) and dry seasons (May 2015).
Bio-indicators	Macroinvertebrate sampling was generally performed according to the Queensland AUSRIVAS seasonal protocols (DNRM, 2001). DNRM (2001) indicates that sampling should be undertaken during the following periods: - Autumn (late-wet) – generally from May to July, though more importantly during recessional base flows or when flow has declined to a wadable level. In the Fitzroy Basin this is generally the pool phase where flow has stopped but standing waters remain, EHP (2009a); and - Spring (early-wet) – generally from October to December, though more importantly when flows have been established for at least four weeks. During an average year in the Isaac catchment, ephemeral creeks are likely to flow for shorter periods, generally 1 to 2 weeks.	Stream flow data provided by BMA indicated that peak discharges in the receiving environment commenced in December 2014 with recessional flows in late January 2015. As such, macroinvertebrate sampling in March 2015 represent an Autumn, late-wet sample, while sampling in June 2015 is not considered to meet the criteria of the AUSRIVAS Spring, early-wet sample, but rather represents a dry season sample.

3 METHODS

The methods presented below are a summary of Gauge (2014) and CQU (2012).

3.1 Habitat

Habitat characteristics were recorded using the Queensland AUSRIVAS field sheets for macroinvertebrates. Any notable site characteristics and features were recorded and accompanied by photographs. A brief site summary was compiled recording features including water depth/width, riparian coverage, substrate coverage, shading and habitat features.

3.2 Stream Flow

Stream flow has previously been monitored at six locations, as described in Table 2-1. Stream flow monitoring is conducted by measurement of stream flow height using pressure sensors and calculating discharge volumes using flow rating curves developed by Water Solutions Pty Ltd for each site.

3.3 Surface Water Quality

In accordance with the Queensland Monitoring and Sampling manual (EHP, 2009b), a single water sample was collected from each monitoring site. Samples were filtered (where required), then placed on ice and transported to ALS Environmental for laboratory analysis. Samples were assessed for:

- Physicochemical parameters (electric conductivity, pH, turbidity, dissolved oxygen total suspended solids);
- Alkalinity (hydroxide alkalinity, carbonate alkalinity, bicarbonate alkalinity, and total alkalinity);
- Cations (calcium, magnesium, potassium, sodium, total cations);
- Anions (chloride, sulphate, fluoride, total anions);
- Total hardness as CaCO_3 and ionic balance;
- Dissolved organic carbon;
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, reactive phosphorus and total phosphorus);
- Total and dissolved metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, gallium, iron, lead, manganese, mercury, molybdenum, nickel, selenium, uranium, vanadium, zinc); and
- Petroleum Hydrocarbons (C6-C9 and C10-C36).

Monitoring in September and December 2014, and January 2015 was undertaken by BMA, while the March 2015 and June 2015 survey events were carried out by CQU. Water Quality Assurance and Quality Control (QA/QC) sampling measures implemented in the 2014/2015 monitoring cycle are described in Appendix 3.

Water quality results were compared to guidelines of the following relevant environmental values:

- Aquatic ecosystem protection guidelines defined in EHP (2013), EHP (2009a) and ANZECC/ARMCANZ (2000). Where metal and metalloid guidelines were available these were compared to the dissolved fractions;
- Irrigation and general water uses (farm supply) guidelines defined in ANZECC/ARMCANZ (2000). The short-term trigger values (STVs) in irrigation water have been used as they represent the maximum concentration that can be tolerated for approximately 20 years. The general water use guidelines are only relevant for pH and total hardness, and are largely defined to protect farm infrastructure (pipes, sprayers, etc.). Where metal and metalloid guidelines were available these were compared to the recorded total concentrations;
- Aquaculture and human consumption guidelines defined in EHP (2013) and ANZECC/ARMCANZ (2000), respectively. The guidelines developed for the protection of tropical freshwater aquaculture have been used for this assessment. Where metal and metalloid guidelines were available these were compared to the recorded dissolved fractions;
- Recreational water quality guidelines (primary and secondary contact) defined in ANZECC/ARMCANZ (2000). Visual aesthetics guidelines relate to clarity and colour of water, which were not assessed by CQU. Where metal and metalloid guidelines were available these were compared to the recorded total concentrations; and
- The Water Quality Objectives (WQOs) defined by ANZECC/ ARMCANZ (2000) for drinking water supply in the vicinity of off-takes, including groundwater, before treatment. The Australian Drinking Water Guidelines defined by NHMRC/NRMMC (2011) were considered for use; however, they apply to waters post treatment or at the point of use (i.e. at the tap). Therefore, they were not considered appropriate for this assessment.

3.4 Sediments

In accordance with ANZECC/ARMCANZ (2000) and AS5667.1 Guidance on Sampling of Bottom Sediments, a single sediment sample was collected from each monitoring site via the use of PVC corers and plastic shovels. Samples were then placed on ice and transported to ALS for laboratory analysis. Samples were assessed for:

- Moisture content;
- Particle size [clay (<2 µm), silt (2-60 µm), sand (0.06-2.00 mm), gravel (>2mm) cobbles (>6cm)]; and

- Total metals and metalloids (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, vanadium, zinc, mercury).

Sediment QA/QC sampling measures implemented in the 2014/2015 monitoring cycle are described in Appendix 3.

The ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQGs) were used to compare collected data with. The Low-ISQG values defined were used, as these are the most conservative. Where concentrations were above the Low-ISQG, they were further compared with the High-ISQG and background levels (those measured upstream of the mine). Where concentrations were above background levels, ANZECC/ARMCANZ (2000) recommended that the bioavailable fraction of analytes be compared to the Low-ISQG to identify the level of risk to aquatic ecosystems. The bioavailable fraction of analytes was not assessed; therefore, this final comparison could not be undertaken.

In the absence of guidelines, ANZECC/ARMCANZ (2000) also recommended adopting a trigger value of two times (or up to three times for disturbed systems) the background (upstream site) concentration.

3.5 Macroinvertebrates

Macroinvertebrate sampling was undertaken in accordance with AUSRIVAS protocols for Queensland streams (DNRM 2001). It was intended that triplicate samples would be collected from each sites. However, in some instances the sampling area was not sufficient for such replication. Therefore duplicates or even single samples were collected from each site.

Macroinvertebrate data were used to calculate a number of community descriptors (indices), including:

- Taxonomic richness;
- Total abundance;
- Plecoptera, Ephemeroptera and Trichoptera (PET) richness;
- SIGNAL 2; and
- % tolerant taxa.

The results of macroinvertebrate indices were compared against the relevant biological WQOs, which for all catchments in the Fitzroy Basin are based on the 20:80 percentile guideline values for the central coast region, as presented in the Queensland Water Quality Guidelines (QWQGs) (EHP, 2009a).

The macroinvertebrate and predictor variable (habitat) data were analysed using the AUSRIVAS macroinvertebrate predictive modelling program, version 3.2.0 (Ransom and

Blackman 2003). Based on the period of sampling and the habitat macroinvertebrates were collected, the Autumn pool/bed predictive model was used to provide an indication of water quality and habitat condition.

The model produces various outputs, of which the most valuable for interpreting is the OE50 (observed to expected ratio). It provides a measure of biological impairment at each site (Coysh *et al.* 2000). The OE50 scores are assigned to band sections provided by the model, ranging from Band X (better than AUSRIVAS database reference condition) to Band D (extremely impaired).

AUSRIVAS predictive modelling has been implemented as it is conditioned by the EA. At this stage there are limited data regarding ephemeral systems and how the model responds to natural degradation (i.e. when flow stops and the watercourse naturally begins to dry) (Sheldon and Leigh, n.d). It has been acknowledged that the model requires further testing and development in ephemeral streams (Sheldon and Leigh, n.d).

As samples were only collected from an individual site, no statistical analyses were undertaken.

4 RESULTS

4.1 Habitat

Phillips Creek US

Phillips Creek US is approximately 5.5 km upstream of a release point. It is described in the REMP (Gauge, 2014) as a 'background' monitoring site, and it was acknowledged that it is influenced by surrounding and upstream land uses and disturbance (e.g. agriculture, coal mining). The following habitat observations were made by CQU in March 2015:

- Mean depth of water, 0.2 m (Figure 4-1);
- 30% canopy cover;
- Riparian vegetation comprised largely of grasses (50% cover), followed by with trees (>10m high) (40% cover);
- Bed substrate dominated by sands (95%) with smaller amounts of silts/clays (5%);
- Slight amounts of bank overhanging and trailing bank vegetation; and
- 100 m survey reach comprised solely of sandy pool habitat (100%).

Habitat characteristics are largely assessed to help explain identified macroinvertebrate communities and to a lesser extent water and sediment quality. Due to dry conditions, macroinvertebrates were not sampled from Phillips Creek US in June 2015 (Figure 4-1)

Phillips Creek DS

Due to dry conditions, habitat characteristics were not assessed at Phillips Creek DS during either seasonal survey (Figure 4-2).

Hughes Creek US

Due to dry conditions, macroinvertebrates were not sampled from Hughes Creek US during either seasonal survey (Figure 4-3).

Hughes Creek DS

Due to dry conditions, macroinvertebrates were not sampled from Hughes Creek DS during either seasonal (Figure 4-4).



View Upstream – March 2015



View Downstream - March 2015



View Upstream – June 2015



View Downstream - June 2015

Figure 4-1 Photographs of Philips Creek US during March and June 2015



View Upstream – March 2015



View Downstream - March 2015



View Upstream – June 2015



View Downstream - June 2015

Figure 4-2 Photographs of Phillips Creek DS during March and June 2015



View Upstream – March 2015



View Downstream - March 2015



View Upstream – June 2015



View Downstream - June 2015

Figure 4-3 **Photographs of Hughes Creek US during March and June 2015**



View Upstream – March 2015



View Downstream - March 2015



View Upstream – June 2015



View Downstream - June 2015

Figure 4-4 **Photographs of Hughes Creek DS during March and June 2015**

4.2 Stream Flow

Stream flow is largely monitored to ensure that the release of mine-affected water into the receiving environment is in accordance with Table W4 of the EA. This stipulates the minimum flow rate (>0.1 cumecs during November to March and >1 cumecs during April to October) requirements prior to discharge of mine-affected waters.

Flow within the receiving environment was of an ephemeral nature throughout the 2014/2015 monitoring period, with extended periods of nil flow interspersed with flow events largely between December 2014 and February 2015. Earlier events were also recorded in September and August 2014. Peak flows across the local catchment occurred in December 2014. Three authorised releases occurred between December 2014 to January 2015, including:

- The release of 32 ML of mine-affected waters on 13th December 2014 from release point 4 (Philips Creek);
- The release of 59 ML of mine-affected waters over two days commencing on the 22nd January 2015 from release point 4 (Phillips Creek); and
- The release of 39 ML of mine-affected waters over two days, commencing on the 29th January 2015 from release point 4 (Phillips Creek).

Review of Figure 4-5 and Figure 4-6 indicated that the daily flow rate within the local catchment during all three release events was greater than the conditioned flow rate (≥ 0.1 cumecs). Review of figure x, indicates considerable differences in flow patterns between Spring Creek US and Spring Creek DS. Greater frequency of flows and flow volumes at Spring Creek DS are likely attributed to the additional tributaries that drain into Spring Creek prior to the gauging sites.

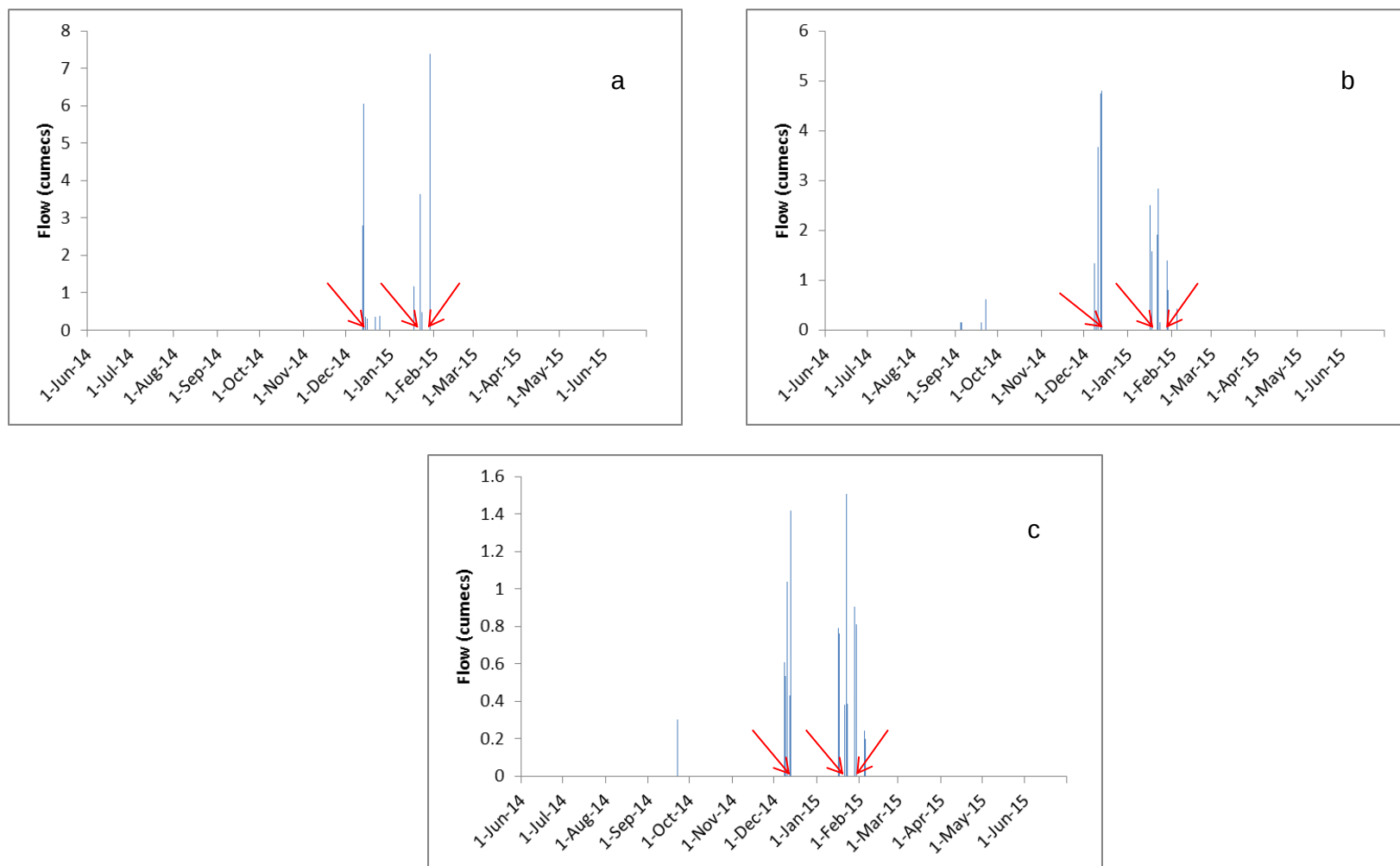


Figure 4-5 Surface flows (cumecks) recorded at Phillips Creek DS (a) Hughes Creek US (b) Hughes Creek DS (c). Arrows indicate time of release of mine-affected waters.

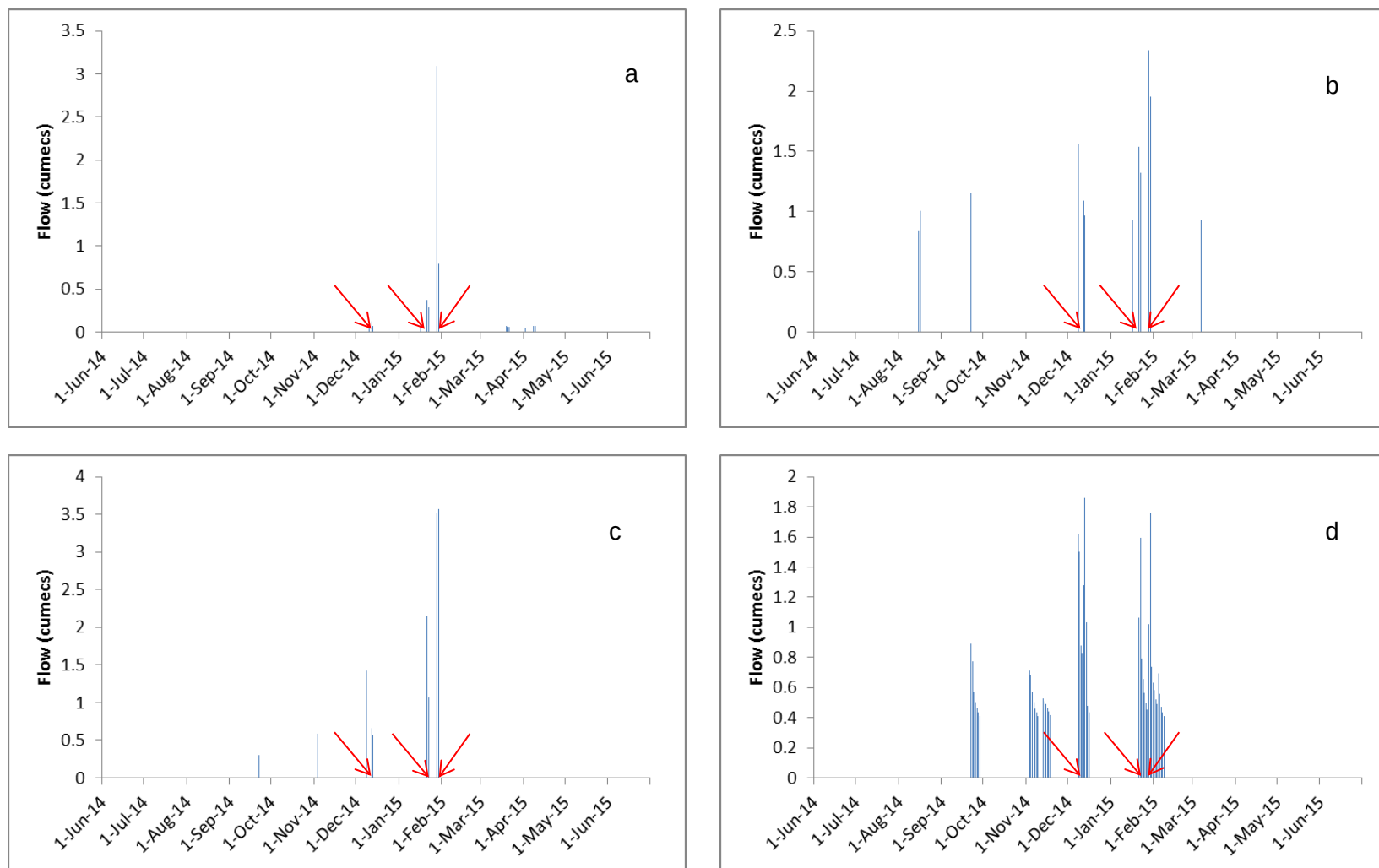


Figure 4-6 Surface flows (cumecks) recorded at One Mile Creek US (a), One Mile Creek DS (b), Spring Creek US (c), Spring Creek DS (d)

4.3 Surface Water Quality

Table 4-1 presents EV guideline comparisons to water quality results for the 2014/2015 monitoring period, while water quality results are presented in Table 4-2. Where analyte concentrations were above defined EV protection guidelines, these have been highlighted. It is noted that for water quality only one upstream site, Phillips Creek US, was sampled due to dry conditions at the time of sampling. Therefore, an assessment of the receiving environment was only possible for samples during high flow conditions.

Monitoring undertaken during high flow conditions (September and December 2014, and January 2015), resulted in reduced water clarity (turbidity) across all monitored sites, though turbid waters are common during high flow conditions in ephemeral systems of the Isaac River catchment. Some other parameters were elevated based on different environmental values and are further summarised and discussed below.

In December 2014, during the release monitoring, electrical conductivity levels at Phillips Creek DS were higher than Hughes Creek DS which was monitored in the same month. Electric conductivity (934 $\mu\text{S}/\text{cm}$) was also above the historical Phillips Creek upstream 80th percentile (690 $\mu\text{S}/\text{cm}$) and the aquatic ecosystem protection guideline (250 $\mu\text{S}/\text{cm}$). Further, in January 2015, electrical conductivity was considered high at Phillips Creek DS (1250 to 3250 $\mu\text{S}/\text{cm}$), and One Mile Creek DS (1200 $\mu\text{S}/\text{cm}$). Noted elevations at Phillips Creek (both December 2014 and January 2015) coincide with the release of mine-affected waters, and are considered the likely cause of noted elevations. As no releases occurred into One Mile Creek, noted elevations in conductivity are likely attributed to runoff from the SRM, particularly as the historical One Mile Creek upstream 80th percentile is much lower (235 $\mu\text{S}/\text{cm}$). The EA compliance level for conductivity at both Phillips Creek (10,000 $\mu\text{S}/\text{cm}$) and One Mile Creek (6000 $\mu\text{S}/\text{cm}$) for this period however was not exceeded. Noted elevations were generally below the electrical conductivity limit (2,500 $\mu\text{S}/\text{cm}$) identified by Prasad *et al.* (2012). This limit is said to provide protection to 95% (acceptable for slightly to moderately disturbed ecosystems) of aquatic species in the Fitzroy Basin, though it is noted that this does not consider potential differences in the ionic composition of natural waters and mine waters and potential variable response to differences in ionic composition of the biota.

Monitoring of the Phillips Creek US site during March 2015 were undertaken in baseflow conditions. Results showed elevated concentrations in electrical conductivity, sulphate, sodium and total hardness of water. This site is located upstream of the mine and sampling conducted in March 2015 was from small drying pools, which naturally experience elevated salinities (i.e. evaporation and subsequent concentration of salts). Assessment of water quality in the receiving environment based on the seasonal REMP sites could not be undertaken as the downstream sites were dry at the time of sampling.

Table 4-2 indicates that no dissolved fractions of analytes were higher than their recorded total concentrations. Selenium detection limits are above the aquatic ecosystem protection guideline, as such cannot be compared to the defined guideline.

Table 4-1 Environmental values of the Isaac Western Upland Tributaries and associated analyte concentrations above defined EV protection guidelines

Environmental value		September 2014 high flow conditions		December 2014 high flow conditions – release monitoring			January 2015 high flow conditions – release monitoring			March 2015 baseflow conditions	June 2015 (baseflow conditions)
		One Mile Creek DS 22/09/2014	One Mile Creek DS 23/09/2014	Hughes Creek DS 10/12/2014	Phillips Creek DS 13/12/2014	Phillips Creek DS 23/1/2014	Phillips Creek DS 29/01/2015	One Mile Creek DS 29/01/2015	Hughes Creek DS 29/01/2015 ^b	Phillips Creek US 16/03/2015	Phillips Creek US
Aquatic ecosystems		turbidity	turbidity	turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity, TSS, NH ₄ , oxidised N	turbidity	EC, SO ₄ , dissolved Cu	dry
Irrigation		-	-	total Al	-	-	-	-	-	total hardness (CaCO ₃)	
Livestock watering		-	-	total Al	-	-	-	-	-	-	
Farm supply		-	-	-	-	-	-	-	-	-	
Aquaculture		-	-	-	-	-	-	-	-	total hardness (CaCO ₃), dissolved Mn	
Human consumption		-	-	-	-	-	-	-	-	-	
Recreation and aesthetics	 (primary recreation)  (secondary recreation)  (visual recreation)	-	-	total Al, total Cr, total Fe	-	-	-	NH ₄	-	total hardness (CaCO ₃)	
Drinking water		EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, turbidity	EC, Na	

Table 4-2 2014/2015 water quality results. Shaded values indicate analyte concentrations above defined EV protection guideline.

Parameter/ analyte	Units	Aquatic Ecosystem protection guideline	Recreational protection guideline	ANZECC trigger values - STV in irrigation water and general uses	ANZECC trigger values- in livestock drinking water	ANZECC trigger values for tropical aquaculture and human consumption	Drinking Water protection guideline	September 2014 (high flow conditions)		December 2014 (high flow conditions)		January 2015 (high flow conditions)				March 2015 (baseflow conditions)
								One Mile Creek DS 22/09/2014	One Mile Creek DS 23/09/2014	Hughes Creek DS 10/12/2014	Phillips Creek DS 13/12/2014	Phillips Creek DS 23/1/2015	Phillips Creek DS 29/01/2015	One Mile Creek DS 29/01/2015	Hughes Creek DS 29/01/2015 ⁿ	Phillips Creek US 16/03/2015
electrical conductivity	µS/cm	<720 ^a <250 ^a	-	-	<7460g	-	400	448	372	470	1250	3250	934	1200	417 ⁿ 401	1900 ^m 1962
pH	pH units	6.5-8.5	6.5-8.5	6.0-9.0 ^k	-	6.8-9.5	6.5-8.5	6.93	7	7.89	8	8.14	8.05	7.72	7.69 ⁿ 7.65	8.08 ^m 7.69
dissolved oxygen	mg/L	-	-	-	-	>4	-	8.4	7.3	5.2	7.7	4.7	8.3	7.9	9.0 8.8	8.89
Turbidity	NTU	<50	-	-	-	-	<500 (level 1) <1000 (level 2)	8080	1980	21200	7520	713	3830	2200	864 858	7.6
Total suspended solids	mg/L	<55	-	-	-	-	-	-	-	-	-	-	-	1370	-	24
Major anions and cations																
Fluoride	mg/L	-	-	2	2	-	-	-	-	-	-	-	-	0.4	-	0.2
Chloride	mg/L	-	400	-	-	-	-	-	-	-	-	-	-	-	-	357
Sulphate as SO ₄	mg/L	25	400	-	-	-	250	-	-	-	-	-	-	-	-	152
Total anions	meq/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.3
Calcium	mg/L	-	-	-	-	10-160	-	-	-	-	-	-	-	-	-	69
Magnesium	mg/L	-	-	-	-	10-160	-	-	-	-	-	-	-	-	-	98
Sodium	mg/L	-	300	-	-	-	180 ^j	-	-	-	-	-	-	-	-	198
Potassium	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Total cations	meq/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.3
Ionic balance	(%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
Total hardness as CaCO ₃	mg/L	-	500	60-350 ^k	-	20-450	-	-	-	-	-	-	-	-	-	576
Alkalinity																
Bicarbonate alkalinity	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	353
carbonate alkalinity	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
Hydroxide alkalinity	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1
Total alkalinity	mg/L	-	-	-	-	20-400	-	-	-	-	-	-	-	-	-	353
Nutrients																
Ammonia	mg/L	<0.02	0.01	-	-	1	-	-	-	-	-	-	-	0.06	-	0.006
Nitrate	mg/L	<0.06	10	-	-	1-100	-	-	-	-	-	-	-	-	-	<0.002
Nitrite	mg/L	<0.06	1	-	-	<0.1	-	-	-	-	-	-	-	-	-	<0.002

Parameter/ analyte	Units	Aquatic Ecosystem protection guideline	Recreational protection guideline	ANZECC trigger values - STV in irrigation water and general uses	ANZECC trigger values- in livestock drinking water	ANZECC trigger values for tropical aquaculture and human consumption	Drinking Water protection guideline	September 2014 (high flow conditions)		December 2014 (high flow conditions)		January 2015 (high flow conditions)				March 2015 (baseflow conditions)
								One Mile Creek DS 22/09/2014	One Mile Creek DS 23/09/2014	Hughes Creek DS 10/12/2014	Phillips Creek DS 13/12/2014	Phillips Creek DS 23/1/2015	Phillips Creek DS 29/01/2015	One Mile Creek DS 29/01/2015	Hughes Creek DS 29/01/2015 ⁿ	Phillips Creek US 16/03/2015
Nitrate + Nitrite	mg/L	<0.06	-	-	-	-	-	-	-	-	-	-	-	0.28	-	<0.002
Total kjeldahl nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.51
Total nitrogen	mg/L	<0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	0.51
Reactive phosphorous	mg/L	<0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	0.002
Total phosphorous	mg/L	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	0.026
Dissolved organic carbon	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Metals and metalloids																
Dissolved aluminium	mg/L	0.055 ^e	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	<0.01
Total aluminium	mg/L	-	0.2	20	5	-	-	-	-	52.4	-	-	-	-	-	0.16
Dissolved arsenic	mg/L	0.024	-	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.001
Total arsenic	mg/L	-	0.05	2	0.5 (up to 5 ^d)	-	-	-	-	-	-	-	-	-	-	<0.001
Dissolved boron	mg/L	0.37	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
Total boron	mg/L	-	1	-	5	-	-	-	-	-	-	-	-	-	-	0.09
Dissolved cadmium	mg/L	0.0002	-	-	-	<0.003	-	-	-	-	-	-	-	-	-	<0.0001
Total cadmium	mg/L	-	0.005	0.05	0.1	-	-	-	-	-	-	-	-	-	-	<0.0001
Dissolved chromium	mg/L	0.001	-	-	-	<0.01	-	-	-	<0.001	-	-	-	-	-	<0.001
Total chromium	mg/L	-	0.05	1	1	-	-	-	-	0.087	-	-	-	-	-	<0.001
Dissolved cobalt	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
Total cobalt	mg/L	-	-	0.1	1	-	-	-	-	-	-	-	-	-	-	<0.001
Dissolved copper	mg/L	0.0014	-	-	-	<0.006 ^h 1.0 ⁱ	-	-	-	<0.001	-	-	-	-	-	0.001
Total copper	mg/L	-	1	5	0.4 or 1 or 5 or 5 ⁱ	-	-	-	-	0.099	-	-	-	-	-	<0.001
Dissolved gallium	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
Total gallium	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
Dissolved iron	mg/L	-	-	-	-	<0.05	-	-	-	<0.05	-	-	-	-	-	<0.05
Total iron	mg/L	-	0.3	10	f	-	-	-	-	59.2	-	-	-	-	-	0.26
Dissolved lead	mg/L	0.0034	-	-	-	<0.03	-	-	-	-	-	-	-	-	-	<0.001
Total lead	mg/L	-	0.05	5	0.1	-	-	-	-	-	-	-	-	-	-	<0.001
Dissolved manganese	mg/L	1.9	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.127
Total manganese	mg/L	-	0.1	10	f	-	-	-	-	-	-	-	-	-	-	0.244
Dissolved mercury	mg/L	0.00006	-	-	-	<0.001	-	-	-	-	-	-	-	<0.0001	-	-
Total mercury	mg/L	-	-	0.002	0.002	-	-	-	-	-	-	-	-	<0.0001	-	-
Dissolved molybdenum	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.001
Total molybdenum	mg/L	-	-	0.05	0.15	-	-	-	-	-	-	-	-	-	-	<0.001
Dissolved nickel	mg/L	0.011	-	-	-	0.01 ^h , <0.04 ^c	-	-	-	-	-	-	-	-	-	0.003

Parameter/ analyte	Units	Aquatic Ecosystem protection guideline	Recreational protection guideline	ANZECC trigger values - STV in irrigation water and general uses	ANZECC trigger values- in livestock drinking water	ANZECC trigger values for tropical aquaculture and human consumption	Drinking Water protection guideline	September 2014 (high flow conditions)		December 2014 (high flow conditions)		January 2015 (high flow conditions)				March 2015 (baseflow conditions)
								One Mile Creek DS 22/09/2014	One Mile Creek DS 23/09/2014	Hughes Creek DS 10/12/2014	Phillips Creek DS 13/12/2014	Phillips Creek DS 23/11/2015	Phillips Creek DS 29/01/2015	One Mile Creek DS 29/01/2015	Hughes Creek DS 29/01/2015 ⁿ	Phillips Creek US 16/03/2015
Total nickel	mg/L	-	0.1	2	1	-	-	-	-	-	-	-	-	-	-	0.003
Dissolved selenium	mg/L	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01
Total selenium	mg/L	-	0.01	0.05	0.02	-	-	-	-	-	-	-	-	-	-	<0.01
Dissolved uranium	mg/L	-	-	-	-	-	-	-	-	<0.001	-	-	-	-	-	<0.001
Total uranium	mg/L	-	-	1	0.2	-	-	-	-	<0.005	-	-	-	-	-	0.001
Dissolved vanadium	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01
Total vanadium	mg/L	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	<0.01
Dissolved zinc	mg/L	0.008	-	-	-	1-2 ^c 5.0 ⁱ	-	-	-	<0.005	-	-	-	-	-	<0.005
Total zinc	mg/L	-	5	5	20	-	-	-	-	0.244	-	-	-	-	-	<0.005
Petroleum hydrocarbons																
C6-C9	µg/L	-	-	-	-	-	-	<20	<20	<20	<20	<20	<20	<20	<20	-
C10-C36 (sum)	µg/L	-	-	-	-	-	-	350	180	140	<100	<100	<100	<100	<100	-

a: based on sub-regional base (<720 µS/cm) and high (<250 µS/cm) flow conditions

b: 20th and 80th percentiles defined for the northern Fitzroy Basin

c: value defined for hard waters

d: could be tolerated if not provided as a food additive and natural levels in the diet are low.

e: value defined for waters with a pH >6.5

f: not sufficiently toxic

g: typical electrical conductivity limit as defined in NRW (2007)

h: value defined for soft waters

i: defined for sheep, cattle, pig and poultry, respectively

j: general guideline defined for sodium

k: value defined for general use waters (i.e. farm supply)

l: value defined for the protection of human consumers of aquatic foods.

m: laboratory measured electrical conductivity

n: physicochemical samples collected from Hughes Creek DS approximately 85 minutes apart

	Where multiple guidelines/trigger values/WQOs exist, value above all of those defined
	Where multiple guidelines/trigger value/WQOs exist, value above a combination of those defined
	Value only above recreational and aesthetic purposes EV protection guideline
	Value only above ANZECC/ARMCANZ aquaculture EV WQOs for freshwater tropical aquaculture
	Value only above drinking EV as defined in ANZECC/ARMCANZ

4.4 Sediment Quality

Sediment quality results are summarised in Table 4-3. Where recorded concentrations are above the Low-ISQG, these have been highlighted. The following notable observations were made:

- Moisture content increased where water and saturated sediments were present. Where sediments were notably dry, moisture content reflected these conditions;
- In-stream particle size was dominated by sands at all sites. This is typical of the Isaac River catchment. Further, sediment density remained similar between sites and seasons;
- Where available, all total metal and metalloid concentrations were below the Low-ISQG;
- Silver laboratory detection limits (2 mg/kg) were above the ANZECC/ARMCANZ (2000) Low-ISQG (1 mg/kg), and as such, results cannot be assessed against the Low-ISQG.
- For parameters which do not have defined guidelines, ANZECC/ARMCANZ (2000) recommended adopting a trigger value of two times (or up to three times for disturbed systems) the background (upstream site) concentration. The following analytes recorded two or more fold concentrations downstream of the SRM:
 - Total aluminium at Hughes Creek DS;
 - Total cobalt at Phillips Creek DS, March 2015 only;
 - Total cobalt at Hughes Creek DS;
 - Total iron at Hughes Creek DS;
 - Total manganese at Hughes and Phillips Creeks DS; and
 - Total vanadium at Hughes Creek DS.
- It should be noted that for the majority of analytes (aluminium, cobalt, iron and vanadium) which recorded greater than two-fold concentrations at Hughes Creek DS, background concentrations at Phillips Creek US were also high. Further, all analytes listed above recorded concentrations were below analyte historical downstream medians (aluminium, 1770 mg/kg; cobalt, 4.7 mg/kg; iron, 22,700 mg/kg; manganese, 121 mg/kg; vanadium 40 mg/kg); and
- No obvious temporal trends in metal and metalloid concentrations were evident, with similar (same order of magnitude) concentration recorded at each site in March and May 2015.

Table 4-3 Sediment quality results from in March and June 2015. Shaded values indicate analyte concentrations above defined EV protection guideline.

Parameter/ analyte	Unit	Aquatic ecosystem protection (Low-ISQG)	March 2015				June 2015			
			Phillips Creek US	Phillips Creek DS	Hughes Creel US	Hughes Creek DS	Phillips Creek US	Phillips Creek DS	Hughes Creel US	Hughes Creek DS
Moisture content	%	-	28.2	<1.0	3.3	14.4	1.1	4.8	<1.0	<1.0
Particle size										
Clay (<2 µm)	%	-	<1	5	1	14	1	<1	<1	3
Silt (2-60 µm)	%	-	<1	1	<1	1	2	3	1	2
Sand (0.06-2.00 mm)	%	-	100	80	96	73	83	91	96	88
Gravel (>2mm)	%	-	<1	14	3	12	14	6	3	7
Cobbles (>6cm)	%	-	<1	<1	<1	<1	<1	<1	<1	<1
Density	g/cm ³	-	2.65	2.64	2.62	2.66	2.63	2.66	2.61	2.61
Total metals and metalloids										
Aluminum	mg/kg	-	1210	1520	500	1500	1270	1330	500	1060
Arsenic	mg/kg	20	<5	<5	<5	<5	<5	<5	<5	<5
Boron	mg/kg	-	<50	<50	<50	<50	<50	<50	<50	<50
Cadmium	mg/kg	1.5	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	mg/kg	80	9	12	2	20	11	13	3	14
Cobalt	mg/kg	-	3	9	<2	4	3	4	<2	4
Copper	mg/kg	65	<5	<5	<5	<5	<5	<5	<5	<5
Iron	mg/kg	-	6020	11200	2650	21200	6670	9130	3030	13700
Lead	mg/kg	50	<5	<5	<5	<5	<5	<5	<5	<5
Manganese	mg/kg	-	76	272	20	112	78	108	33	80
Mercury	mg/kg	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum	mg/kg	-	<2	<2	<2	<2	<2	<2	<2	<2
Nickel	mg/kg	21	6	14	<2	8	8	9	<2	6
Selenium	mg/kg	-	<5	<5	<5	<5	<5	<5	<5	<5
Silver	mg/kg	1	<2	<2	<2	<2	<2	<2	<2	<2
Vanadium	mg/kg	-	9	13	<5	34	11	12	<5	26
Zinc	mg/kg	200	6	11	<5	10	8	11	<5	8

Value above the aquatic ecosystem protection guideline defined for the Queensland central coast region

4.5 Macroinvertebrates

Macroinvertebrate indices are summarised in Table 4-4, while Appendix 4 details the macroinvertebrate community assemblage and associated abundances of each site. All calculated indices at Phillips Creek US were in line with defined guidelines. Due to dry conditions, macroinvertebrates at the upstream site were not collected in March and May 2015 at Hughes Creek or Phillips Creek DS.

Table 4-4 Macroinvertebrate indices recorded during March and June 2015.

Indices	Aquatic ecosystem protection guidelines	March 2015				June 2015			
		Phillips Creek US	Phillips Creek DS	Hughes Creek US	Hughes Creek DS	Phillips Creek US	Phillips Creek DS	Hughes Creek US	Hughes Creek DS
Total abundance	-	1350	dry	dry	dry	dry	dry	dry	dry
Species richness	12-21	21	dry	dry	dry	dry	dry	dry	dry
PET richness	2-5	4	dry	dry	dry	dry	dry	dry	dry
SIGNAL 2	3.33-3.85	3.31	dry	dry	dry	dry	dry	dry	dry
% tolerant taxa	25-50%	50	dry	dry	dry	dry	dry	dry	dry
	Value above the aquatic ecosystem protection guideline defined for the Queensland central coast region								

A summary of the predictive AUSRIVAS modelling results for the autumn pool/bed predictive model, including historical results, is provided in Table 4-5. The following notable observations were made:

- Macroinvertebrate communities at Phillips Creek US indicated habitat and/or water quality that was equivalent to AUSRIVAS database reference condition; and
- March 2015 results were in the same band category as past years (June 2011 and February 2012). However, OE50 scores indicated a slight improvement in water quality and/or habitat condition in March 2015. Variability in flow between years and re-colonisation success from pools can result in high variable systems.

An inspection of the expected (according to AUSRIVAS modelling) but absent taxa in bed samples indicated that most taxa that had a high probability (>50%) of occurring at the site were recorded in March 2015. Those predicted (>50% probability of occurring) by AUSRIVAS to occur at the site but were absent in samples collected in March 2015, included: freshwater prawns (Palaemonidae); dragonfly larvae (Gomphidae); and mayfly larvae (Leptophlebiidae).

Table 4-5 Historical and current AUSRIVAS score (OE score) for the autumn pool/bed predictive model.

Site	Previous investigation (Month – Year) ^b				
	Jun-11	Dec-11	Feb-12	Jun 12	Mar 15
Phillips Creek US	0.9	0.41	0.98	0.45	1.19

a: average OE score from duplicate samples

b: Historical values are approximates (interpreted from graphs in previous REMP report (Gauge 2014)). Results from each sampling event have been processed through the Autumn (late-wet) AUSRIVAS model.

	Band X: more biologically diverse than the AUSRIVAS database reference site. Could be associated to mild organic enrichment
	Band A: AUSRIVAS database reference condition. Most/all of the expected families found
	Band B: significantly impaired. Fewer families than expected. Potential impact on water and/or habitat
	Band C: severely impaired. Many fewer families than expected. Substantial impact on water and/or habitat
	Band D: extremely impacted: few of the expected families remain. Extremely poor water and/or habitat quality

5 SUITABILITY OF CURRENT RECEIVING WATERS CONTAMINANT TRIGGER LEVELS FOR MANAGEMENT OF MINE WATER RELEASES

The development of local guidelines has been suggested as part of the EA and after the collection of sufficient reference data. ANZECC/ARMCANZ (2000) detailed a recommended approach to deriving site-specific trigger levels. This entails, at a minimum, the collection of monthly data over two years. The collected data are then used to calculate 20th (for stressors that cause problems at low levels such as dissolved oxygen, pH, etc.) and 80th (for stressors at high concentrations such as nutrients, BOD etc.) percentile values for each parameter.

Data collection for the SRM REMP is largely undertaken in the first quarter of each year. SRM operates in an area that includes a range of freshwater habitats that are highly seasonal. They generally experience long periods of no flow interspersed with short periods of high flow. Pools either completely dry out or have small pool habitat remaining. As such, it is not possible to collect monthly water quality data.

Standing waters of these pools are particularly important as refugia for aquatic organisms, even though pool water quality is generally poorer than that found in flowing streams. Organisms residing within these ecosystems generally have a lifecycle strategy adapted to the flood and drought cycles and will be resilient to naturally occurring variations in physicochemical stressors. Therefore, it is considered appropriate to derive trigger values on data collected from a small sampling window.

Gauge (2014) found that many parameter concentrations varied greatly between streams and, as such, an individual stream assessment approach was recommended (i.e. development stream specific guidelines). In-site variability for water quality is not known at this stage, though ideally, more than a single site (i.e. more than one upstream site in each creek) would be utilised to calculate local guidelines. ANZECC/ARMCANZ (2000) indicated that local guidelines should be developed based on reference condition data. The local and wider Isaac catchment is considerably altered by agriculture, so no such reference conditions are evident across the study area. As such, upstream site data have been used to develop local guidelines as they identify water quality that is not influenced by SRM activities.

Table 5-1 presents a summary of the comparison of 80th and 20th (where relevant) percentiles against EA receiving waters contaminant triggers. The current EA only details receiving water triggers for electrical conductivity, pH and sulphate. Dependant on the parameter, up to 117 data points have been collected, most of which were collected during flowing periods. Other upstream sites do not have the required number of data points, and as such, triggers have not been calculated for these sites.

Electrical conductivity and pH demonstrated percentiles (80th and where relevant 20th percentiles) were in line with EA compliance levels. The current compliance levels therefore provide scope for managing mine water releases.

Table 5-1 Summary of percentile results against EA receiving waters contaminate triggers. Ticks indicate percentiles are within range or below the EA compliance levels.

Parameter	Units	EA receiving water contaminant triggers	Phillips Creek	One Mile Creek	Hughes Creek
electrical conductivity	µs/cm	10,000¹ 6000²	✓	✓	✓
In-situ pH	pH unit	6.5-9.0	✓	✓	✓
Sulphate as SO ₄	mg/L	To be correlated with EC	✓	✓	✓

1: electrical conductivity EA compliance level stipulated for Phillips Creek

2: electrical conductivity EA compliance level stipulated for One Mile Creek and Hughes Creek

6 SUMMARY AND RECOMMENDATIONS

6.1 Summary

As conditioned by the EA, Table 6-1 compares assessed parameters downstream of the mine to upstream results to determine the suitability of current release contaminant limits to protect downstream environmental values. No changes in flow or sediment quality were noted downstream of the mine. Water quality was largely assessed in December and January at downstream sites during release events, with monitoring indicating elevated conductivity. Based on the limited monitoring and lack of upstream site data within this round of monitoring the suitability of current release contaminant levels to protect downstream environmental values cannot be assessed.

Table 6-1 Noted parameter changes downstream of the SRM

Parameter	Changes noted downstream of SRM	Comments
Habitat	-	Not assessed
Stream flow	Similar	Similar peak discharges and volumes
Water quality	Inconclusive	Minimal upstream data to assess against
Sediment	Similar	Metal and metalloid concentrations recorded similar concentrations upstream and downstream of the mine
Macroinvertebrates	-	Not sampled downstream of SRM

6.2 Recommendations

The following refinements/improvements to REMP program are recommended:

- Metal and metalloid analyses during release monitoring could be reduced to focus on those analytes defined in the EA;
- Minimal seasonal variation was noted in analyte concentration in sediments. Sampling could therefore be refined to just a single event each year; and
- Where possible, sampling should be timed in accordance with AUSRIVAS sampling protocol (DNRM, 2001) to ensure the collection of macroinvertebrates and improve the reliability of any conclusion made from predictive modelling efforts. Monitoring of rainfall and stream flow to identify the appropriate sampling window should generally begin at the start of October prior to the commencement of the wet seasons. The early-wet (spring) macroinvertebrate sample should be collected with the commencement of stream flow. The late-wet (autumn) sample should be collected once stream flow peaks have ceased and base flow has been limited to standing pools. If flow is limited through the wet season then identified grace periods for macroinvertebrates (and water) collection will need to be adjusted accordingly.

7 REFERENCES

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APPENDIX 1 EA CONDITIONS

Condition	Description
W19	Receiving Environment Monitoring Program The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorized mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine-affected water is being discharged from the site. For the purposes of the REMP, the receiving environment is the waters of the Hughes, One Mile, Spring and Phillips Creeks and connected waterways within five (5) kilometres downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorized mining activity that will potentially be directly affected by an authorized release of mine-affected water.
W20	The REMP must: • Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); • Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; • Include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in Table W6); • Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the Queensland Water Quality Guidelines 2006. This should include monitoring during periods of natural flow irrespective of mine or other discharges; • Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in Table 2 and 3; • Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.1 Guidance on Sampling of Bottom Sediments); • Include, where appropriate, monitoring of macroinvertebrates in accordance with the AUSRIVAS methodology; • Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; • Describe sampling and analysis methods and quality assurance and control; • Incorporate stream flow and hydrological information in the interpretations of water quality and biological data.
W21	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions W19 and W20 must be prepared annually and made available on request to the administering authority. This must include an assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.

APPENDIX 2 ENVIRONMENTAL VALUES

There are a range of environmental values (EVs) applicable to waterways in Queensland. These include the value of the waterways to aquatic ecosystems, primary industries, recreation and aesthetics, drinking water, industrial uses as well as cultural and spiritual values. Isaac Western Upland Tributaries (EHP, 2013) EVs pertain to SRM receiving environment and are listed in Table 7-1.

These are based on stakeholder consultations undertaken by the department and the Fitzroy Basin Association to identify EVs and water quality objectives (WQOs) in the Fitzroy Basin.

Table 7-1 Environmental values of the Isaac Western upland tributaries (EHP 2013).

Label	Environmental Value	Isaac Western upland tributaries EVs
	Aquatic ecosystem	✓
	Irrigation	✓
	Farm supply	✓
	Stock watering	✓
	Aquaculture	✓
	Human consumption	✓
	Primary recreation	✓
	Secondary recreation	✓
	Visual appreciation	✓
	Drinking water	✓
	Industrial	✓
	Cultural and spiritual values	✓

Industrial and cultural and spiritual values do not have any relevant measureable parameters so are not included in the analyses.

Aquatic Ecosystem Protection

Water Quality

Where available, local water quality guidelines take precedence over those defined at a state or national scale, which are more generic in nature (EHP, 2009a).

Guidelines most relevant to SRM include the water quality guidelines defined for the Upper Isaac catchment (EHP, 2013) and those stipulated under the schedules of the Queensland Water Quality Guidelines (QWQG) for the central coast region (EHP, 2009a). For parameters not specified (i.e. metals and metalloids) in EHP (2013) or EHP (2009a), the triggers published in the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (the national guidelines) (ANZECC/ARMCANZ 2000) for tropical Australia are also pertinent to SRM. Guidelines defined under the schedules of EHP (2013; 2009a) and ANZECC/ARMCANZ (2000) are those for slightly to moderately disturbed ecosystems.

Excluding electrical conductivity, all parameters defined locally for the Upper Isaac catchment are based on the QWQG central coast regional water quality guidelines. These provide water quality objectives for the larger central coast region. Electrical conductivity WQOs have been calculated from long term monitoring datasets within each catchment and thus provide a more contextual basis to compare with. As either stagnant or dry pools were present during the March and May 2015 surveys, electrical conductivity WQOs defined for baseflow conditions were considered appropriate for use. As creeks were discharging during the September and December 2014, and January 2015 monitoring events the high flow WQO for electrical conductivity was compared to data collected during these months.

Sediment Quality

ANZECC/ARMCANZ (2000) defines sediment quality guidelines to protect aquatic ecosystems, which are largely based on best available overseas data. As such they are considered to be interim sediment quality guidelines (ISQG).

For contaminants with no guideline value, ANZECC/ARMCANZ suggests using a value of two times the background concentration as a trigger for further investigation. For the purpose of this assessment downstream sites (downstream of SRM) were compared to upstream concentrations of the same creek.

Biological Indicators

EHP (2013) defines guidelines for a number of common macroinvertebrate indices which represent system health. These guidelines are also based on the EHP (2009a) calculated indices for the central coast regions. EHP (2009a) defines guidelines for a range of indices (taxa richness, PET taxa richness, SIGNAL 2 and % tolerant taxa) and habitat (edge and composite), which are relevant to SRM. Similar to WQOs, macroinvertebrate indices are defined for slightly to moderately disturbed ecosystems.

Human Use EV Protection

ANZECC/ARMCANZ (2000) defines WQOs to protect human use EVs, which comprise those EVs other than the aquatic ecosystem EV (e.g. recreation, drinking water, stock watering, farm supply, aquaculture and crop irrigation, etc.). Where more than one EV applies to a given water (for example aquatic ecosystem and recreational use), the adoption of the most stringent WQO for each water quality indicator will then protect all identified EVs. WQOs in this section (unless otherwise specified) are based on relevant national water quality guidelines defined in ANZECC/ARMCANZ (2000).

APPENDIX 3 QUALITY ASSURANCE AND QUALITY CONTROL

Stream flow

On-line monitoring of stream flow, electric conductivity and the pH of surface waters were also recorded. These data were not available and the closest regulatory monitoring flow station data were used instead.

Water Sampling

The following quality assurance and quality control (QA/QC) procedures were implemented:

- Powder-less nitrile gloves were used when collecting all water samples, and care was taken not to touch the inside of any sampling containers, or place open bottles/lids onto the ground or any potential contaminated or metallic surfaces;
- For parameters which required filtering, samples were collected in an HDPE bottle which was acid washed prior to the commencement of sampling. The HDPE bottle was rinsed three times with ambient site water prior to obtaining the sample;
- Filtering of water samples for dissolved metals and nutrients was conducted on-site. A fresh syringe and filter was used for each sample;
- Collected samples were stored within an esky and placed on ice, with delivery to the analytical laboratory within appropriate holding times (as specified by the laboratory); and
- The analytical procedures used by the laboratory for water quality analysis were in accordance with National Association of Testing Authorities (NATA), Australia accreditation.

No field quality control or replicate samples were collected during either survey. Therefore, the precision and repeatability of sampling methods or potential contamination of samples during either sampling and/or processing cannot be quantified.

Sediment Sampling

Specific QA/QC procedures implemented during sediment sampling included:

- Decontamination of sampling equipment prior to use at each site;
- Sediment corers or shovels were made of PVC and plastic, respectively;
- Samples were stored within an esky and placed on ice, with delivered to the laboratory within the appropriate holding times (as specified by the laboratory); and
- The analytical procedures used by the laboratory for sediment analysis were in accordance with NATA, Australia accreditation.

Macroinvertebrate Sampling

No sample residue was collected, so biases that may result during the invertebrate picking process could not be quantified. Further, no macroinvertebrate identification QA/QC measures (i.e. calculation of percent taxa error) were implemented so errors that may result from an individual taxonomist also cannot be quantified.

APPENDIX 4 BIO-INDICATOR DATA

Order/Family	Phillips Creek US
Hydra	4
Nematoda	5
Oligochaeta	43
Acarina	3
Cladocera	3
Ostracoda	69
Copepoda	145
Dytiscidae	4
Hydrophilidae	3
Hydraenidae	12
Hydrochidae	1
Culicidae	31
Ceratopogonidae	136
Tanypodinae	70
Chironominae	121
Baetidae	22
Caenidae	642
Corixidae	7
Libellulidae	11
Hydroptilidae	2
Leptoceridae	16

Appendix C

CQ University Australia
Trend Report

Saraji Mine Trend Report

2011-2016

BE WHAT **YOU** WANT TO BE



SUMMARY

- *How was monitoring undertaken consistent with the EA for each site?*

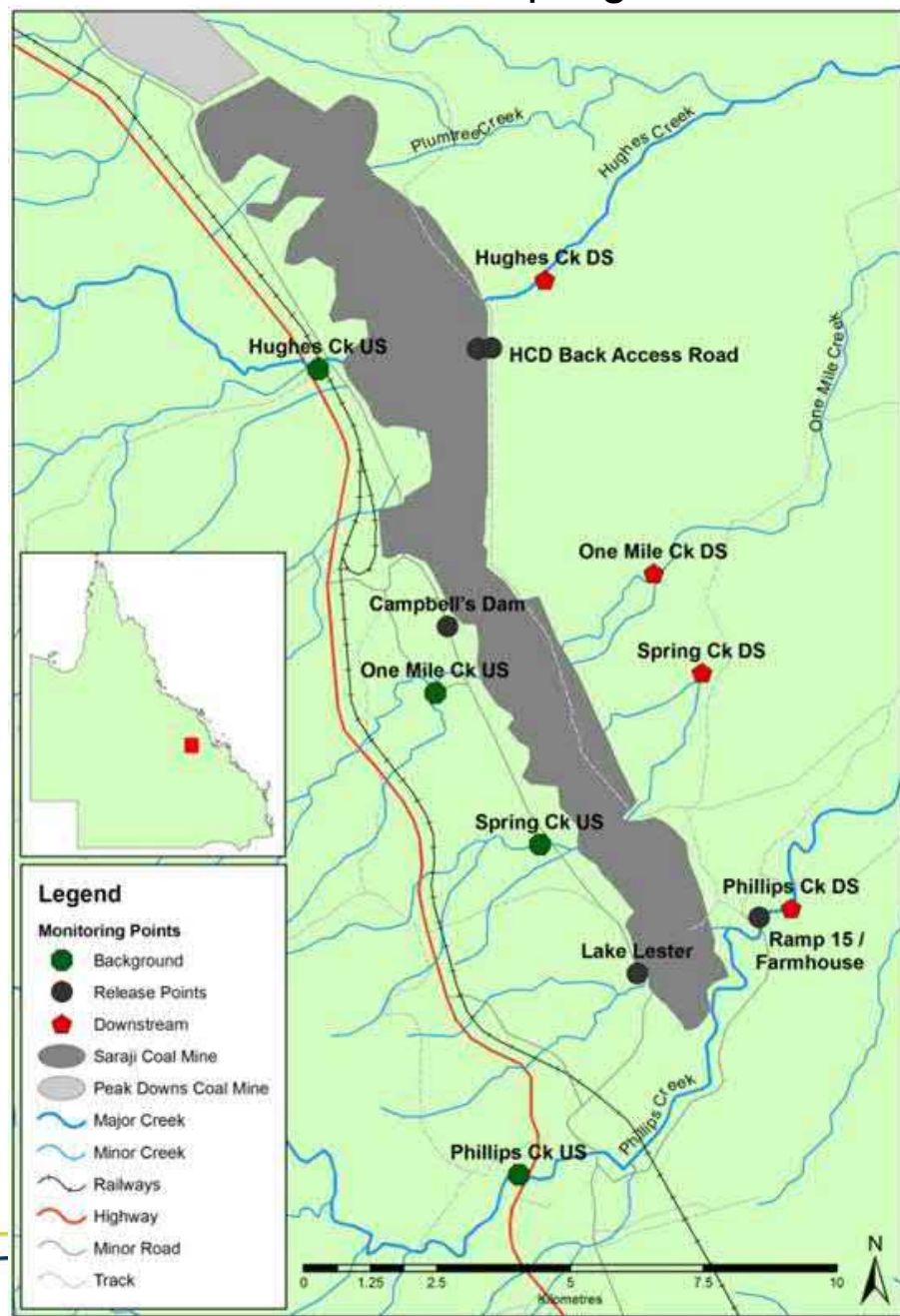
Monitoring occurred pre and post releases during the early and the late wet season of each year and utilised the monitoring sites listed in the Environmental Authority (EA) (Mining Lease) Non Code Compliant Level 1 Mining Project Permit Number: EPLM00862313 – Saraji Mine (effective 19 November 2015), Table W6 (receiving water upstream background sites and down stream monitoring points) and similar points in previous versions of that authority applicable at the time of sampling. It followed the recommendations outlined in the condition W21 of the EA for the implementation of monitoring in regard to development of the REMP by assessing condition of receiving waters by comparing to background water quality characteristics (upstream sites) and taking into account temporal variation in the water and sediment chemistry and macroinvertebrate communities. All water quality/chemical data were compared with limits outlined within the Environmental Authority (EA), as well as to the Upper Isaac River Water Quality Objectives and the ANZECC guidelines (2000). SRM site staff were responsible for the monitoring at times of release.

- *Overall statement on aquatic impacts – what is the impact of mine discharge on the ecology of streams?*

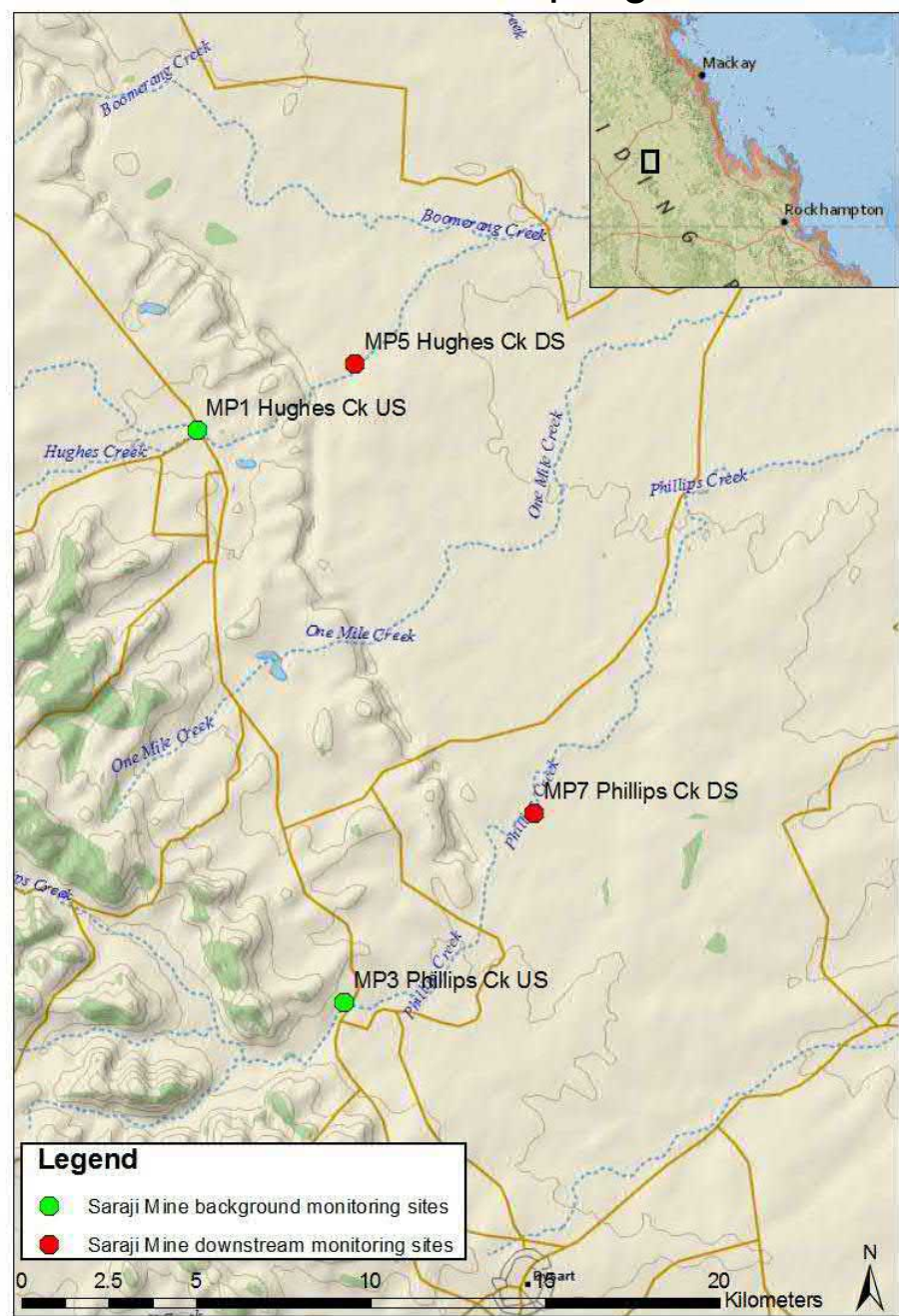
No adverse impacts of mine discharge on macroinvertebrate composition and indices were detected during the period 2011 – 2016.



2011-2013 Sampling Sites



2015-2016 Sampling Sites



- *What is the impact of saline discharge on macroinvertebrate communities at each mine site?*

No statistically significant change was identified in the macroinvertebrate communities at upstream and downstream locations within each stream system, nor for sampling times between different years (inter-annual or flood and drought year differences).

- *What other environmental factors influence the impact of discharge?*

Whilst NO impact of discharge was detected in this program, elements such as Dissolved Organic Carbon (DOC), sedimentation, water hardness, overarching flood and drought regimes and groundwater may influence the impacts of discharge.

- *At what scale (spatial and temporal) do impacted biotic communities recover from disturbance?*

No change was identified statistically in the macroinvertebrate community at upstream and downstream locations within each system hence an impact of discharge was not detected.

Large shifts in populations between years are common in the Fitzroy River system and are dependant upon the timing and extent of the wet season reset of processes. However, the actual point to which the population will reset can be different between years although normally similar following similar wet seasons. Temporal variation was shown between years in regard to macroinvertebrate community composition. This is likely to be related to seasonal successions in macroinvertebrates present and the influence of changes in hydrology between early and late wet seasons and between years rather than to disturbance caused by mine releases.

High abundance of the orders Ephemeroptera, Diptera and Coleoptera were recorded in 2012, high abundance of Diptera, Ephemeroptera and Microcrustacea were recorded during 2013 and 2015 and high abundance of Diptera and Microcrustacea recorded in 2016.

- *Suggest potential effective discharge criteria and/or release methods that minimises impact on ecological condition and better positions BMA in negotiating release criteria.*
- The EA should include the use of modified ANZECC Guidelines that take hardness into account. This is particularly important in flood years in the Fitzroy system when increased hardness (groundwater intrusion) is a major determinant of increased conductivity. Discharge criteria should incorporate the hardness of the release and receiving waters. The revised ANZECC guidelines should then be applied with respect to the EA.

- *Suggest actions moving forward in developing a long term monitoring programme that will better position BMA in negotiating release criteria.*
 - Dissolved organic carbon , alkalinity and water hardness should be incorporated to all monitoring programmes as precise speciation of metals, most applicable ANZECC Guidelines and their accompanying toxicity can be ascertained.
 - The construction of an overview of macroinvertebrate successional sequences between and within flood and drought years would aid in interpreting impacts of mine water in this highly variable system. (This has already been undertaken for algae in the lower Fitzroy River system and applicability of the scientifically published model to the remainder of the system will hopefully be tested in the coming years.)
 - There are a number of QA/QC practices that could be similar between sites so as to make certain all results are legally reportable. These include:
 1. Sending samples with signed security seals directly from site preferably prior to Thursday morning so as to enable laboratory delivery within the working week.
 2. Requiring contractor to deliver download of files from *insitu* monitoring prior to leaving site with required repeat of sampling where large variation in turbidity indicates the stirring of sediments and possible contamination of samples.
 3. Review Chain of Custody (COC) and Sample Receipt Notification (SRN) returned from laboratory or contractor to check samples received within holding time. Review of other QA/QC data upon arrival.
 4. Request repeat testing of total and dissolved metal results where the dissolved concentration far exceeds the total and is outside the possible limits of the test procedure.



Water and Sediment Chemistry: Key areas to note

- *There was no clear separation between upstream and downstream sites, early and late wet season sampling times and years.*
- MP8 Spring Creek Downstream continually recorded turbidity readings above the WQO during 2012 and 2013.
- *Dissolved Copper:* MP8 Spring Creek Downstream recorded concentrations of Copper above the ANZECC guideline (1.4 µg/L) during all sampling runs. However, once hardness of site waters was taken into consideration and the ANZECC guideline for dissolved Cu adjusted for hardness, only one result was above the adjusted ANZECC Guideline (MP8 Spring Creek Downstream (Dec 11) with soft water). However, the validity of MP8 Spring Creek Downstream samples from December 2011 is questionable as a result of the Limit of Reporting being ten times higher than normal. No sites in moderately hard, hard, very hard and extremely hard water exceeded the adjusted ANZECC guidelines for dissolved Cu in these categories.
- *Dissolved Uranium:* MP5 Hughes Creek Downstream and MP8 Spring Creek Downstream were shown to have concentrations of dissolved U above the EA Table W3 Release Contaminant Trigger Investigation Level on specific occasions between 2011 and 2013. MP1 Hughes Creek Upstream was dry and sampling was not possible on many occasions during this time period. In 2016, two upstream sites had elevated dissolved U concentrations. In 2016, MP1 Hughes Creek Upstream, MP5 Hughes Creek Downstream and MP3 Phillips Creek Upstream recorded dissolved U concentrations above the W3 Release Trigger. In terms of dissolved U concentration; MP5 Hughes Creek Downstream recorded the highest result during the early sampling run (Nov 2012).
- Total Fe, Cr, U and V in sediments were highest at Hughes Creek DS and showed a similar pattern over time.



METHODS

Time series plots of water and sediment data were constructed using Sigmaplot 13 (Systat Software).

The current trigger levels with respect to the Environmental Authority (Mining Lease) Non Code Compliant Level 1 Mining Project Permit Number: EPML00862313 - Saraji Coal Mine (effective 19 October 2015) in addition to ANZECC Guidelines and the Upper Isaac River Water Quality Objectives are shown on these graphs.

Where concentrations were <LOR, half of that value has been plotted

METHODS

The dataset from Saraji Mine monitoring sites was investigated using the following univariate and multivariate techniques:

- Time series line graphs (using Sigmaplot 13)
- Principal Components Analysis (PCA) (Primer 7)
- Hierarchical Agglomerative Clustering (Primer 7)
- Multi-Dimensional Scaling (MDS) (Primer 7)
- ANOSIM (Primer 7)
- SIMPER (Primer 7)
- BIO-ENV BEST analysis (Primer 7)

SUMMARY OF STATISTICAL ANALYSES

A Principal Components Analysis (PCA) of environmental data was undertaken in order to identify the trends (fingerprints) in the data and outliers requiring detailed investigation. The PCA was conducted on normalized water quality/chemistry data to determine any differences in water quality/chemistry between sites (Primer 7; Clarke and Gorley (2015)). A similar procedure was used for sediment results.

Water Results: Key trends in Data Summary

Two key trends were shown within the PCA in regards to water quality/chemistry. The first key trend is linked with total copper, turbidity, total Al, Fe, Ni and Cr and dissolved Cu and Mo concentrations and the second key trend is linked with Cl^- , Na^+ , dissolved B, total and dissolved U, and specific conductance (conductivity at 25 °C). There was no clear separation of site scores based on seasons, year and location.

PCA WATER DETAILS

WATER – PCA Results

- The first principal component (PC1) explained 21.2 % of the variation in the data and was highly positively correlated with total Cu, turbidity, dissolved Cu, total Al, Fe, Ni, Cr and dissolved Mo.
- The second principal component (PC2) explained 18.0 % of the variation in the data and was highly correlated with Cl^- , Na^+ , dissolved B, specific conductance (conductivity at 25 °C), dissolved U and total U.
- The third principal component (PC3) explained 10.9 % of the variation in the data and was highly positively correlated with total Mn, dissolved Mn, dissolved Co, Ca^{2+} and total Co and highly negatively correlated with pH and DO.
- MP8 SCD Jun 12 and MP5 HCD Dec 11 were separated from the cluster along the PC2 axis.

PCA SEDIMENT DETAILS

Sediment: Key trends in Data

No clear trend was shown between sites and sediment data, with no site showing complete separation from the cluster during all sampling runs.

SEDIMENTS – PCA Results

- The first principal component (PC1) explained 52.2 % of the variation in the data and was positively correlated with total Ni, Zn, Co, Fe, Cr, V, Cu, Mn, Al and Pb.
- The second principal component (PC2) explained 24.7 % of the variation in the data and was positively correlated with total Cr, Fe, V, Co and Mn; and negatively correlated with total Pb, Al, Cu, As and Zn.
- The third principal component (PC3) explained 9.8 % of the variation in the data and was positively correlated with total V, Fe, Cr and Cu; and negatively correlated with total Mn, Ni and Co.
- MP2 OMU Feb 12 and MP6 OMD Jun 13 were separated from the cluster along the negative PC2 axis.

METHODS FOR DATA ANALYSIS: MACROINVERTEBRATE COMPOSITION

- Composition data for macroinvertebrates were analysed using the Bray-Curtis similarity index (square-root transformed) and then visualized using multidimensional scaling (MDS) (Primer 7; Clarke and Gorley (2015)).
- Hierarchical agglomerative cluster analyses on the group average of the Bray-Curtis similarity results were also conducted to determine the level of similarity.
- ANOSIM analysis was used to compare differences in macroinvertebrate composition between variables (sites, location of sites (upstream and downstream), sampling run and over years) (Primer 7; Clarke and Gorley (2015)).
- One-way Simper analyses (Bray-Curtis similarity) – species contributions, were conducted to determine the changes in macroinvertebrates that are likely to be driving any statistical differences found.
- Bubble plots of key water quality variables were overlaid on top of the MDS plot to give an indication of which factors were important in determining any significant differences highlighted via ANOSIM analysis.
- Principal Component Analysis (PCA) was also conducted on normalized water quality data, followed by the BIO-ENV BEST procedure using Spearman correlations, to determine any relationships between water quality and macroinvertebrates (Primer 7; Clarke and Gorley (2015)).

SUMMARY

MACROINVERTEBRATE COMPOSITION

No clear impact of mining was shown in regards to macroinvertebrate composition with no statistically significant differences between sites, time of sampling (early and late wet season), location of sites (upstream and downstream) and years.

- ANOSIM – (one-way) showed no significant difference in macroinvertebrate composition between sampling years (2012-2016), time (early and late) and location (upstream and downstream) of sites.
- SIMPER analysis showed an average 35.55 % dissimilarity between early and late wet season sampling with Diptera and Microcrustacea being most abundant during both sampling times and Ephemeroptera more abundant during late wet season sampling.
- BEST analysis comparing water quality with macroinvertebrate composition suggested that CO_3^{2-} Alkalinity, dissolved Fe, dissolved Zn, total Co and total P were likely to be the main parameters linked to the separation of sites in the MDS. However, since there is no statistical difference (72.7 % corr.) between sites in composition their influence is likely to be low.
- BEST analysis comparing sediments with macroinvertebrate composition suggested that total Al and Fe in sediments provided the best matching of the biotic patterns identified in the MDS. However, since there is no statistical difference (24.6 % corr.) between sites in composition their influence is likely to be low.

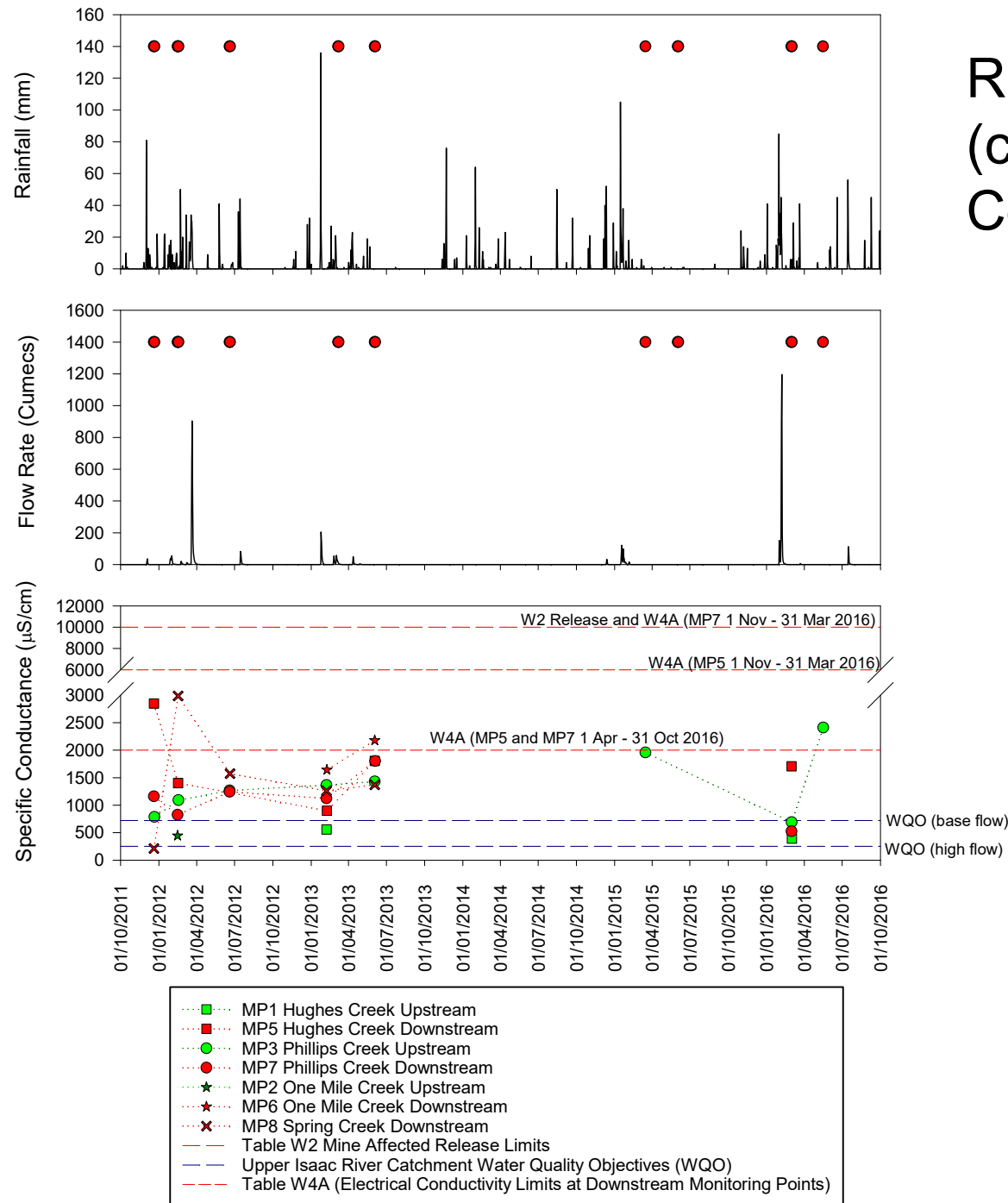


SRM Water Results

2011-2016

BE WHAT **YOU** WANT TO BE

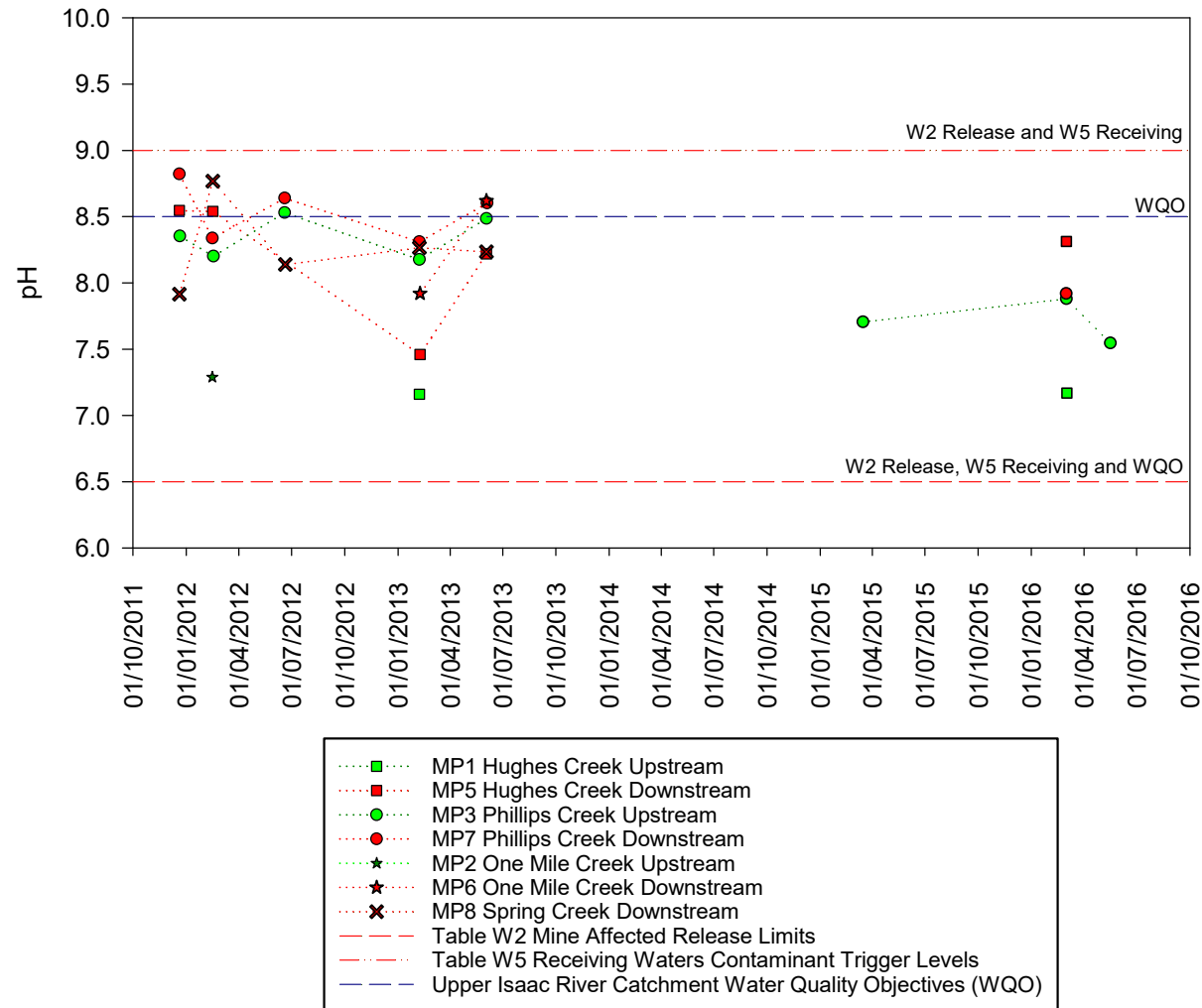




Rainfall (mm), Flow (cumecs) and Specific Conductance ($\mu\text{S}/\text{cm}$)

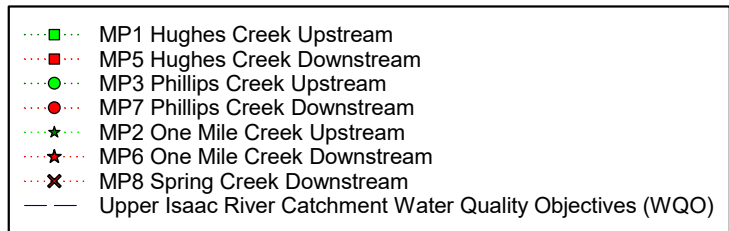
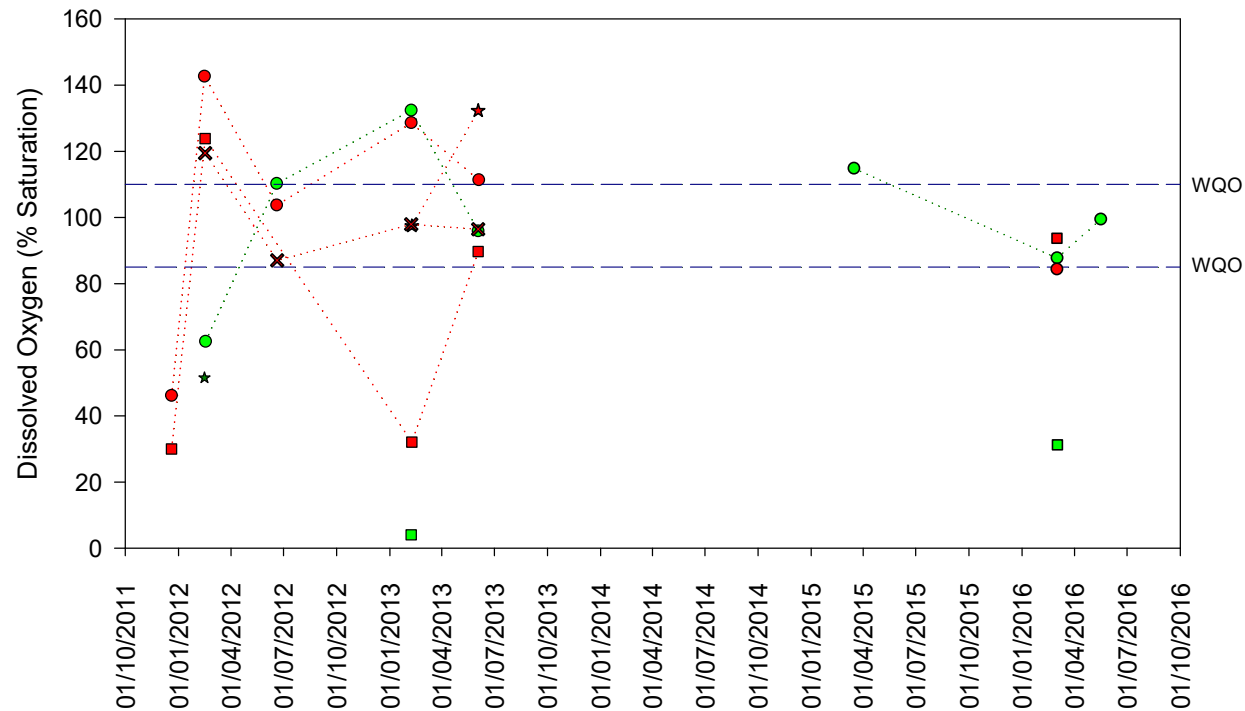
- Figure showing the rainfall and flow recorded at Deverill and specific conductance ($\mu\text{S}/\text{cm}$) recorded at Saraji Mine monitoring sites.
- Dots indicate when sampling occurred.

pH

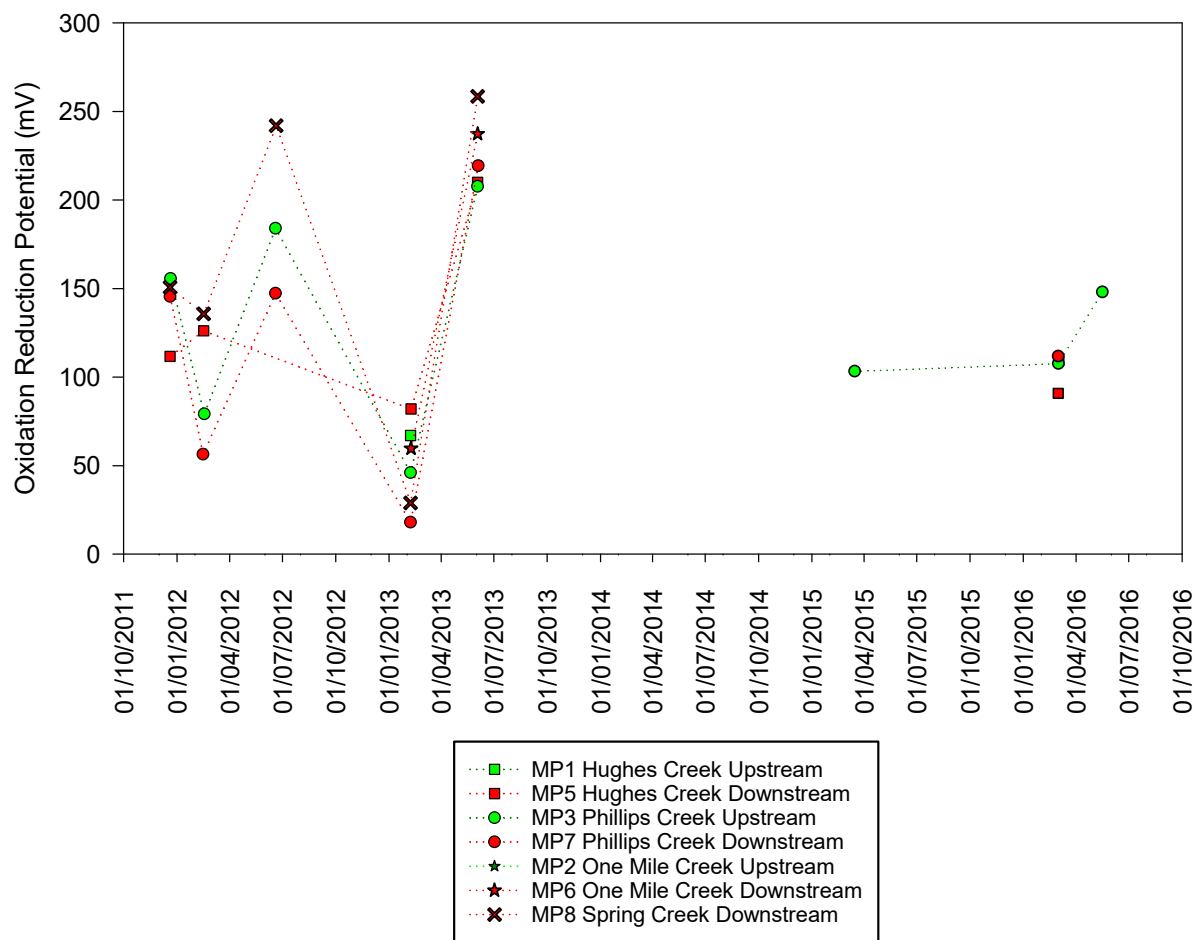


- All sites were within the Table W5 Receiving Waters Contaminant Trigger Levels.

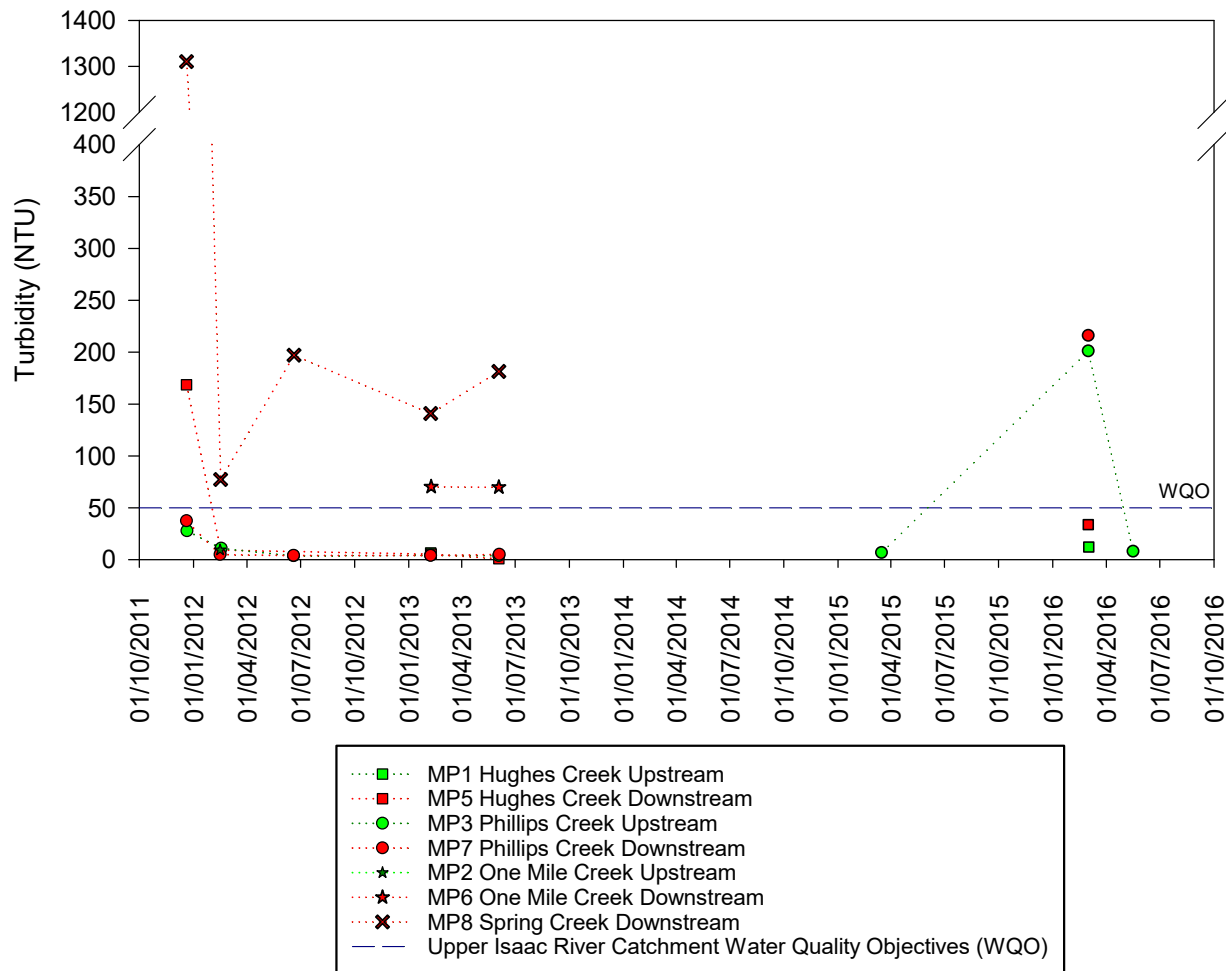
Dissolved Oxygen (% Saturation)



Oxidation Reduction Potential (mV)

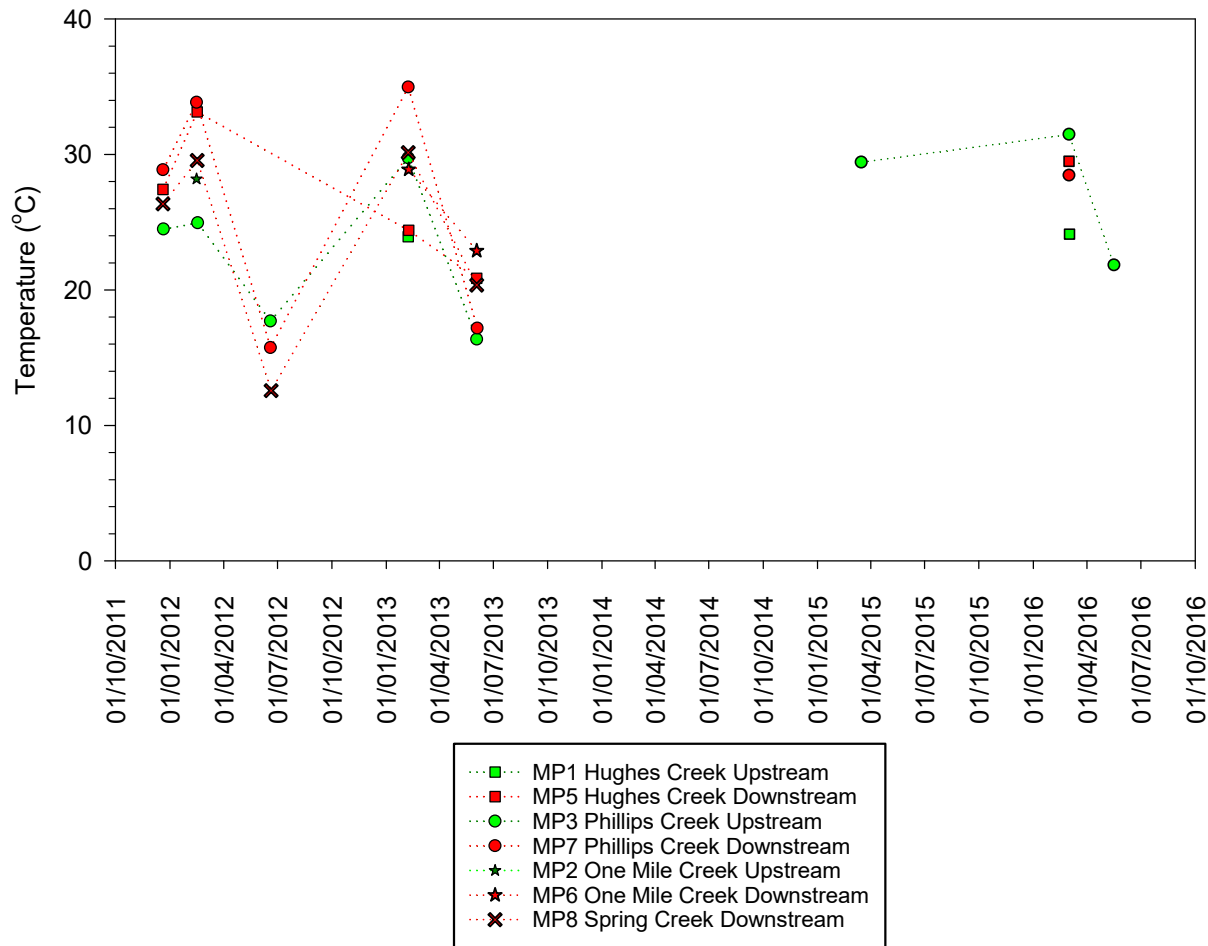


Turbidity (NTU)

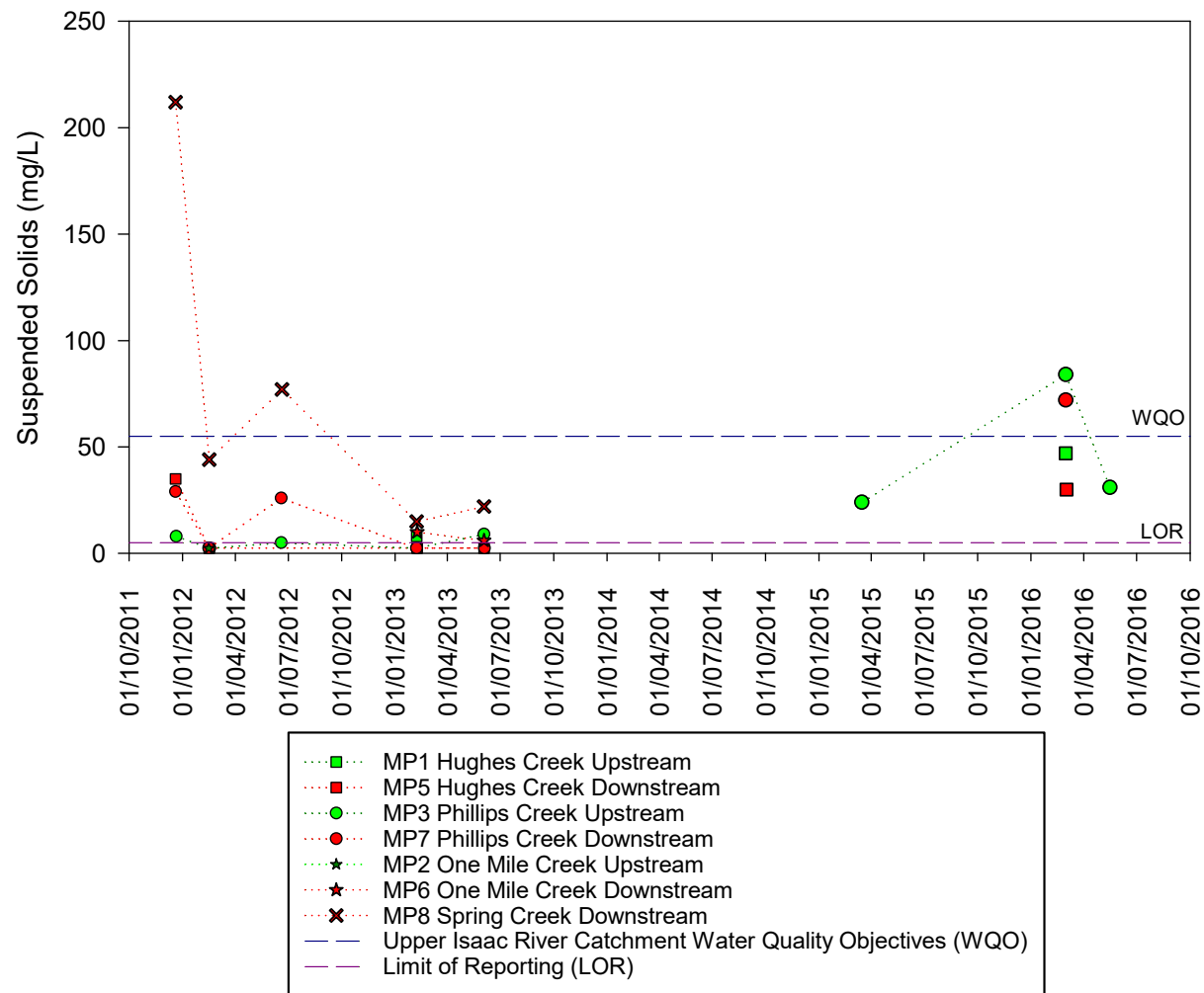


- Turbidity recorded at the downstream sites MP6 and MP8 sites exceeded the WQO on many occasions. MP5 exceeded the WQO during Dec 11 only.

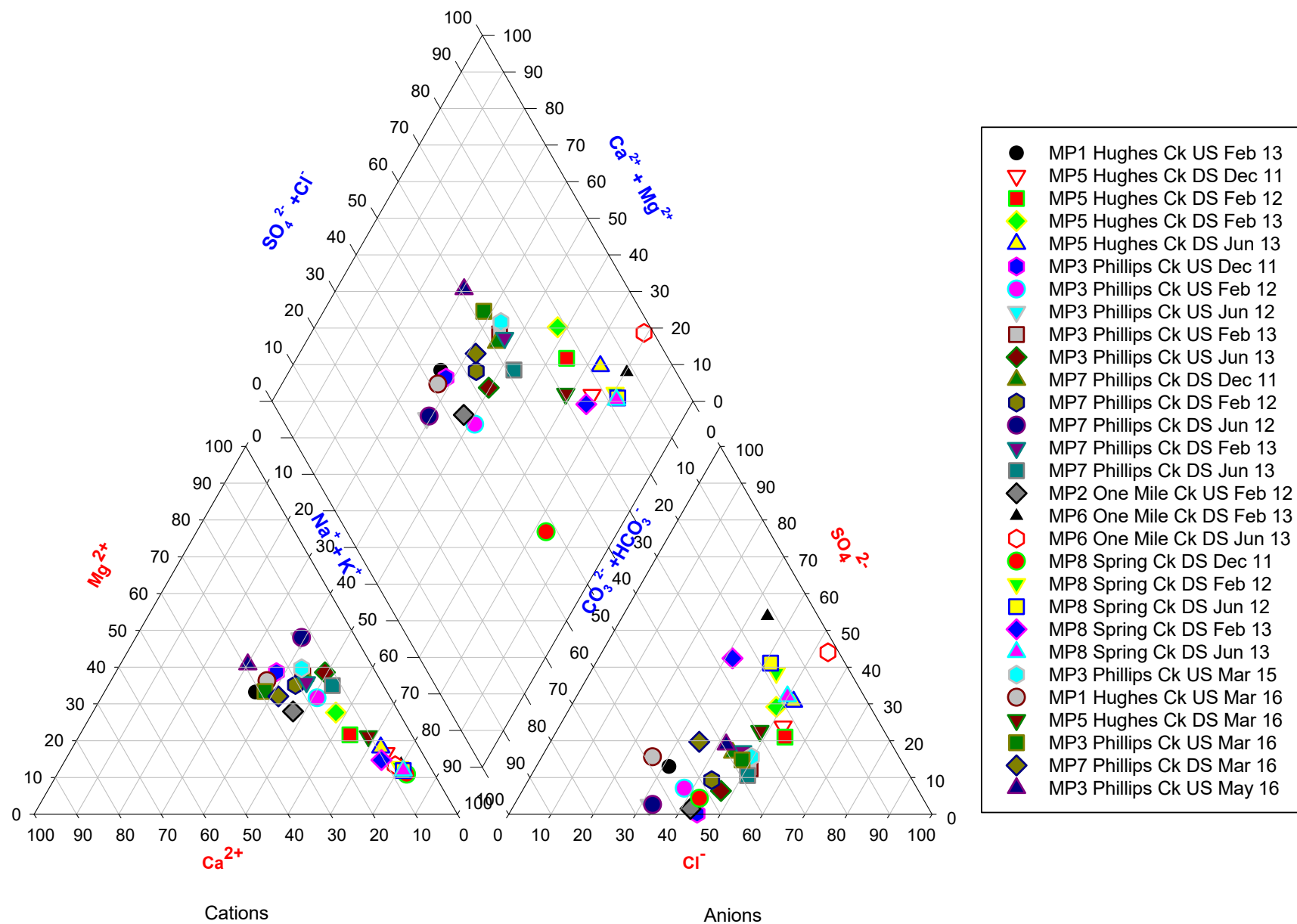
Temperature (°C)



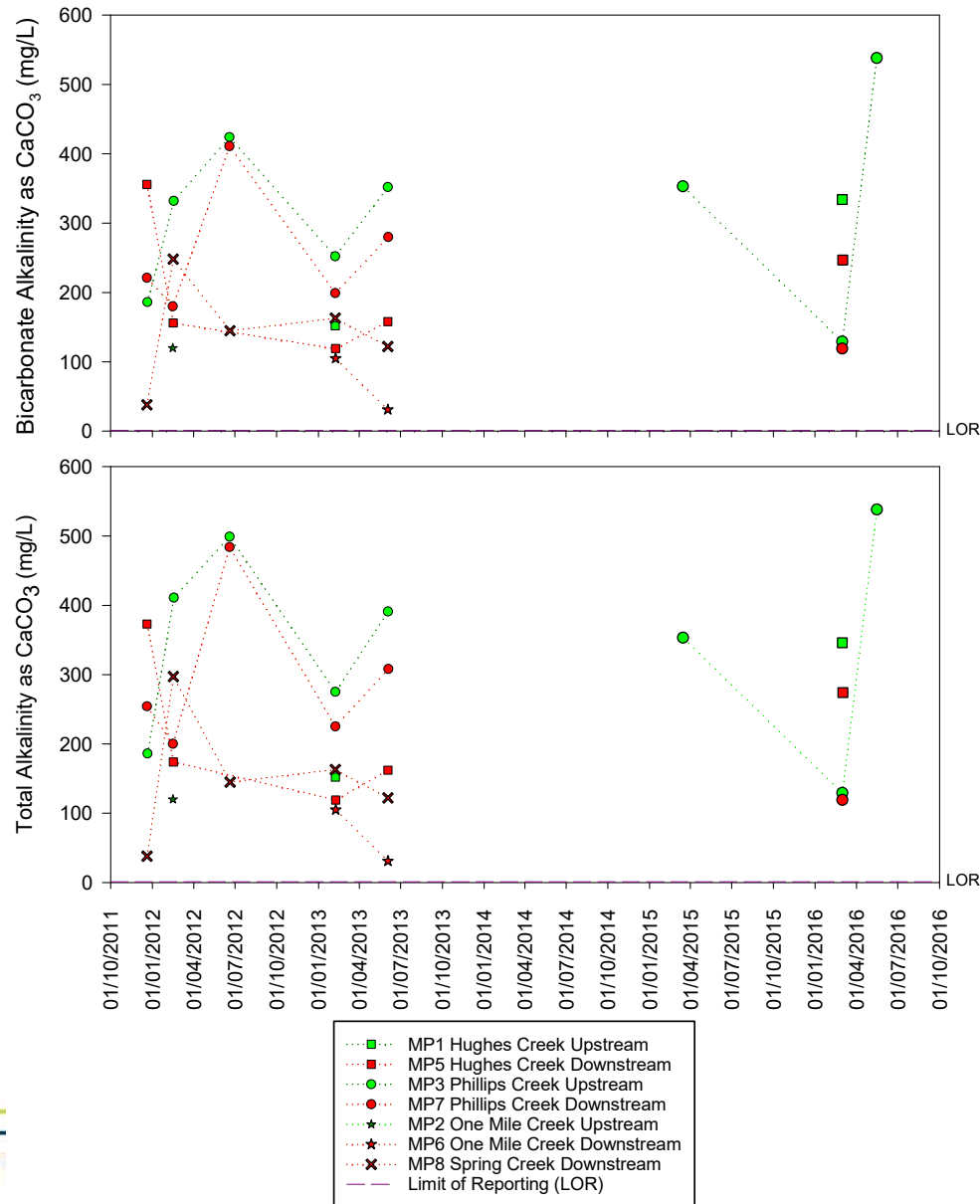
Suspended Solids (mg/L)



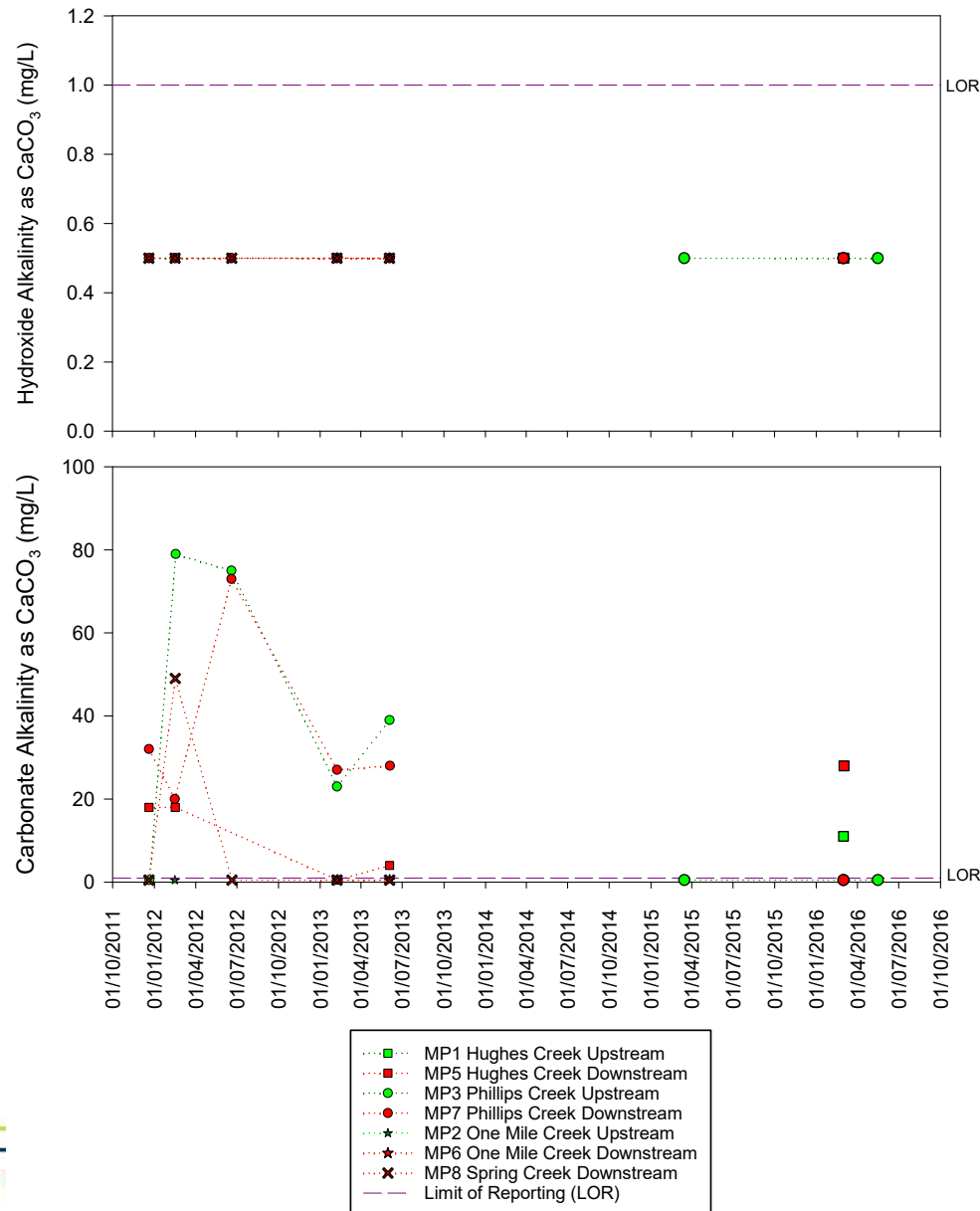
Piper Plot (2011-2016)



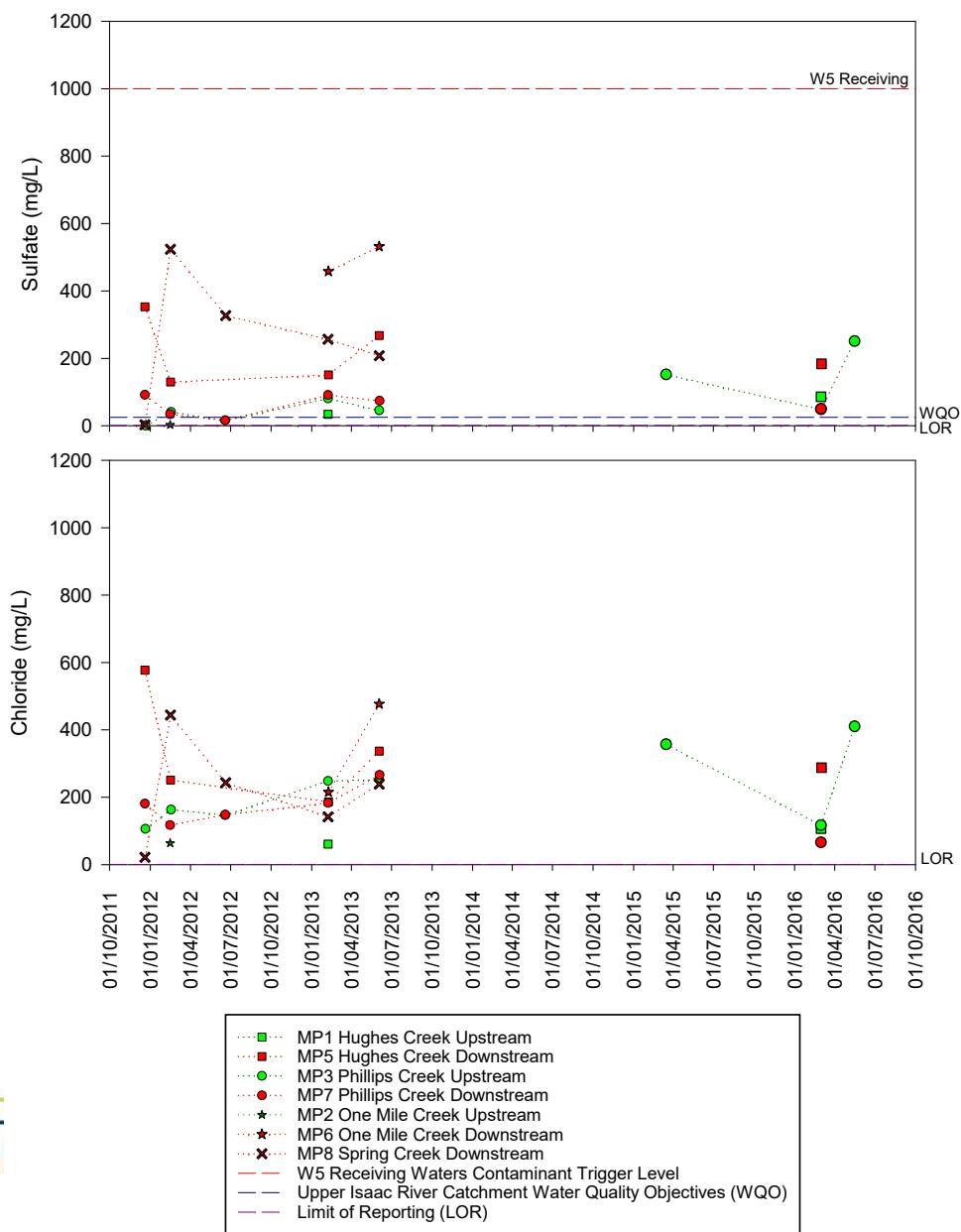
Bicarbonate and Total Alkalinity as CaCO₃ (mg/L)



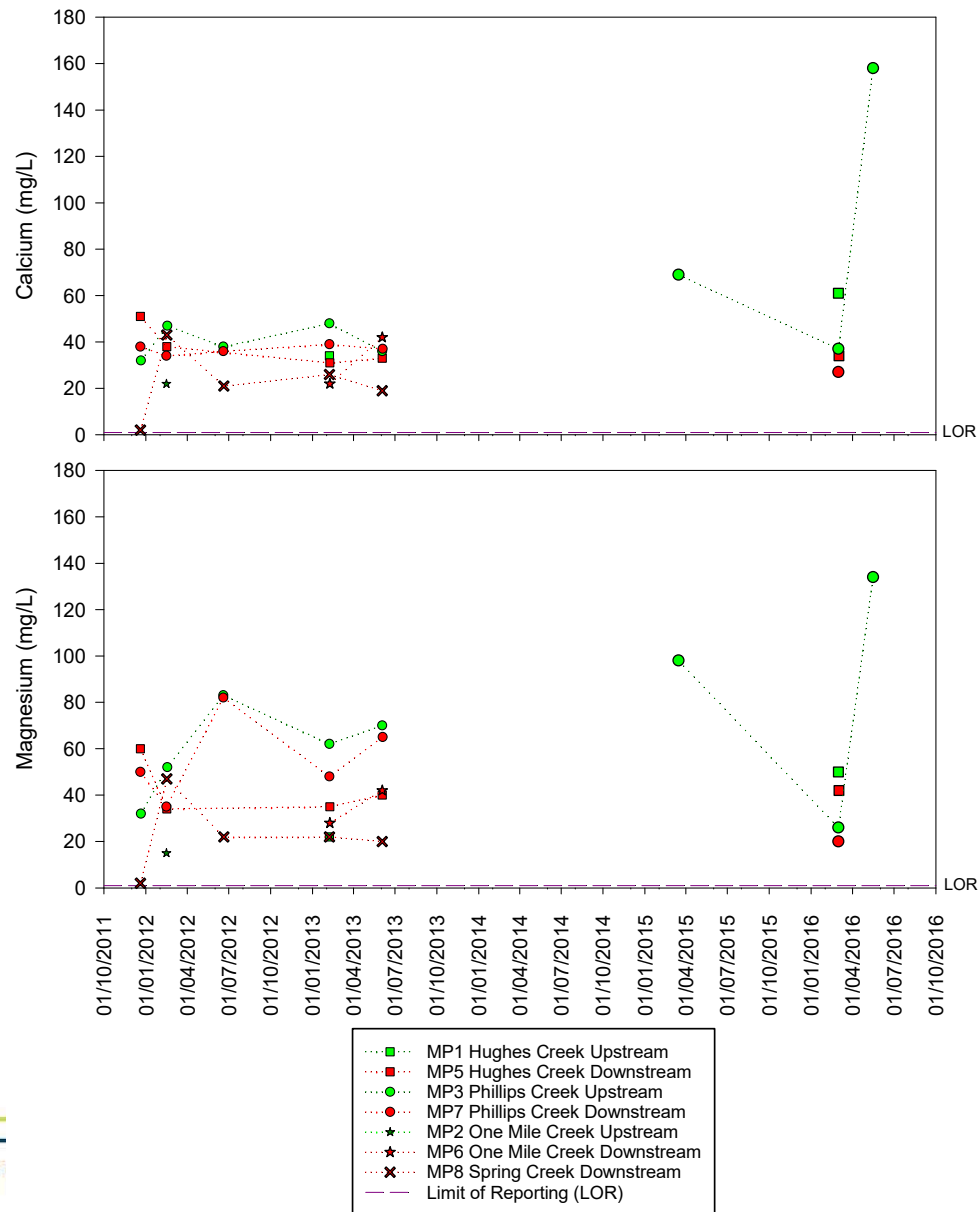
Hydroxide and Carbonate as CaCO_3 (mg/L)



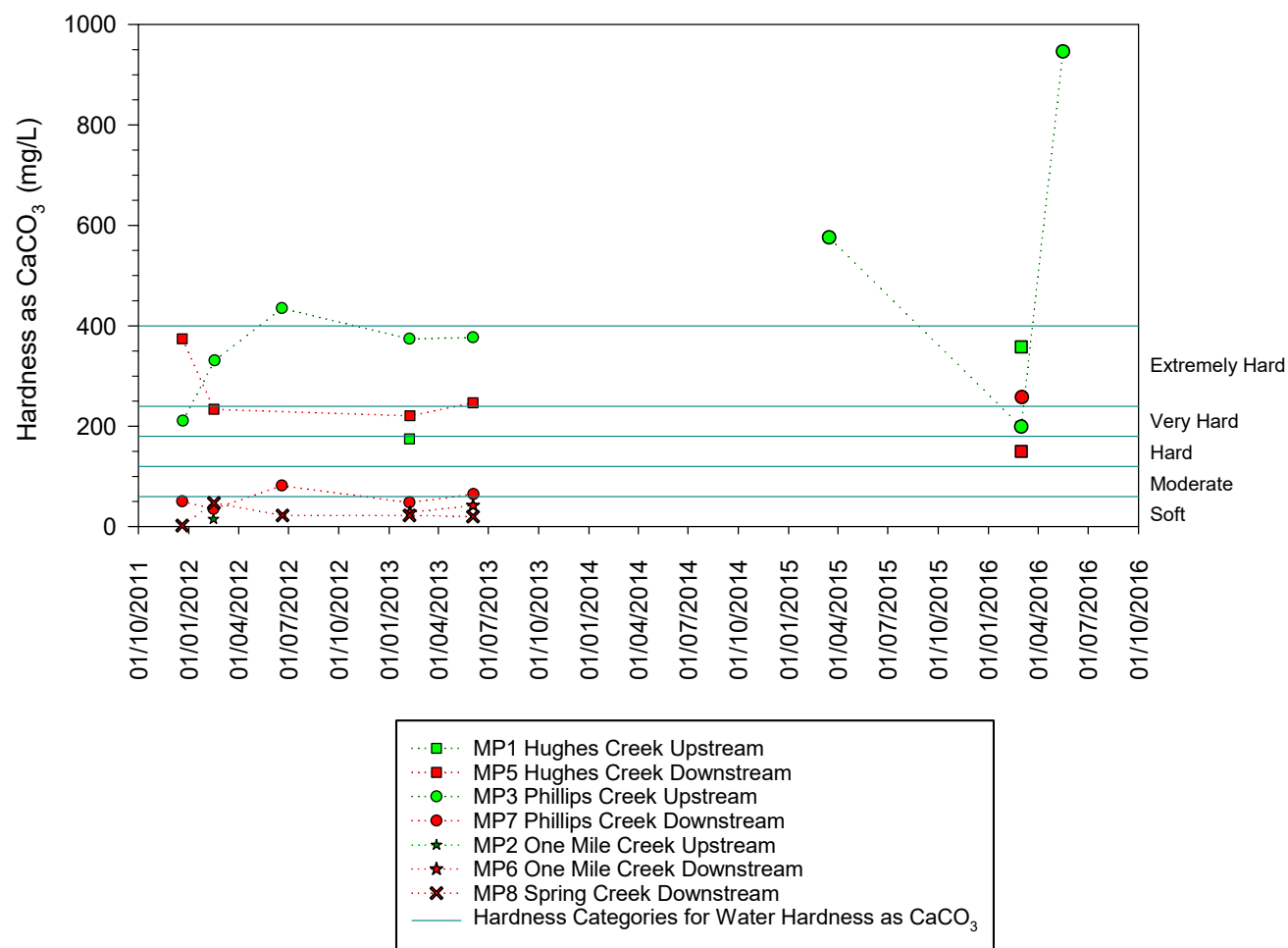
Sulfate and Chloride (mg/L)



Calcium and Magnesium (mg/L)



Total Hardness as CaCO₃ (mg/L)



- Sites were all distributed evenly between the different hardness categories. However, two upstream sites exceeded the extremely hard category during the late wet season 2012 and again in 2015 and 2016.

Approximate factors to apply to soft water trigger values for selected metals in freshwaters of varying hardness as documented in the ANZECC Guidelines

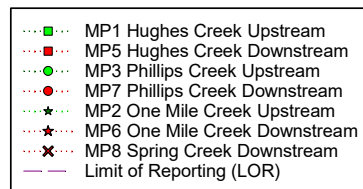
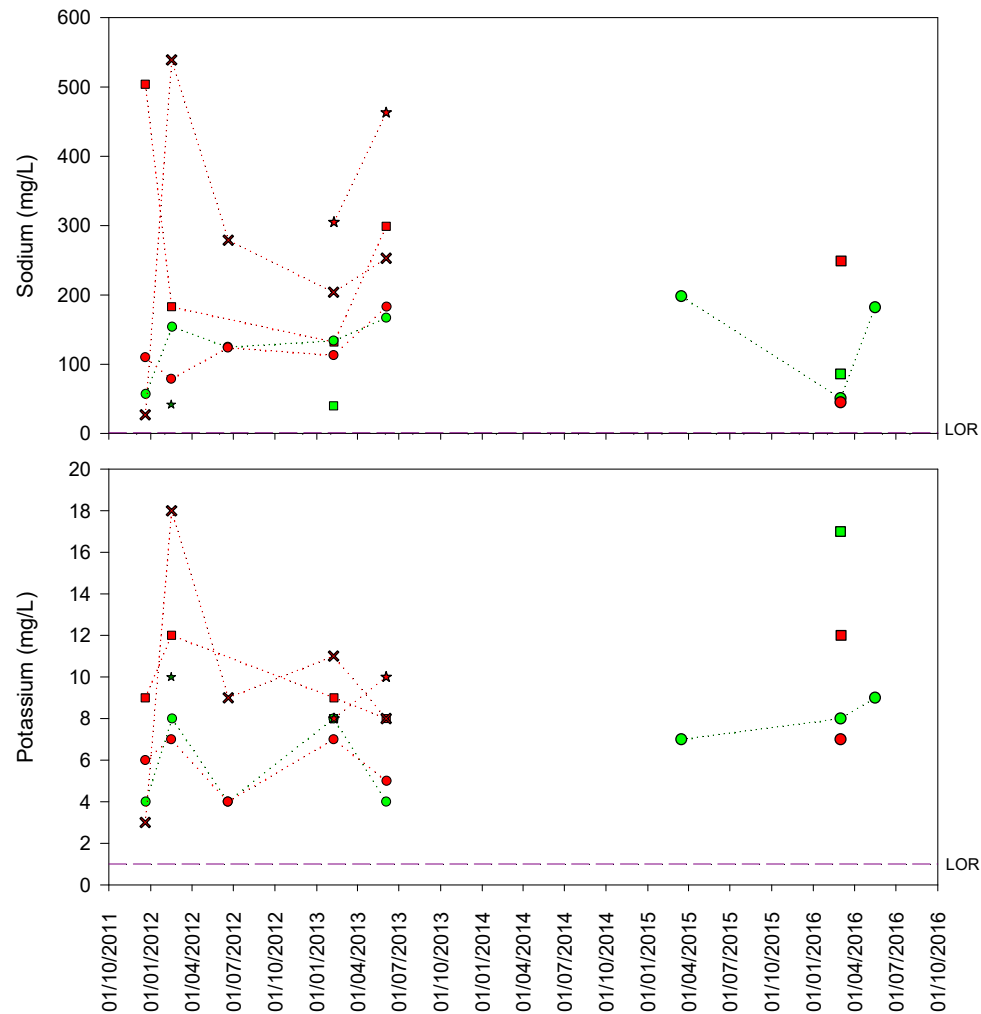
Hardness Category ^b (mg/L as CaCO ₃)	Water Hardness ^c (mg/L as CaCO ₃)	Cd	Cr (III)	Cu	Pb	Ni	Zn
Soft (0-59)	30	TV	TV	TV	TV	TV	TV
Moderate (60-119)	90	x 2.7	x 2.5	x 2.5	x 4.0	x 2.5	x 2.5
Hard (120-179)	150	x 4.2	x 3.7	x 3.9	x 7.6	x 3.9	x 3.9
Very Hard (180-240)	210	x 5.7	x 4.9	x 5.2	x 11.8	x 5.2	x 5.2
Extremely Hard (400)	400	x 10.0	x 8.4	x 9.0	x 26.7	x 9.0	x 9.0

b - Range of water hardness (mg/L as CaCO₃) for each category as defined by CCREM (1987);

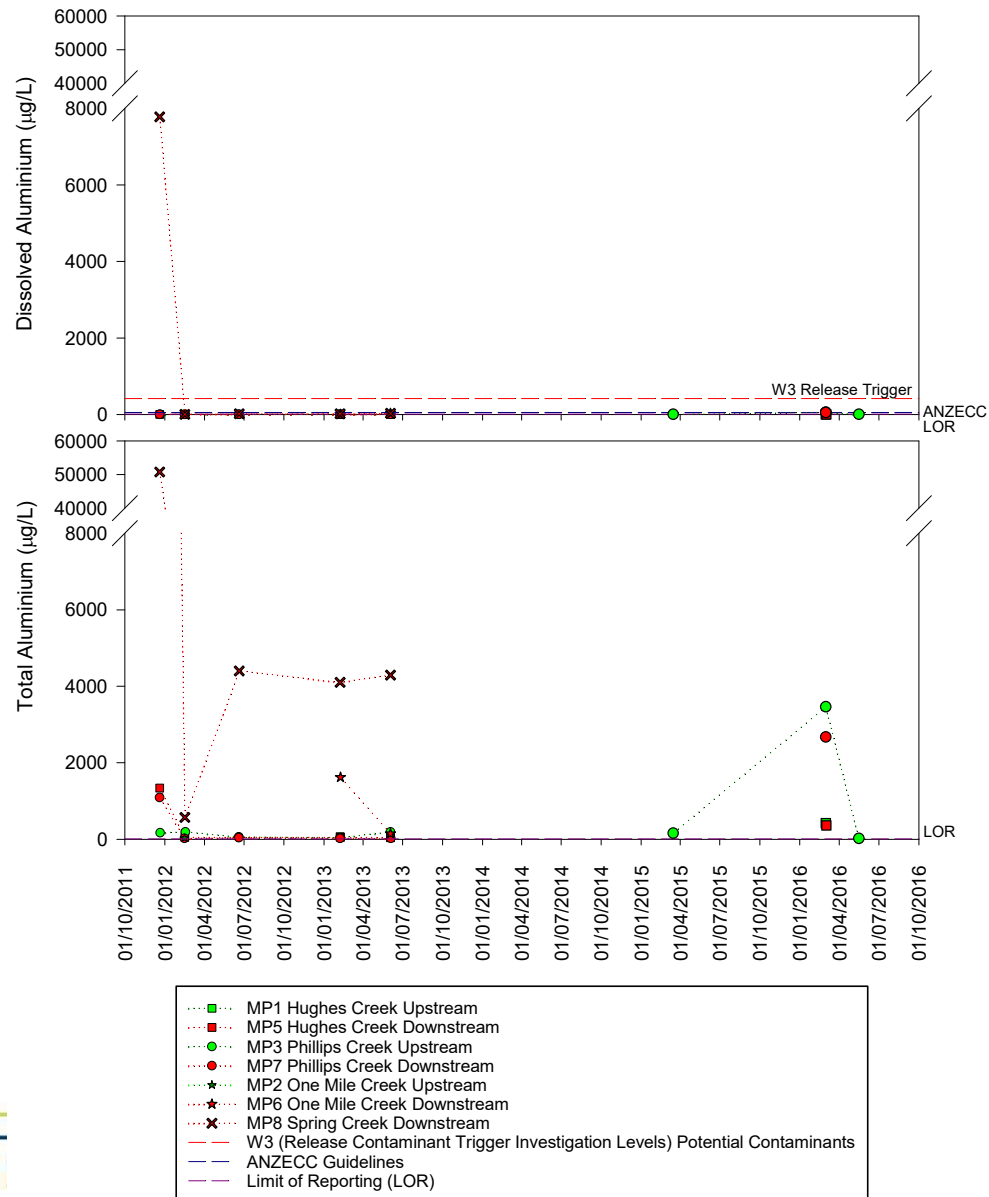
c - Mid-range value for each water hardness category. For example, a copper trigger value of 1.4 µg/L with 95% protection level chosen (e.g. slightly-moderately disturbed system) is applied to a site with very hard water (e.g. 210 mg/L as CaCO₃) by multiplying the trigger value by 5.2 to give a site-specific trigger value of 7.3 µg/L. If the hardness is away from the mid-range, it may be preferable to use the algorithm.



Sodium and Potassium (mg/L)

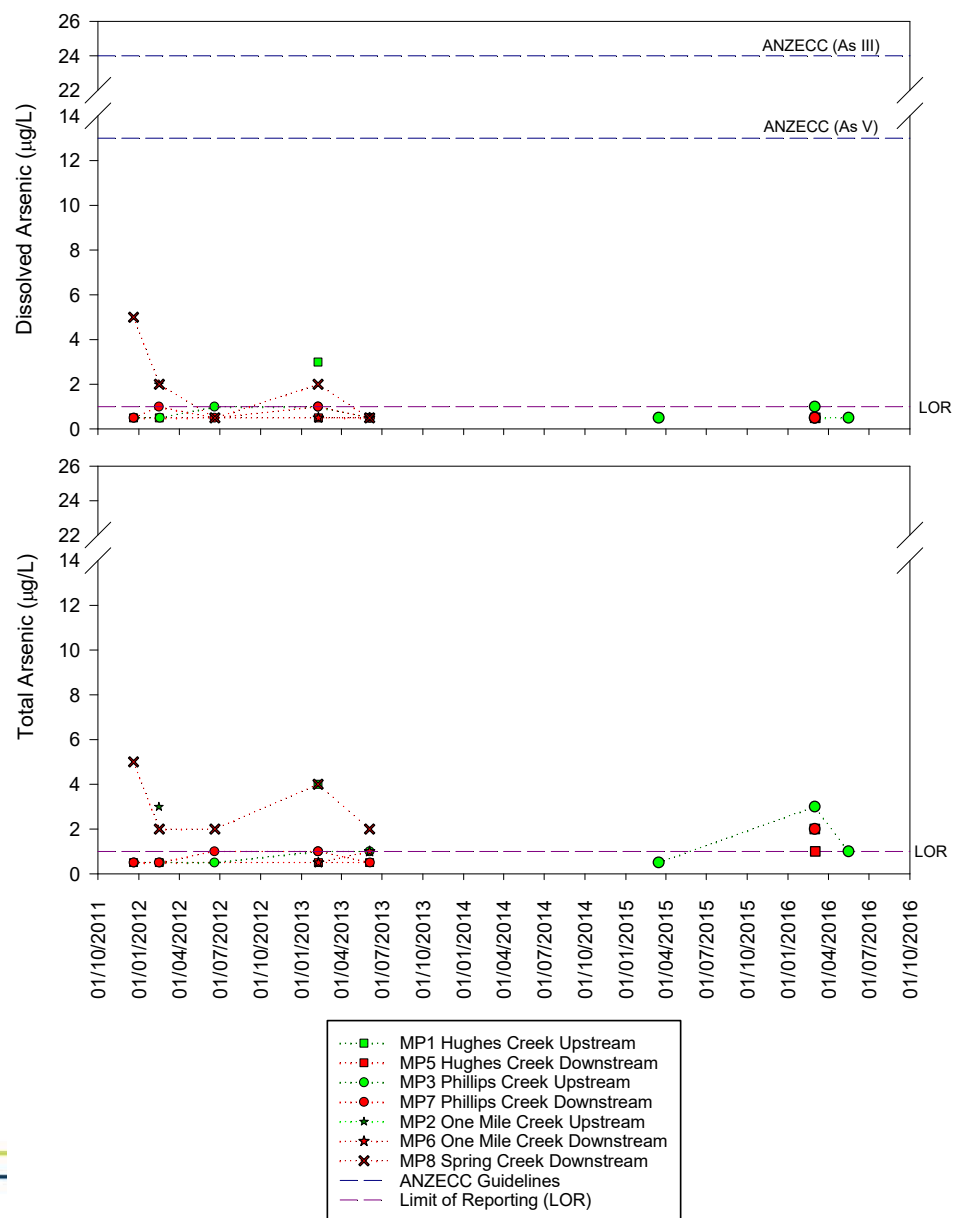


Dissolved and Total Aluminium ($\mu\text{g/L}$)



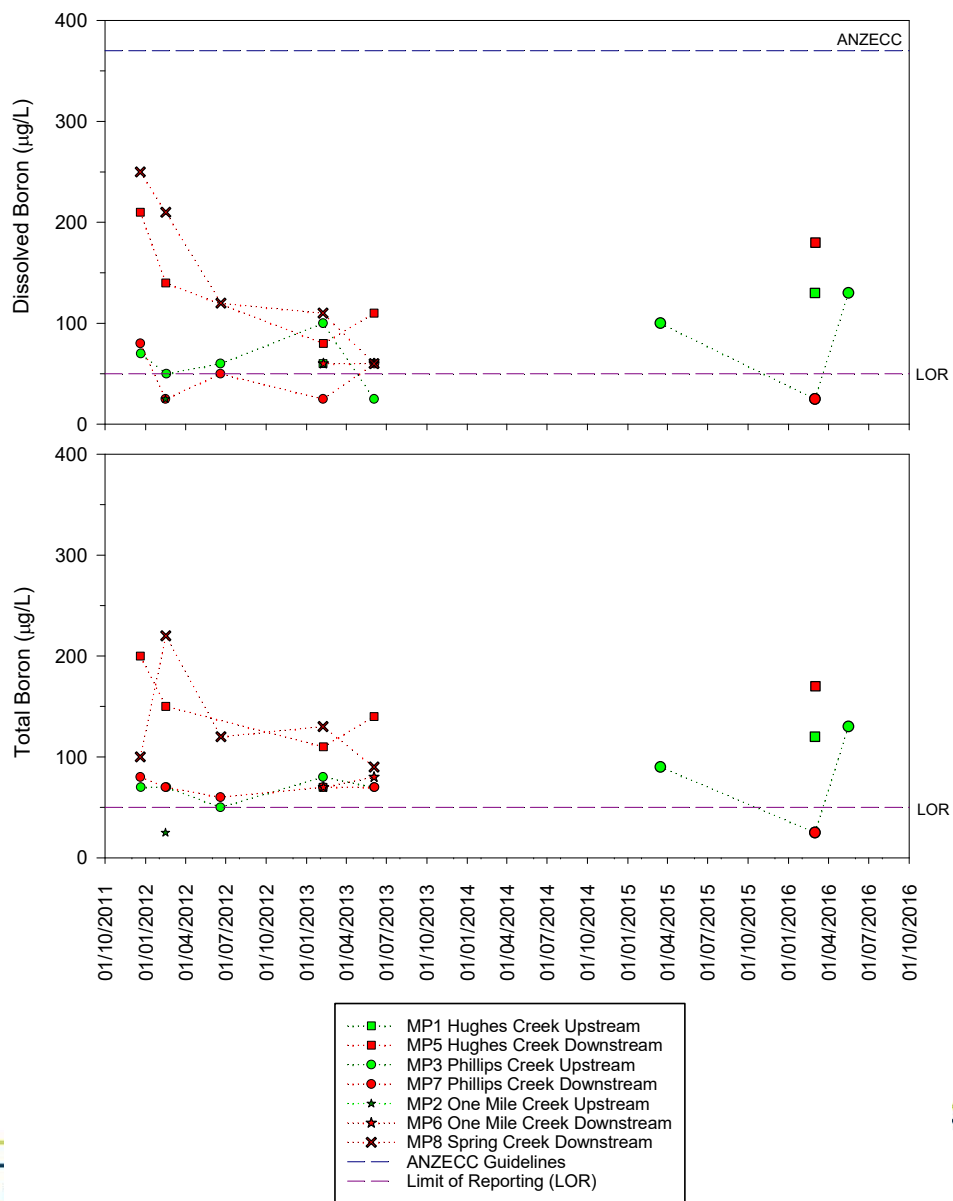
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Arsenic ($\mu\text{g/L}$)



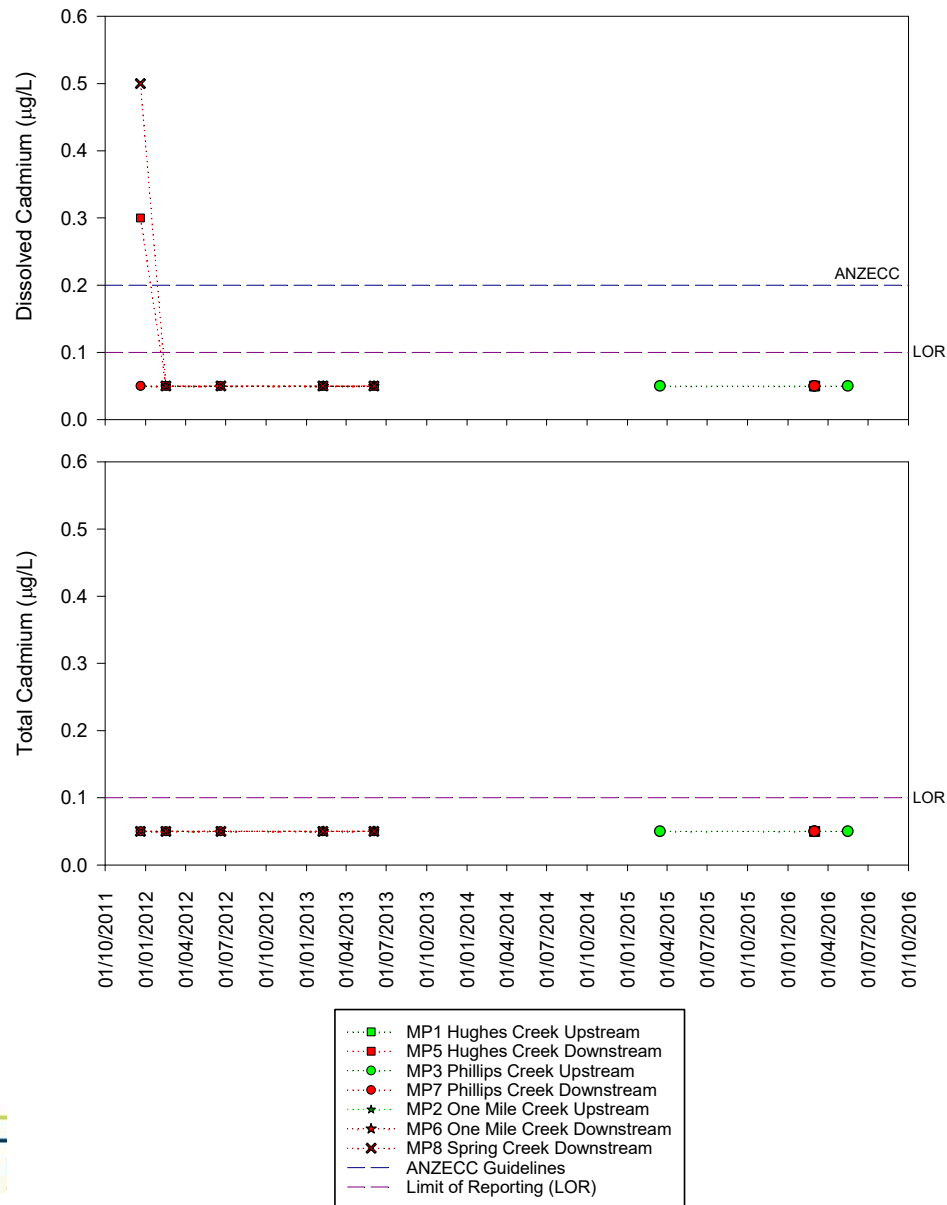
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Boron ($\mu\text{g/L}$)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

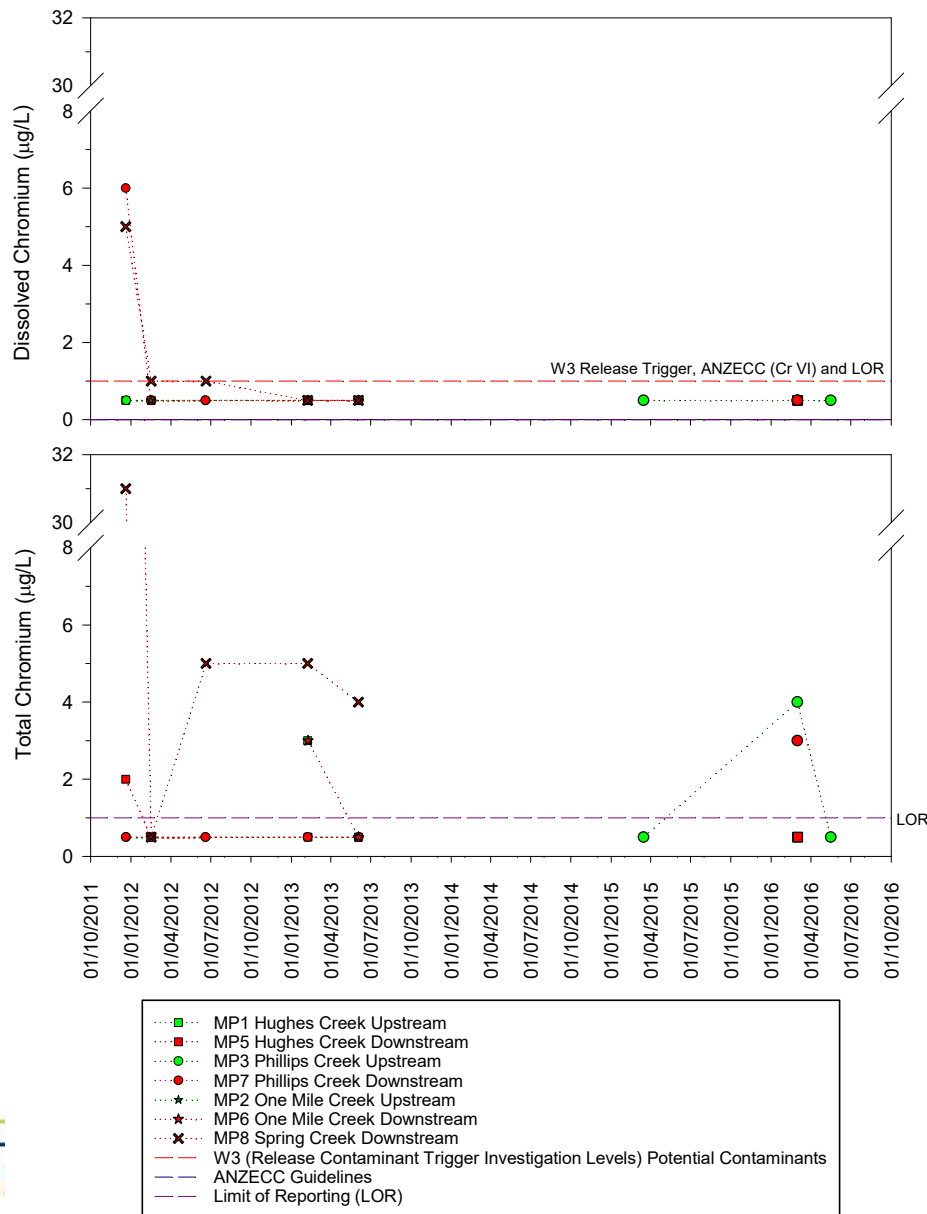
Dissolved and Total Cadmium (µg/L)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites



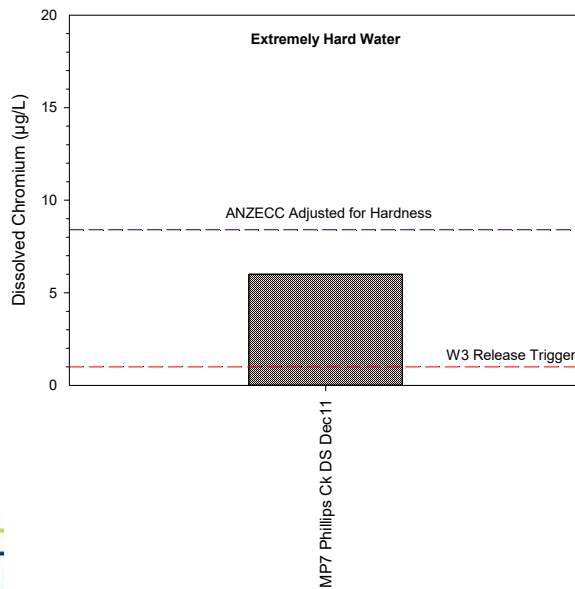
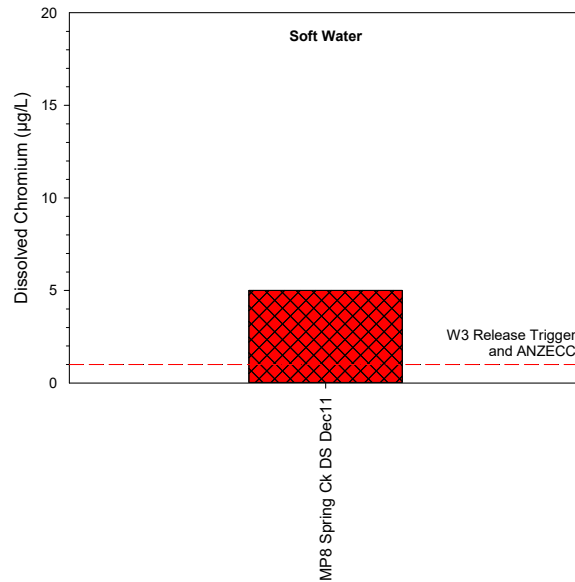
Dissolved and Total Chromium ($\mu\text{g/L}$)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites



Adjusted ANZECC for Dissolved Chromium ($\mu\text{g/L}$) Based on Hardness as CaCO_3

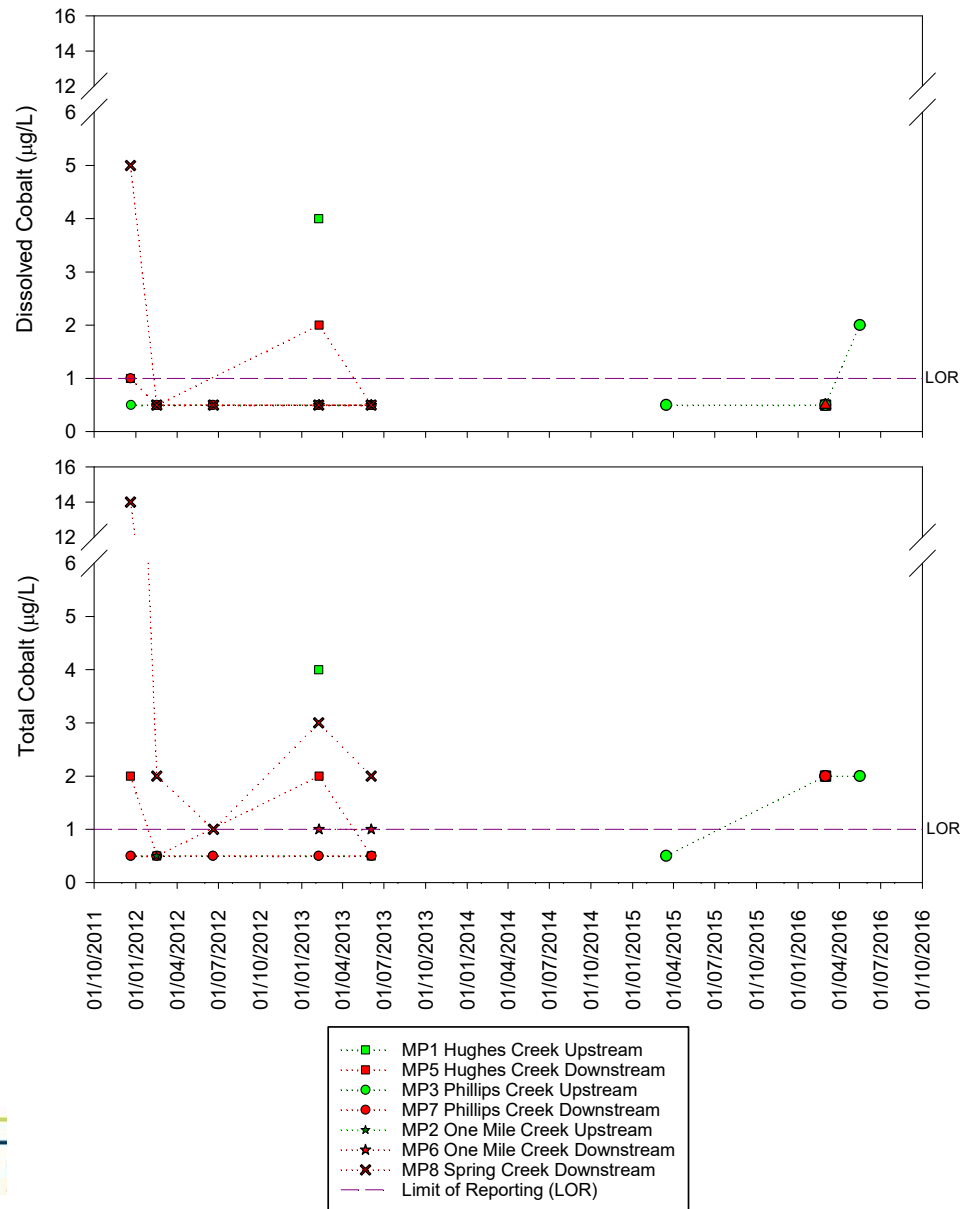


— ANZECC Trigger Values Adjusted for Hardness as CaCO_3
— W3 (Release Contaminant Trigger Investigation Levels) Potential Contaminants

- The concentration of dissolved chromium in the sample from MP8 Spring Creek Downstream Dec 11 exceeded the adjusted ANZECC Guidelines for soft water.
- It should be noted that Phillips Creek Downstream had extremely hard water at this time and the toxicity of dissolved chromium was reduced.

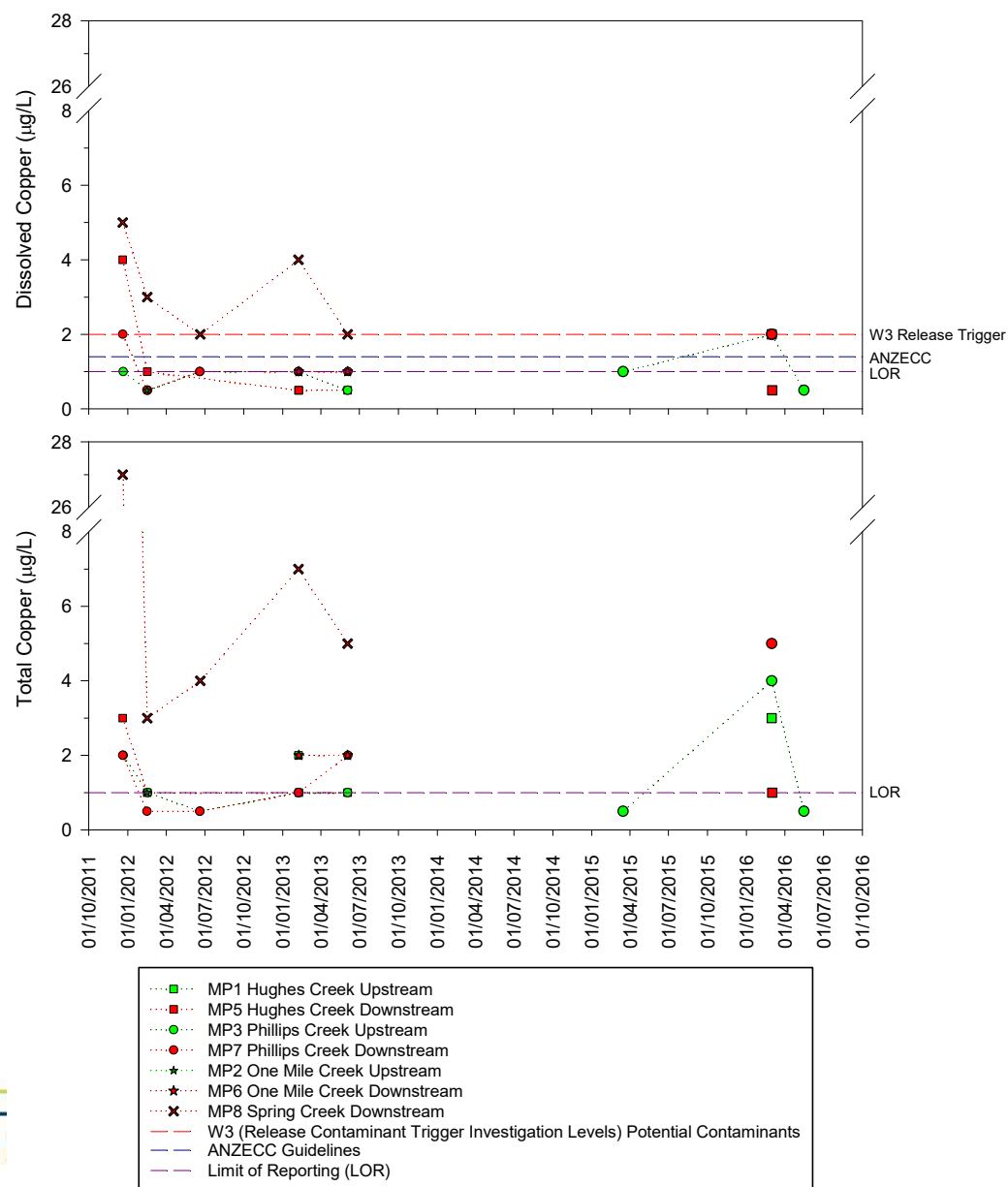


Dissolved and Total Cobalt (µg/L)



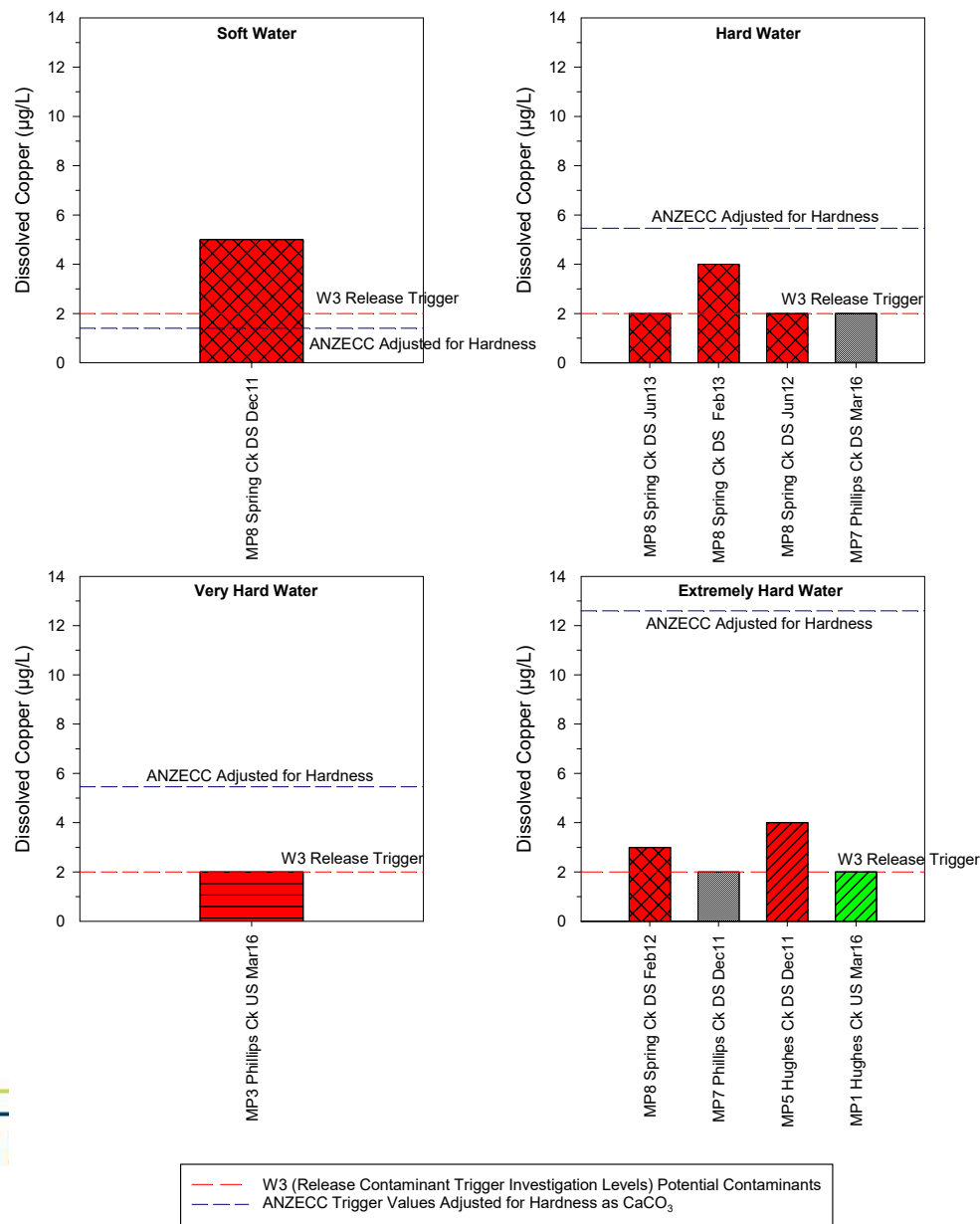
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Copper ($\mu\text{g/L}$)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

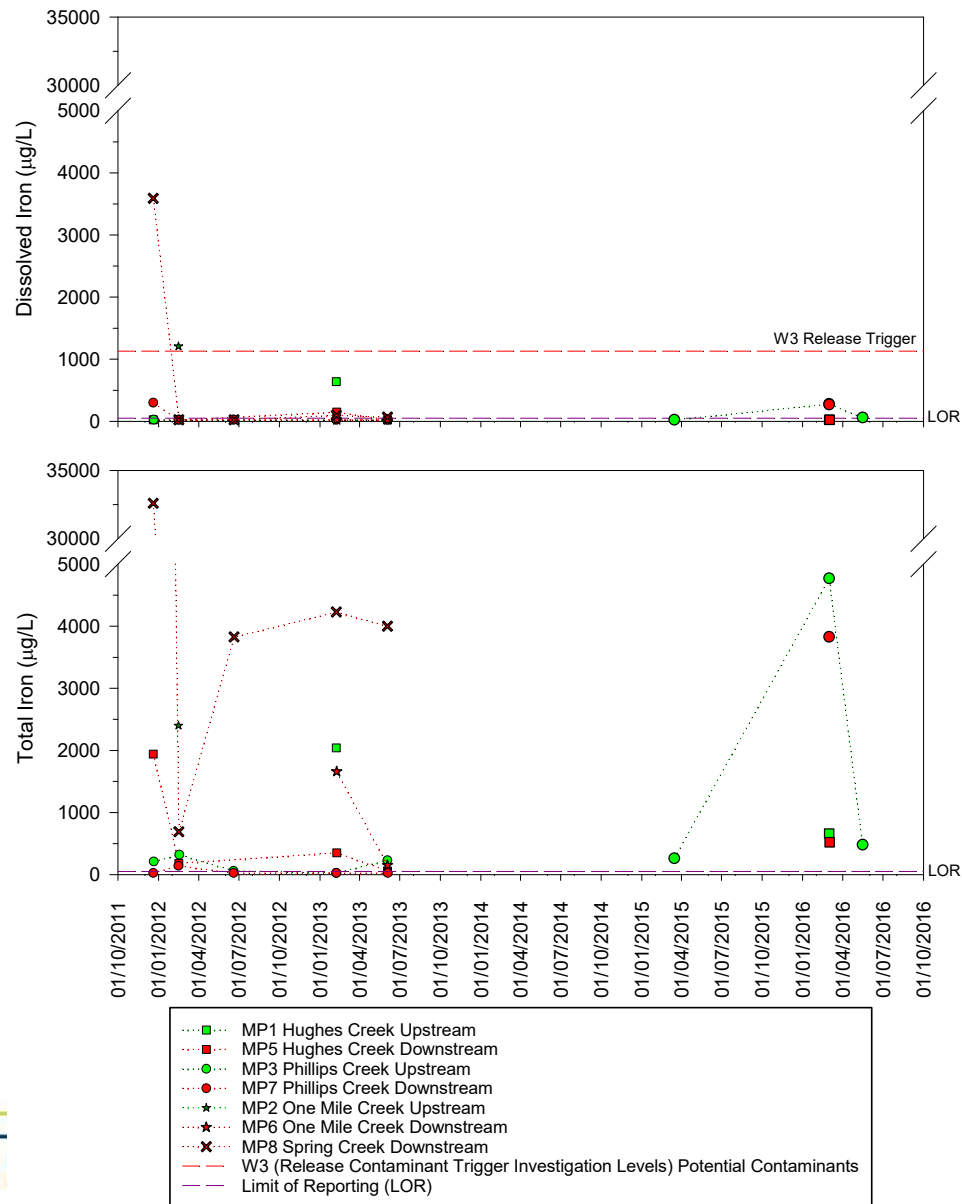
Adjusted ANZECC for Dissolved Copper ($\mu\text{g/L}$) Based on Hardness as CaCO_3



- Results from MP8 Spring Creek Downstream Dec 11 exceeded the adjusted ANZECC guideline for soft water.
- Results from sites with hard, very hard or extremely hard water did not exceed the adjusted ANZECC Guideline.

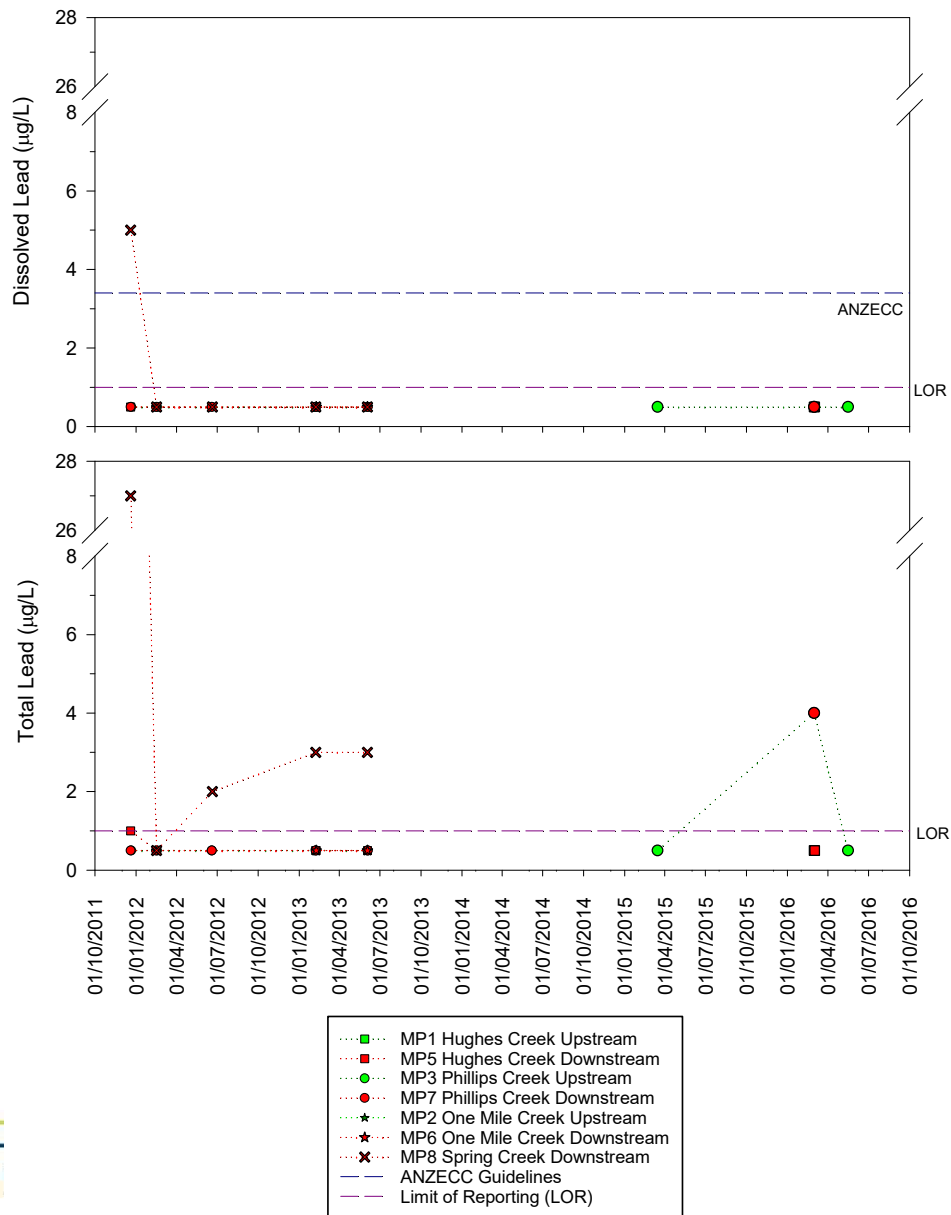


Dissolved and Total Iron ($\mu\text{g/L}$)



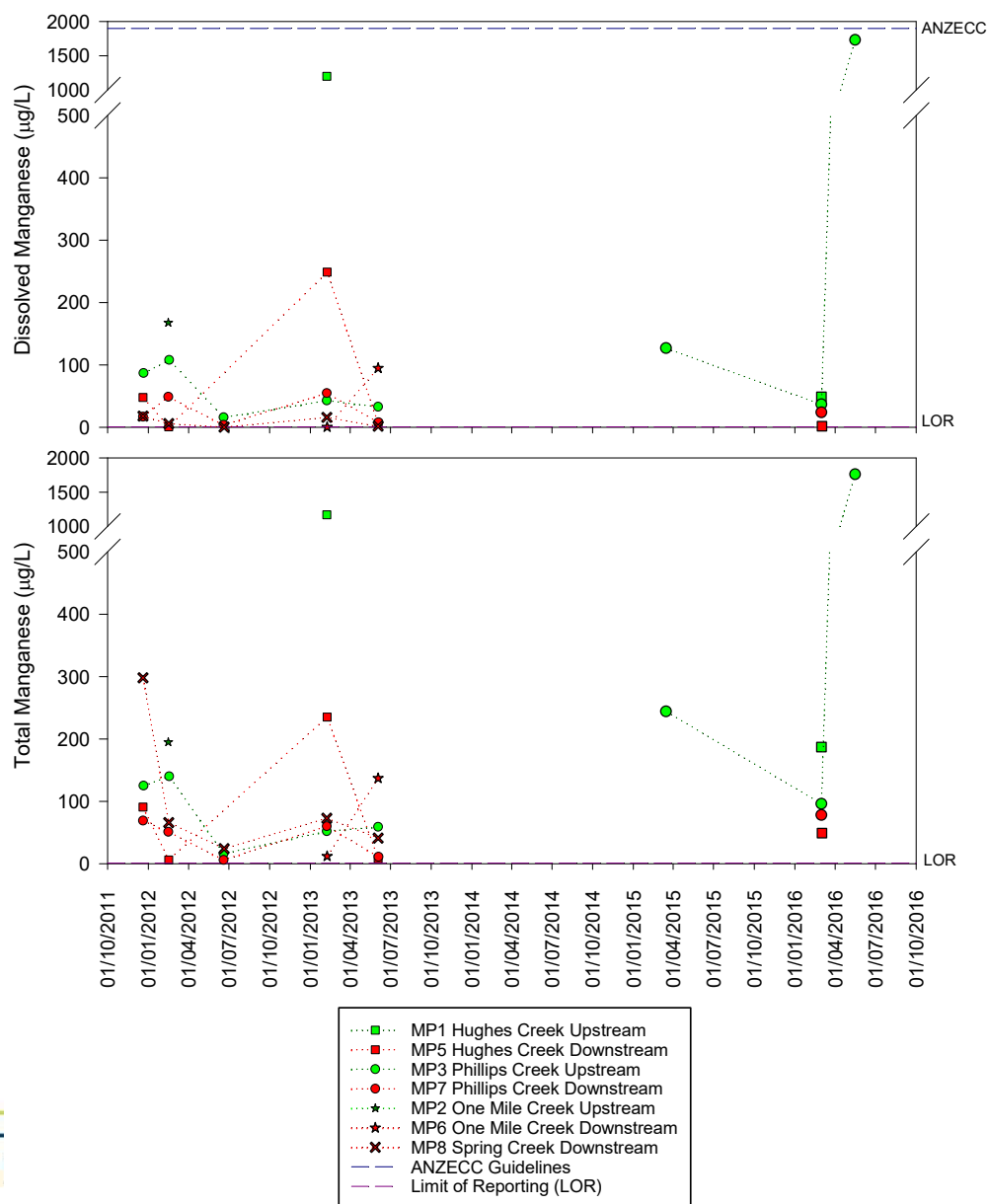
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Lead ($\mu\text{g/L}$)



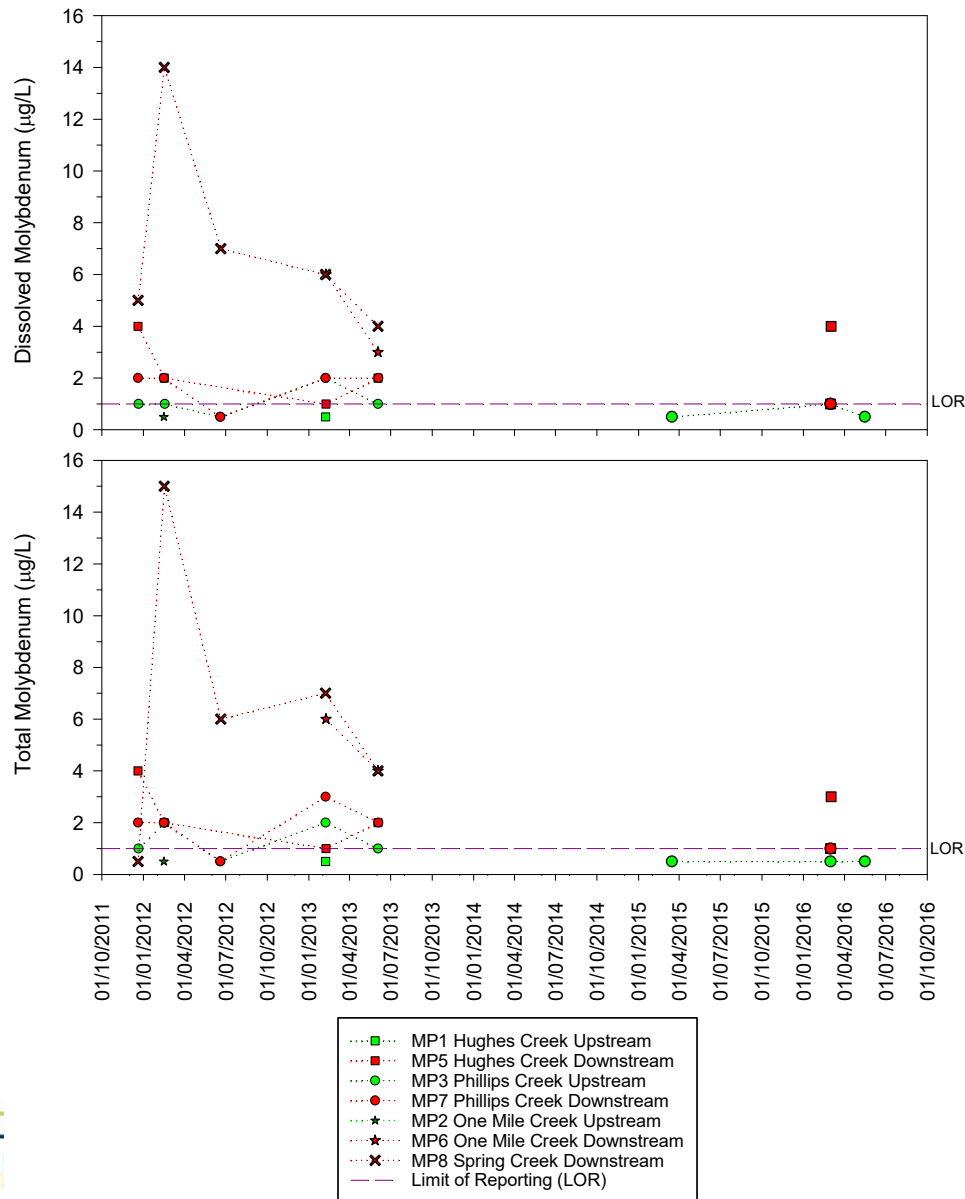
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Manganese ($\mu\text{g/L}$)



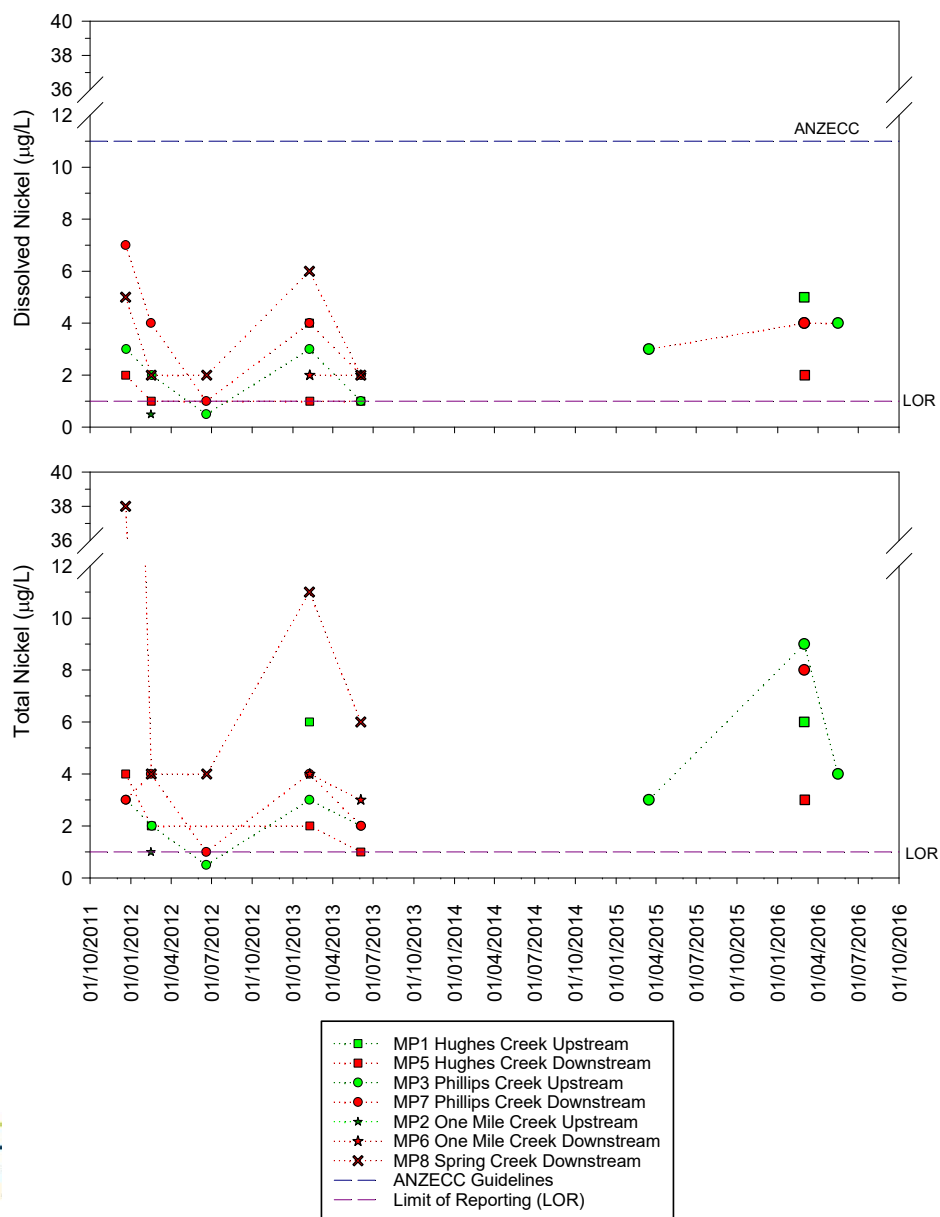
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Molybdenum (µg/L)



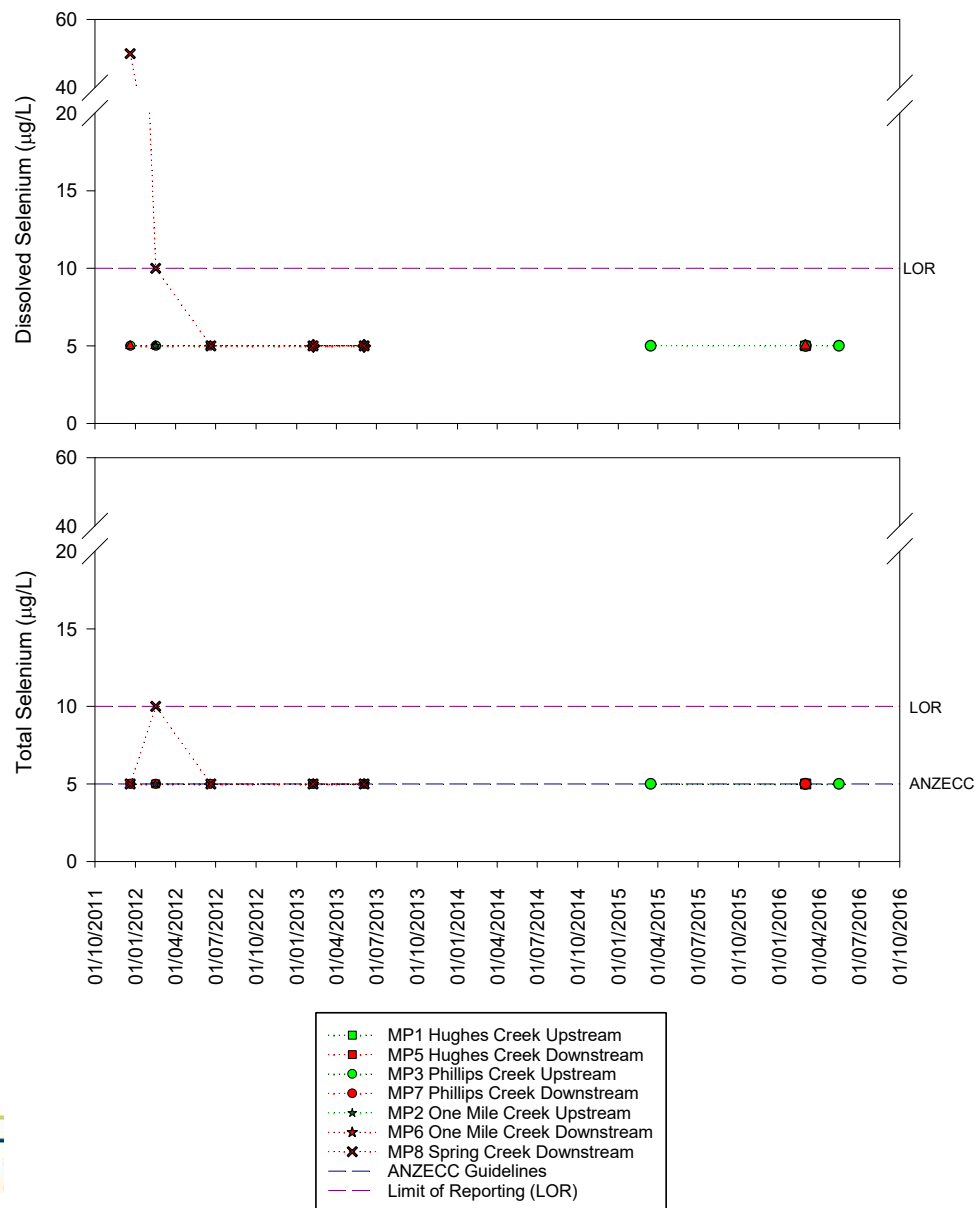
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Nickel ($\mu\text{g/L}$)



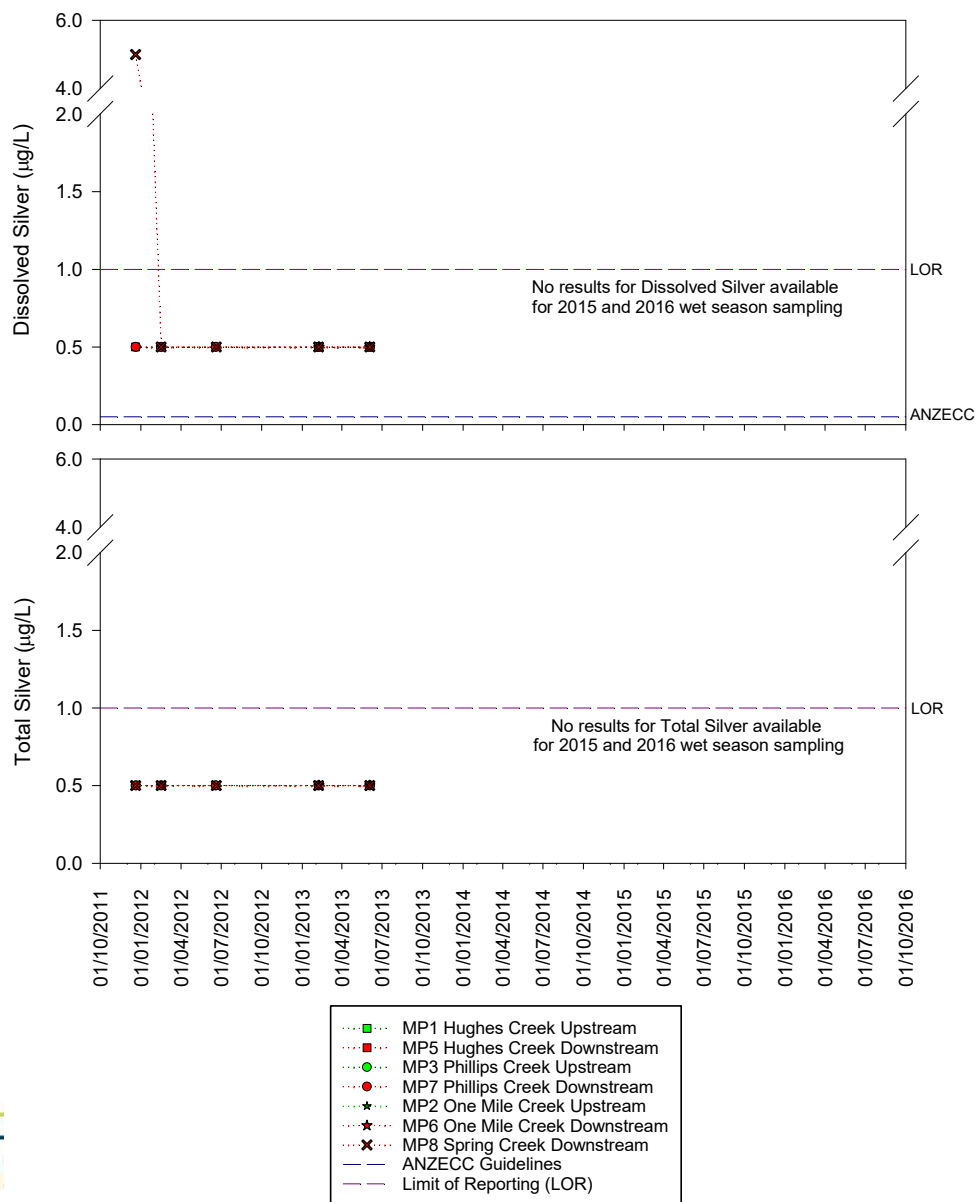
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Selenium ($\mu\text{g/L}$)



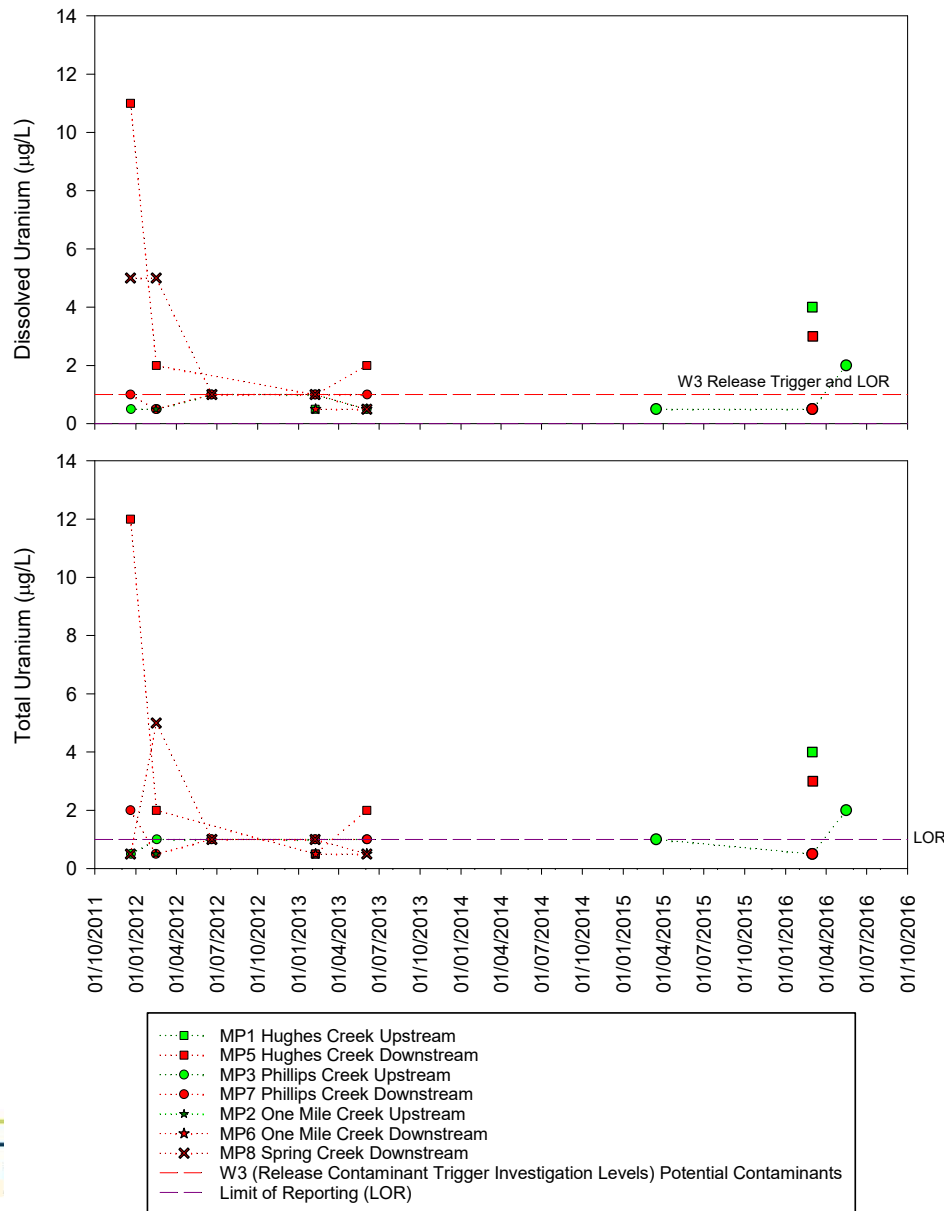
- The discrepancy between total and dissolved selenium suggests a probable error in the result for dissolved selenium.

Dissolved and Total Silver ($\mu\text{g/L}$)



- The discrepancy between total and dissolved silver suggests a probable error in the result for dissolved silver.

Dissolved and Total Uranium ($\mu\text{g/L}$)

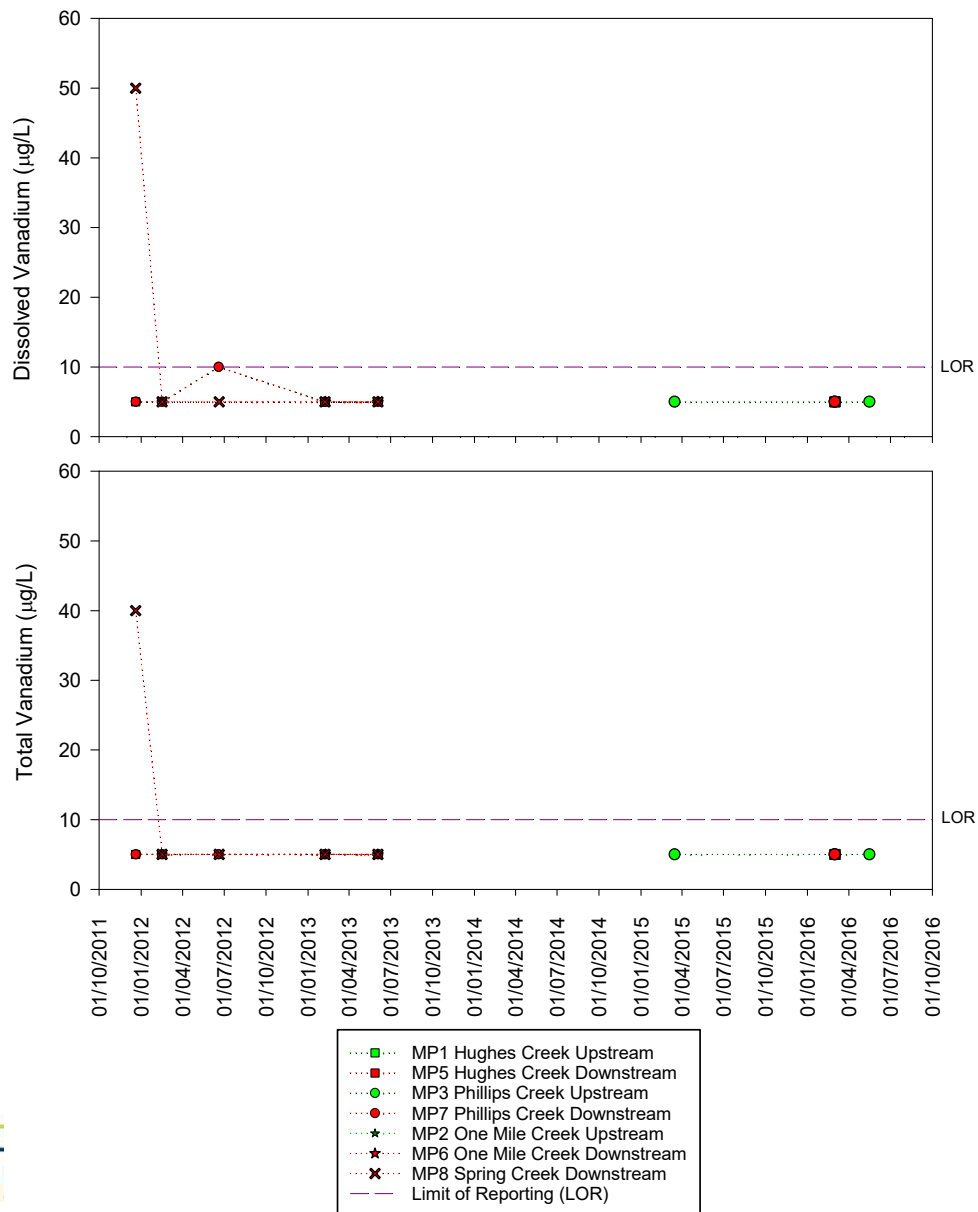


- The concentration of dissolved uranium in Hughes Creek Downstream was at or above the W3 Release Contaminant Trigger Level . Unfortunately the site at Hughes Creek Upstream dries out quickly and is often not available for comparative purposes.



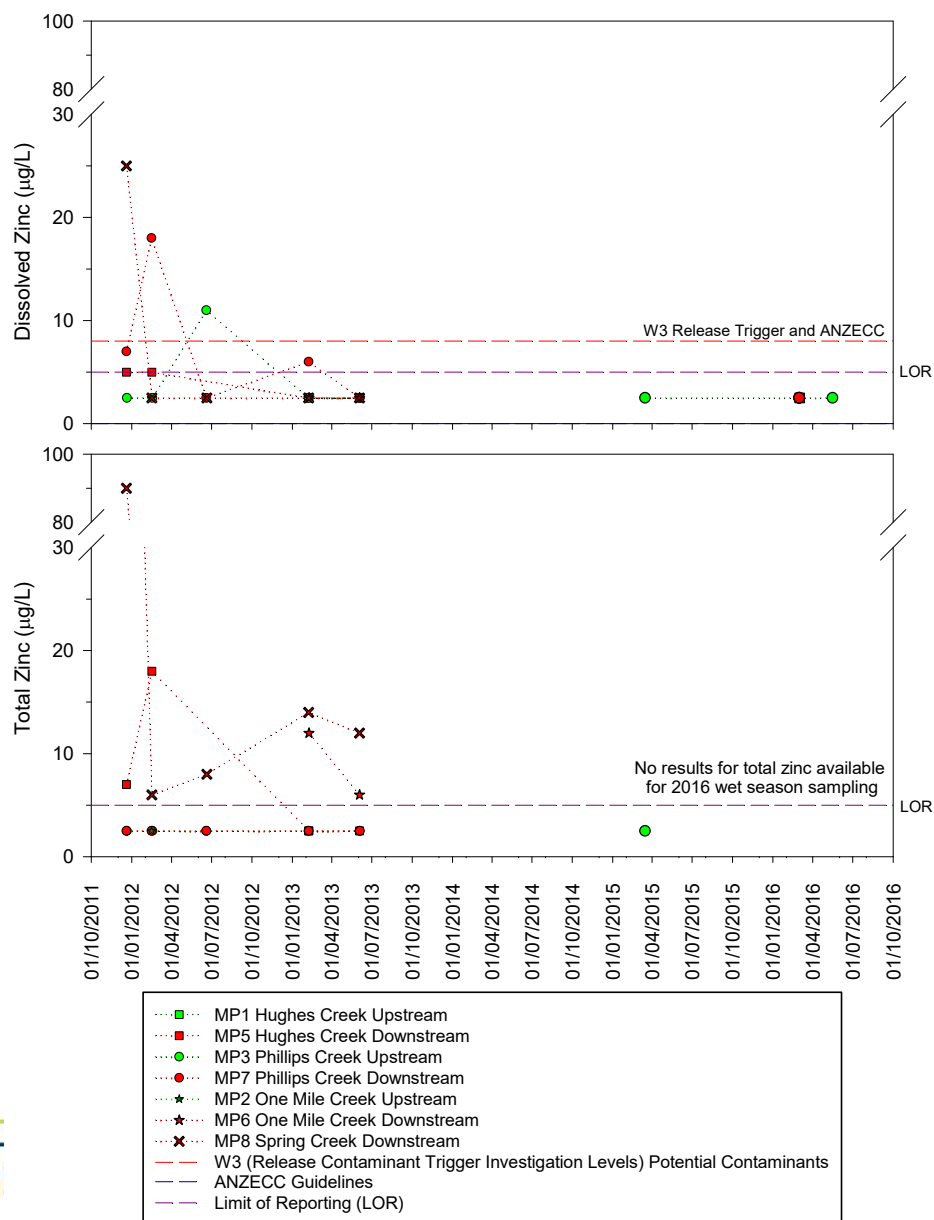
Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Vanadium (µg/L)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Dissolved and Total Zinc ($\mu\text{g/L}$)

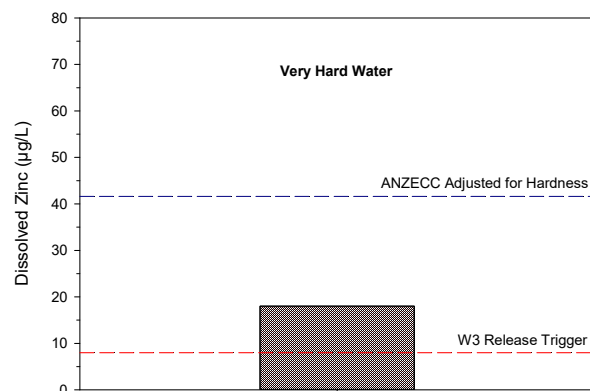


- A result from Phillips Creek Upstream (Jun 12) and another from Phillips Creek Downstream (Feb 12) both exceeded the Table W3 Release Trigger Investigation Level and ANZECC Guideline in 2012.

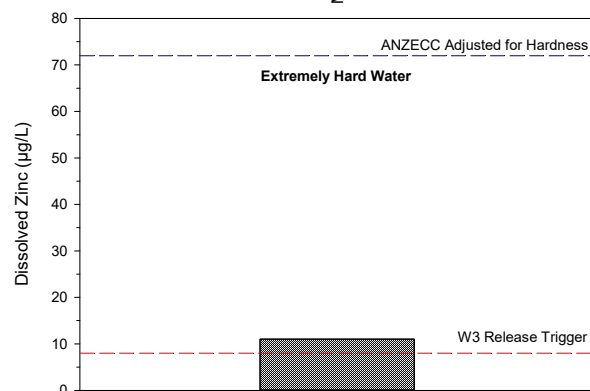


Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

Adjusted ANZECC for Dissolved Zinc ($\mu\text{g/L}$) Based on Hardness as CaCO_3



MP7 Phillips Ck DS Feb12

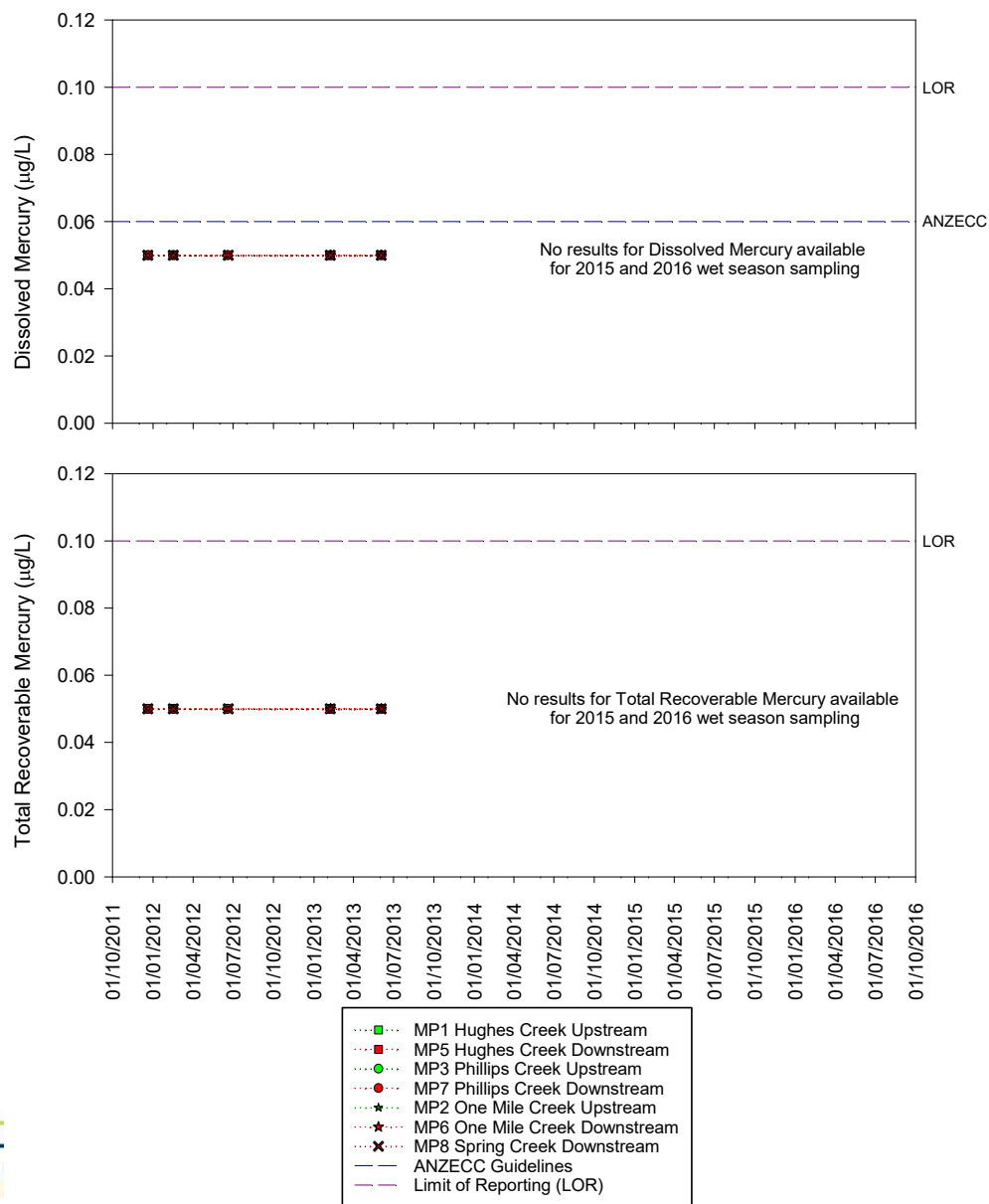


MP3 Phillips Ck US Jun12

- All concentrations were below the adjusted ANZECC Guidelines in very hard and extremely hard water.

— ANZECC Trigger Values Adjusted for Hardness as CaCO_3
— W3 (Release Contaminant Trigger Investigation Levels) Potential Contaminants

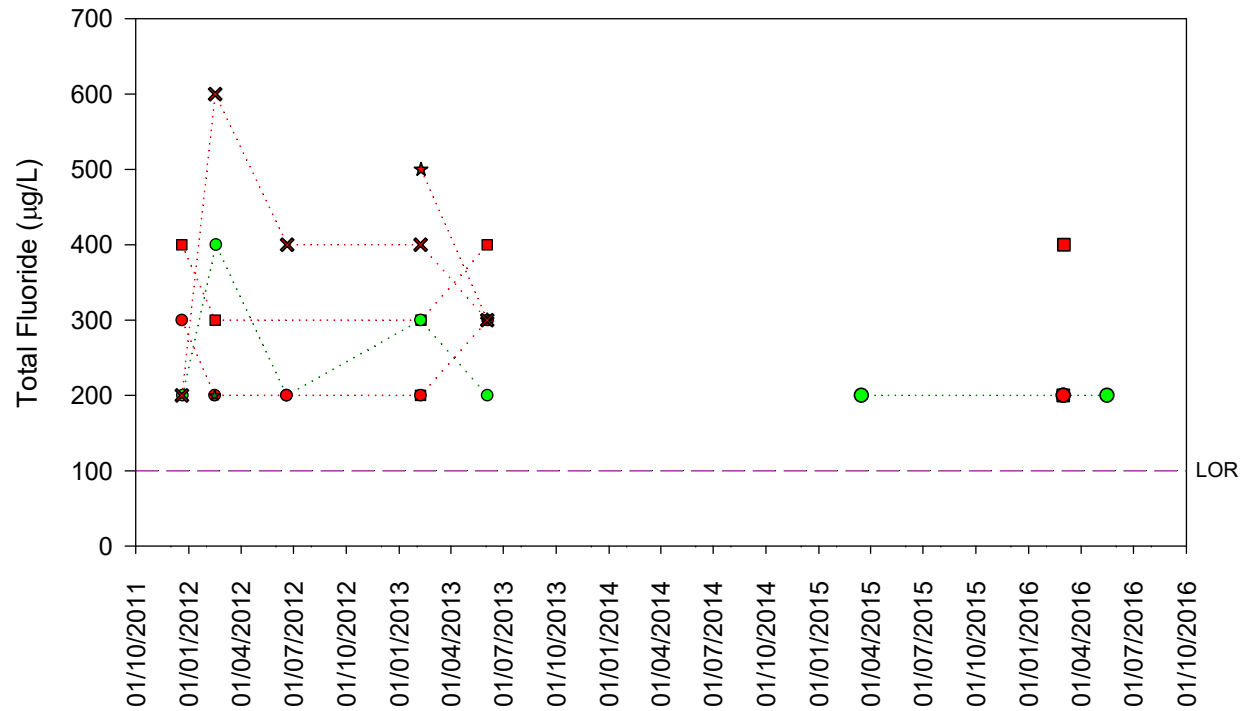
Dissolved and Total Recoverable Mercury ($\mu\text{g/L}$)



Note: The Limit of Reporting of MP8-Spring Ck DS (December 2011) was 10 times higher than that of the other sites

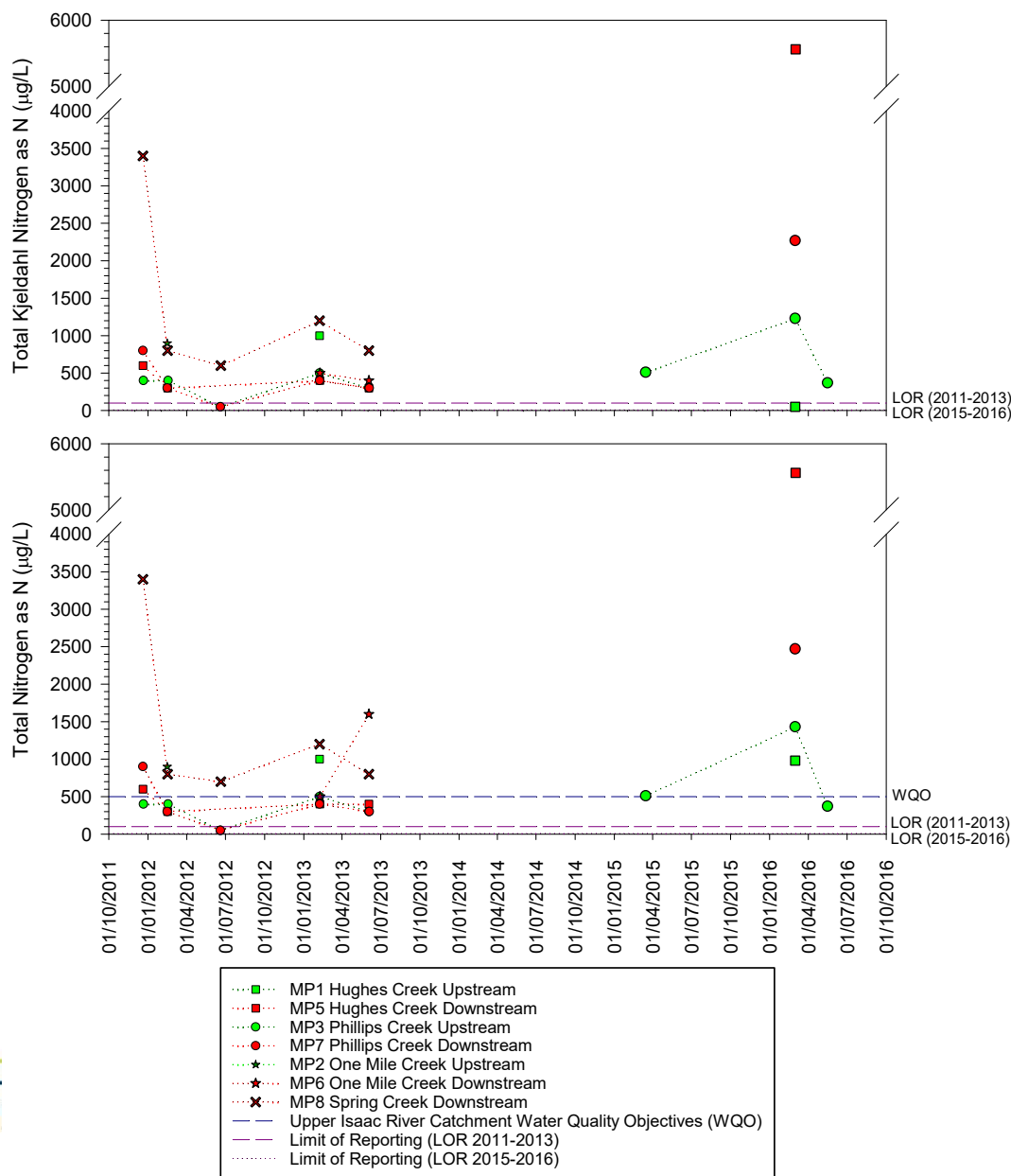


Total Fluoride ($\mu\text{g/L}$)



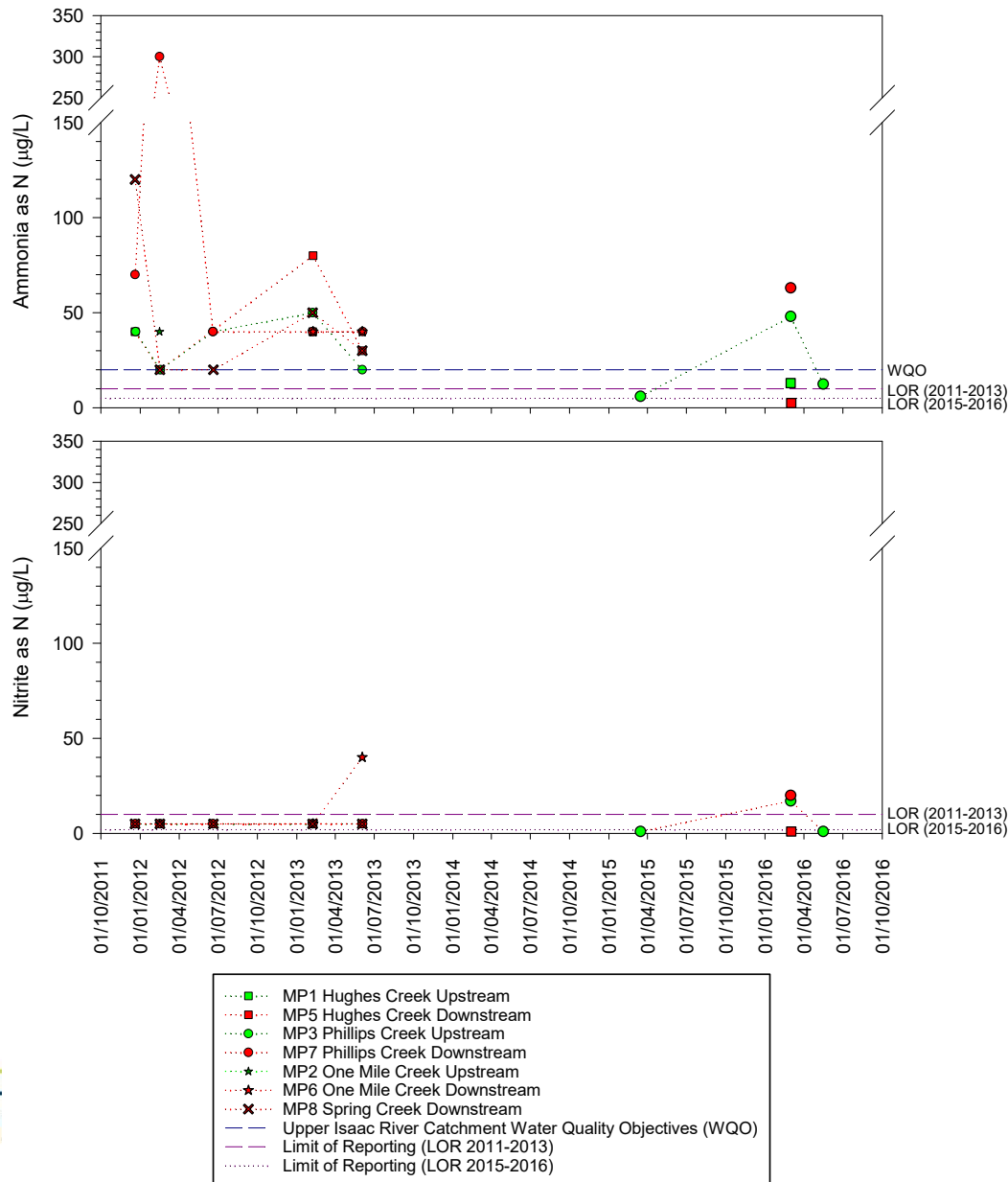
- MP1 Hughes Creek Upstream
- MP5 Hughes Creek Downstream
- MP3 Phillips Creek Upstream
- MP7 Phillips Creek Downstream
- MP2 One Mile Creek Upstream
- MP6 One Mile Creek Downstream
- MP8 Spring Creek Downstream
- Limit of Reporting (LOR)

Total Kjeldahl Nitrogen as N and Total Nitrogen as N ($\mu\text{g/L}$)



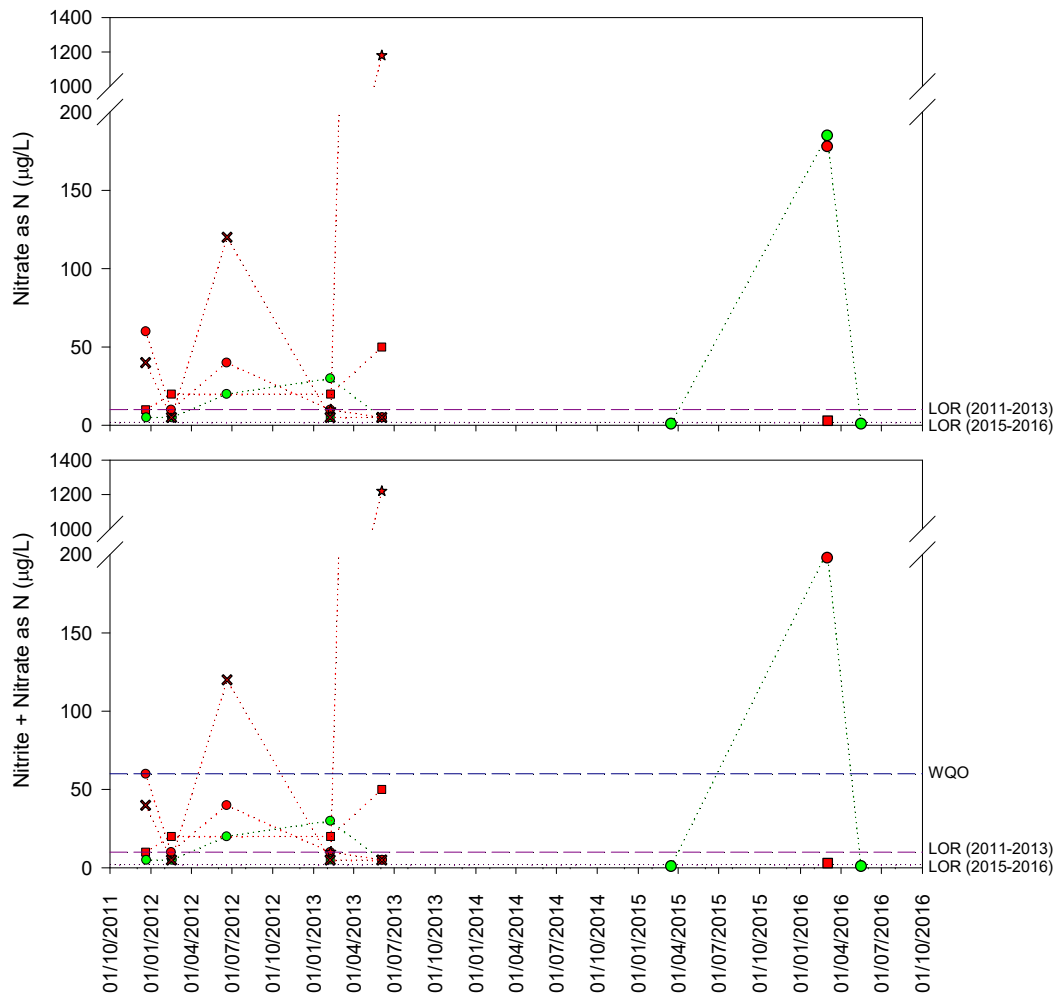
- MP8 Spring Ck DS exceeded the WQO for Total Nitrogen during all sampling runs. MP7 Phillips Ck DS (Dec11), MP5 Hughes Ck DS (Dec11), MP1 Hughes Ck US (Feb 13) and MP6 One Mile Ck DS (June 13) also exceeded the WQO for total Nitrogen.
- In 2015 and 2016 most results were above the WQO, particularly at the downstream sites MP5 Hughes Ck DS (Mar 16) and MP7 Phillips Ck DS (Mar 16).
- Two methods have been used for nutrient analysis. Each LOR has been noted where applicable.

Ammonia as N and Nitrite as N ($\mu\text{g/L}$)

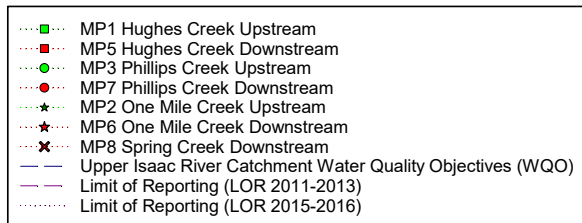


- Most concentrations of ammonia as N were at or above the Water Quality Objective for the Upper Isaac River Catchment.
- It should also be noted that cattle and pigs were often observed near downstream sites and this may contribute to the concentration of ammonia as N at these sites.
- Two methods have been used for nutrient analysis. Each LOR has been noted where applicable.

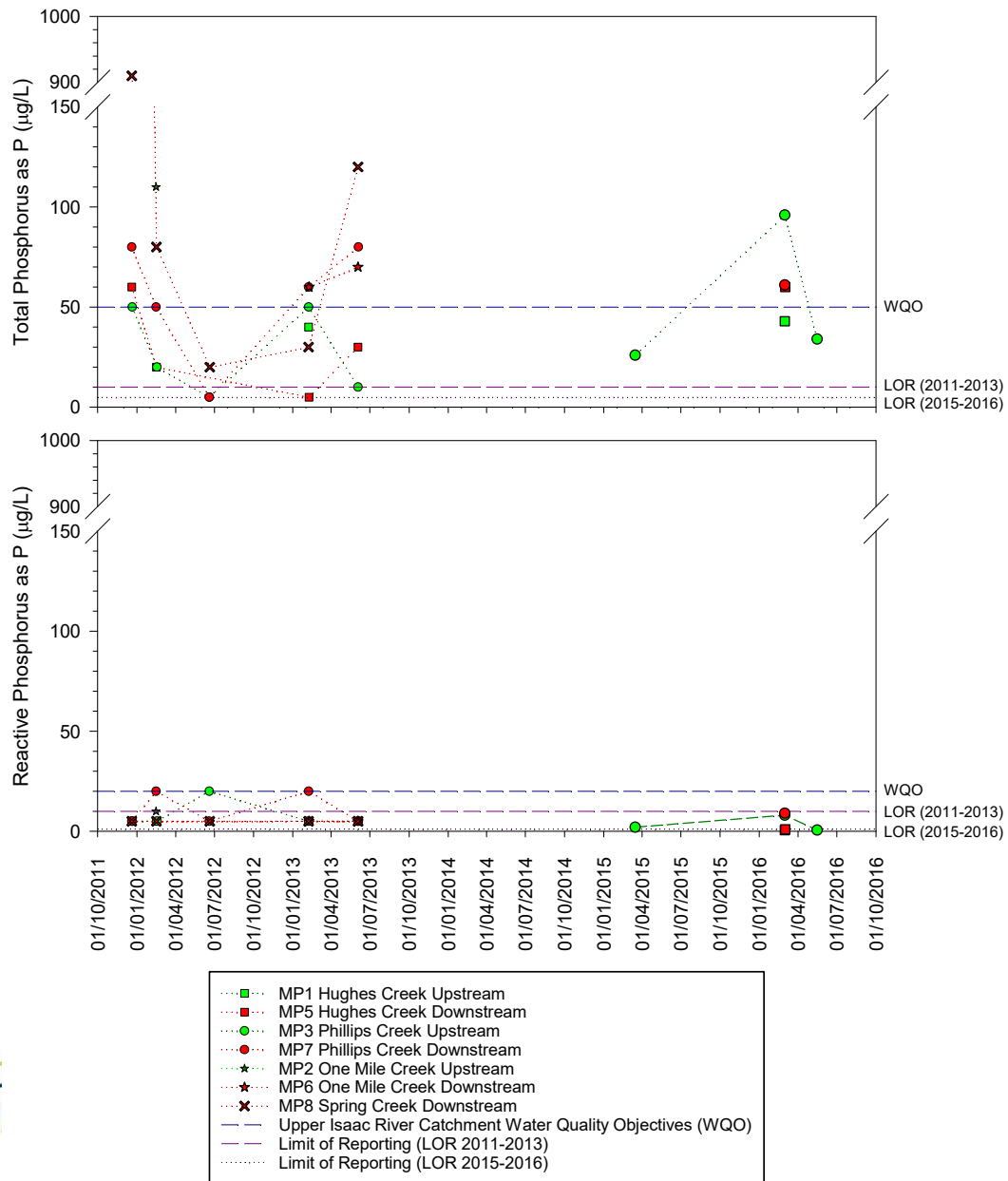
Nitrate as N and Nitrite + Nitrate as N ($\mu\text{g/L}$)



- Two methods have been used for nutrient analysis. Each LOR has been noted where applicable.



Total Phosphorus as P and Reactive Phosphorus as P ($\mu\text{g/L}$)



- Total Phosphorous exceeded the WQO at a number of sites on a number of occasions.
- Two methods have been used for nutrient analysis. Each LOR has been noted where applicable.

Site Names and Abbreviations

Please note for Primer analysis site names were abbreviated as follows:

Site Names	Abbreviations
MP1 Hughes Ck US	MP1 HCU
MP2 One Mile Ck US	MP2 OMU
MP3 Phillips Ck US	MP3 PCU
MP4 Spring Ck US	MP4 SCU
MP5 Hughes Ck DS	MP5 HCD
MP6 One Mile Ck DS	MP6 OMD
MP7 Phillips Ck DS	MP7 PCD
MP8 Spring Ck DS	MP8 SCD

Note: Two sites (MP3 Phillips Ck US Dec11 and MP8 Spring Ck DS Dec11) were removed from the following statistical results as they were missing results for DO.

PRINCIPAL COMPONENT ANALYSIS OF WATER RESULTS

2011-2016

Principal Component Analysis

The Eigenvalues show the percentage of variation in the results that is attributable to each principal component. The particular chemical results that are then correlated with each principal component (trend in the data) are listed on the following page.

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	11.2	21.2	21.2
2	9.55	18.0	39.2
3	5.79	10.9	50.1
4	3.97	7.5	57.6
5	3.6	6.8	64.4

PCA OF WATER RESULTS 2011-2016 SHOWING EIGENVECTORS

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
pH	0.001	0.120	-0.307	0.110	0.033
EC	0.045	0.215	-0.055	0.183	0.185
DO	-0.044	0.051	-0.243	0.108	0.048
ORP	0.045	0.146	-0.082	0.063	-0.015
Turb	0.258	-0.010	-0.059	0.085	0.034
Temp	0.011	-0.112	-0.025	0.166	-0.002
SS	0.178	-0.042	0.038	0.218	-0.062
CO3 Alk	-0.134	0.112	-0.104	-0.026	-0.062
HCO3 Alk	-0.142	0.136	0.153	0.207	0.021
Tot Alk	-0.151	0.141	0.117	0.179	0.006
SO4	0.165	0.193	-0.021	-0.038	0.049
Cl	0.050	0.271	0.016	0.110	0.098
Ca	-0.081	0.102	0.261	0.189	0.086
Mg	-0.167	0.147	0.128	0.214	0.075
Na	0.132	0.260	-0.057	-0.011	0.043
K	0.162	0.103	0.161	-0.171	-0.217
Dis Al	0.168	-0.173	-0.075	0.164	0.006
Dis As	0.061	-0.072	0.177	-0.334	0.062
Dis B	0.115	0.241	0.134	0.022	-0.014
Dis Cd	0.067	0.135	0.055	0.173	0.044
Dis Cr	0.001	0.007	-0.036	-0.008	-0.028
Dis Co	-0.021	-0.060	0.287	-0.099	0.233
Dis Cu	0.229	0.062	-0.001	0.118	-0.063
Dis Fe	0.008	-0.180	0.117	-0.214	0.082
Dis Mn	-0.053	-0.023	0.319	0.017	0.259
Dis Mo	0.202	0.168	-0.082	-0.174	0.029
Dis Ni	0.083	-0.099	0.120	0.083	-0.080
Dis Se	0.113	0.169	0.017	-0.259	-0.008
Dis U	0.096	0.211	0.123	0.087	-0.072
Dis V	-0.127	0.005	-0.061	0.073	-0.022
Dis Zn	-0.104	-0.004	-0.111	-0.061	-0.052
Tot Al	0.228	-0.104	-0.106	0.166	0.063
Tot As	0.170	-0.177	0.145	-0.112	0.042
Tot B	0.113	0.255	0.096	-0.029	0.005
Tot Cr	0.216	-0.136	-0.042	0.113	0.140
Tot Co	0.183	-0.065	0.254	-0.028	0.094
Tot Cu	0.261	-0.087	-0.026	0.091	-0.029
Tot Fe	0.225	-0.166	-0.014	0.097	0.099
Tot Pb	0.197	-0.168	-0.079	0.188	0.047
Tot Mn	-0.043	-0.020	0.332	0.032	0.236
Tot Mo	0.194	0.170	-0.080	-0.192	0.020
Tot Ni	0.217	-0.140	0.079	0.099	-0.012
Tot Se	0.113	0.169	0.017	-0.259	-0.008
Tot U	0.089	0.211	0.114	0.105	-0.065
Fl	0.158	0.195	-0.098	-0.142	0.057
NH4-N	-0.049	-0.071	-0.110	-0.111	-0.021
NO2-N	0.020	-0.016	0.183	0.054	-0.452
NO3-N	0.031	-0.009	0.141	0.060	-0.446
NO2-N + NO3-N	0.030	-0.011	0.147	0.060	-0.450
TKN	0.100	-0.032	0.008	-0.007	0.053
Tot N-N	0.112	-0.034	0.025	0.010	-0.041
Tot P-P	0.137	-0.056	-0.038	-0.096	-0.026
Reac P-P	-0.124	-0.045	-0.098	-0.108	-0.046

- The highlighted numbers in columns correspond with the parameters that are highly positively or negatively correlated with the first (yellow), second (cyan) and third (green) principal component.
- Where two LOR results from different analytical methods pertained to the one nutrient, the highest LOR was applied to data used in analysis.
- Dissolved Pb and Ag, total Cd, Ag, V and Zn were removed from the PCA data as either a complete data set was not available or no results were detected above the limit of reporting.

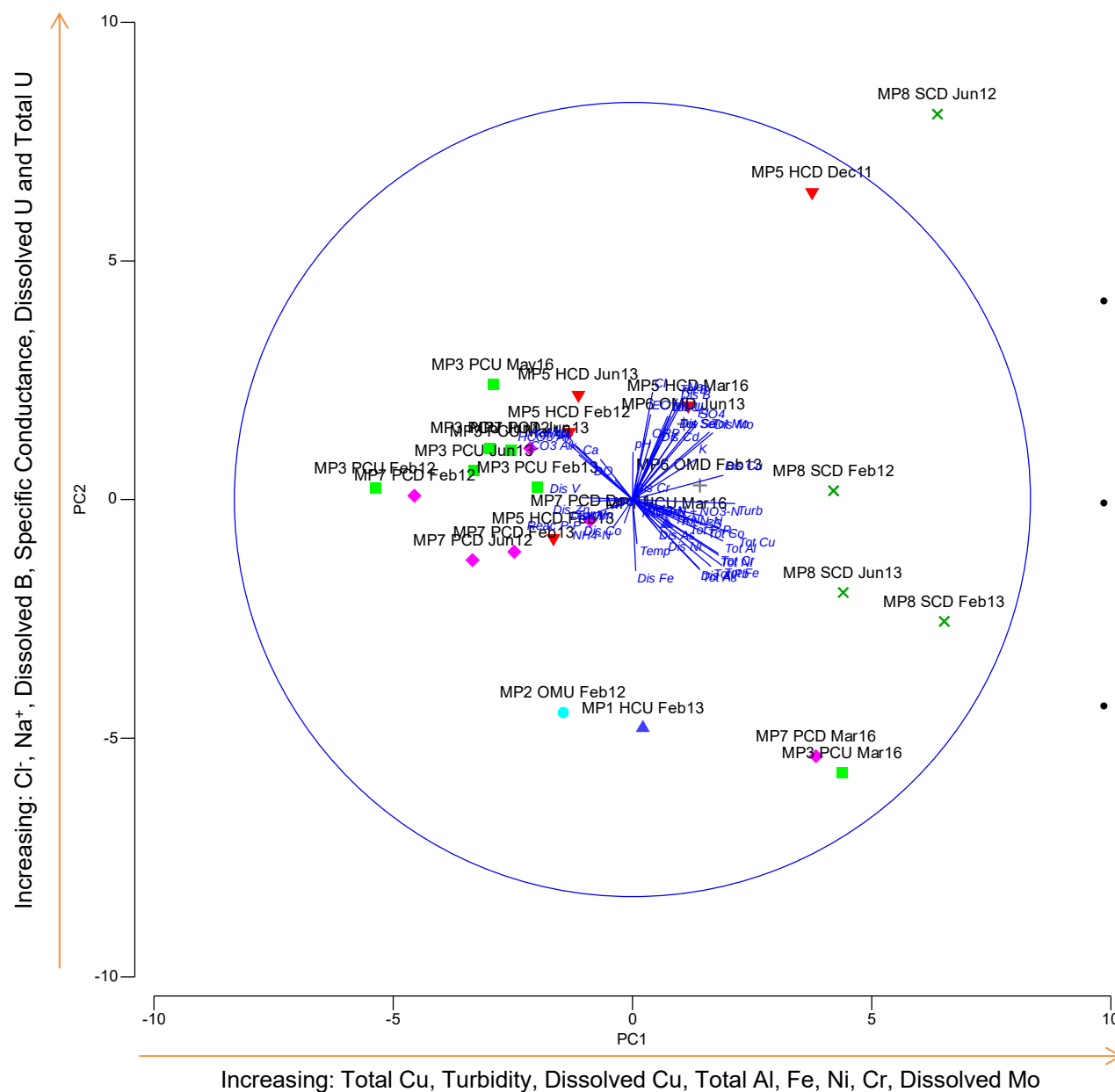
PRINCIPAL COMPONENT SCORES OF WATER RESULTS 2011-2016

Principal Component Scores

Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
MP1 HCUFeb13	0.216	-4.78	6.08	-3.31	2.94
MP5 HCDDec11	3.76	6.44	1.58	3.44	0.787
MP5 HCDFeb12	-1.32	1.42	-1.18	-0.327	-0.384
MP5 HCDFeb13	-1.65	-0.809	1.14	-1.71	0.536
MP5 HCDJun13	-1.13	2.19	-1.16	-0.669	0.145
MP3 PCUFeb12	-5.37	0.235	-1.19	0.369	-0.353
MP3 PCUJun12	-2.98	1.08	-1.12	0.0211	0.026
MP3 PCUFeb13	-1.98	0.261	-0.534	-0.0965	0.0161
MP3 PCUJun13	-3.32	0.619	-1.04	0.668	0.341
MP7 PCDDec11	-0.884	-0.435	-0.862	0.149	-0.577
MP7 PCDFeb12	-4.56	0.0815	-1.26	1.64	-0.205
MP7 PCDJun12	-3.34	-1.27	-2.56	-1.99	-0.698
MP7 PCDFeb13	-2.47	-1.1	-1.34	-0.639	-0.352
MP7 PCDJun13	-2.14	1.07	-1.58	0.223	0.245
MP2 OCUFeb12	-1.45	-4.46	0.952	-3.94	0.0697
MP6 OCDFeb13	1.41	0.297	-1.95	-1.11	0.621
MP6 OCDJun13	1.08	1.58	-1.3	-0.0429	-1.62
MP8 SCDFeb12	4.2	0.185	-2.39	1.65	1.01
MP8 SCDJun12	6.37	8.08	0.483	-5.14	-0.14
MP8 SCDFeb13	6.52	-2.55	-0.00822	0.18	0.802
MP8 SCDJun13	4.41	-1.95	-2.07	0.783	0.814
MP3 Phillips Ck US Mar 15	-2.55	1.02	0.702	1.77	0.648
MP1 Hughes Ck US Mar 16	0.714	-0.508	5.46	0.918	-7.97
MP5 Hughes Ck DS Mar 16	1.17	1.97	0.219	-0.18	-0.0232
MP3 Phillips Ck US Mar 16	4.39	-5.71	-0.639	2.41	-0.0145
MP3 Phillips Ck US May 16	-2.91	2.42	6.45	3.06	3.61
MP7 Phillips Ck DS Mar 16	3.83	-5.38	-0.885	1.89	-0.283

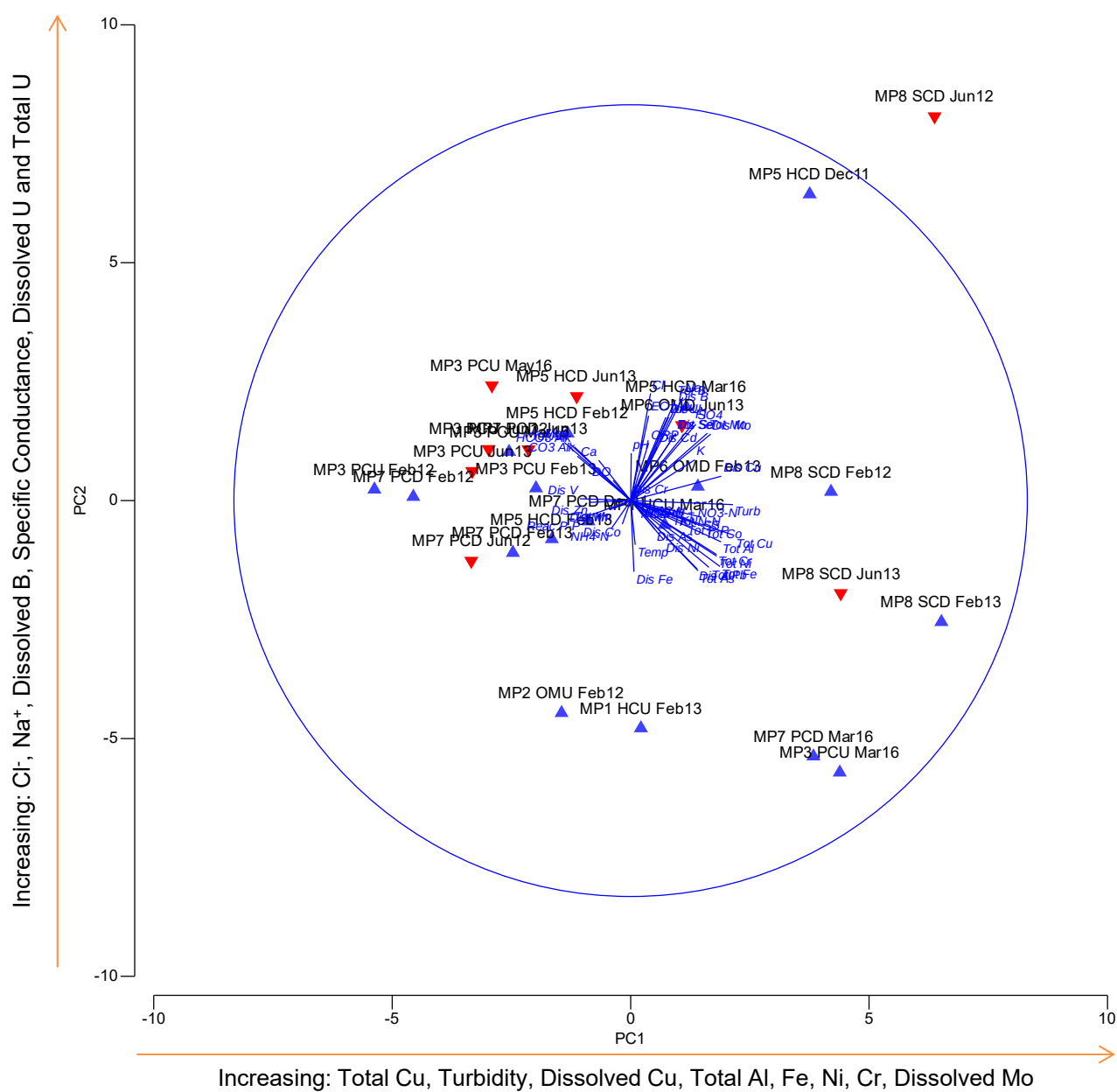


PCA graph of PC1 and PC2 of Water (2011-2016) by SITES



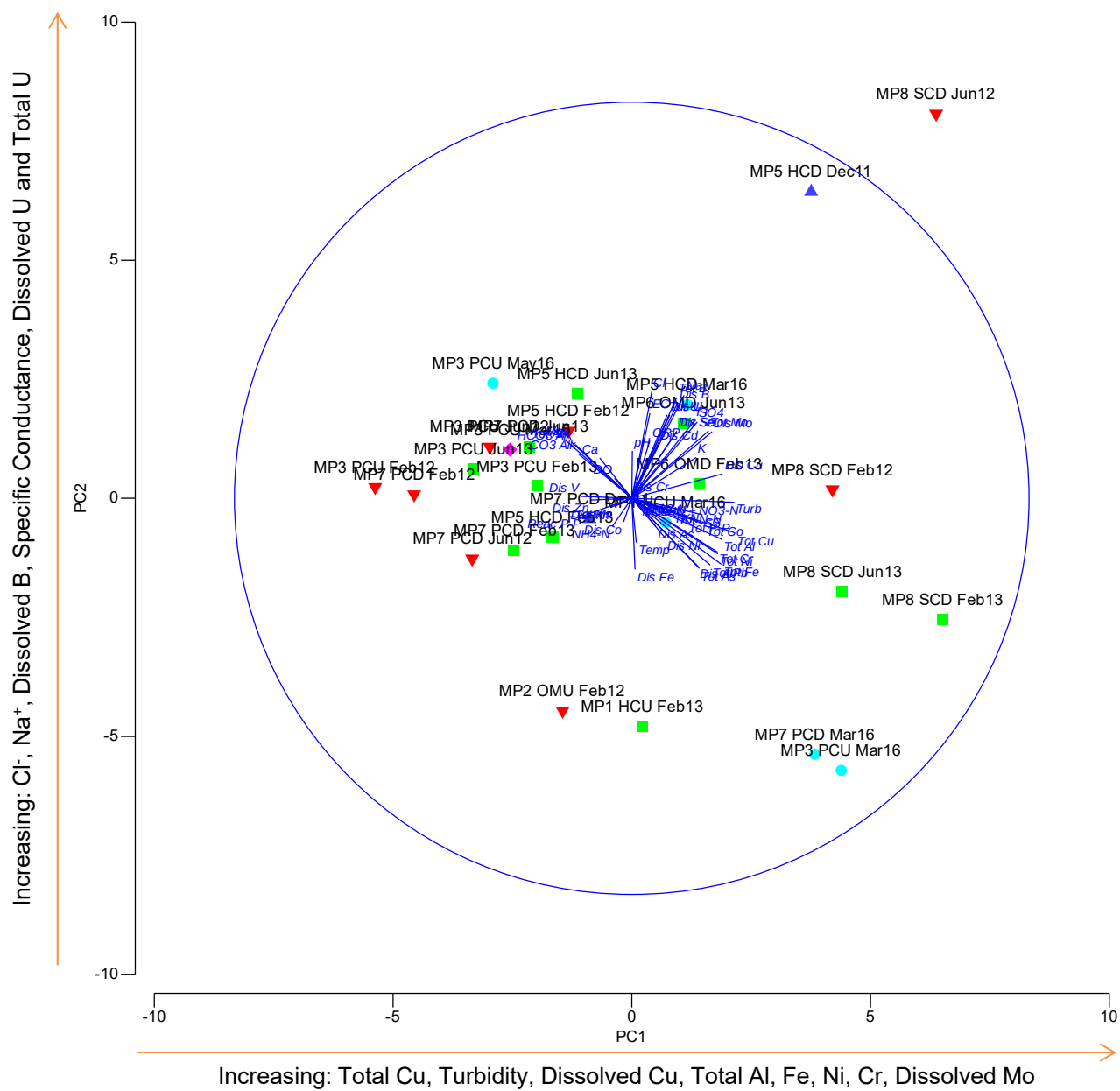
- The first principal component (PC1) explained 21.2 % of the variation in the data.
- The second principal component (PC2) explained 18.0 % of the variation in the data.
- MP8 SCD Jun12 and MP5 HCD Dec11 were separated from the cluster along the PC2 axis.

PCA graph of PC1 and PC2 of Water (2011-2016) by TIME

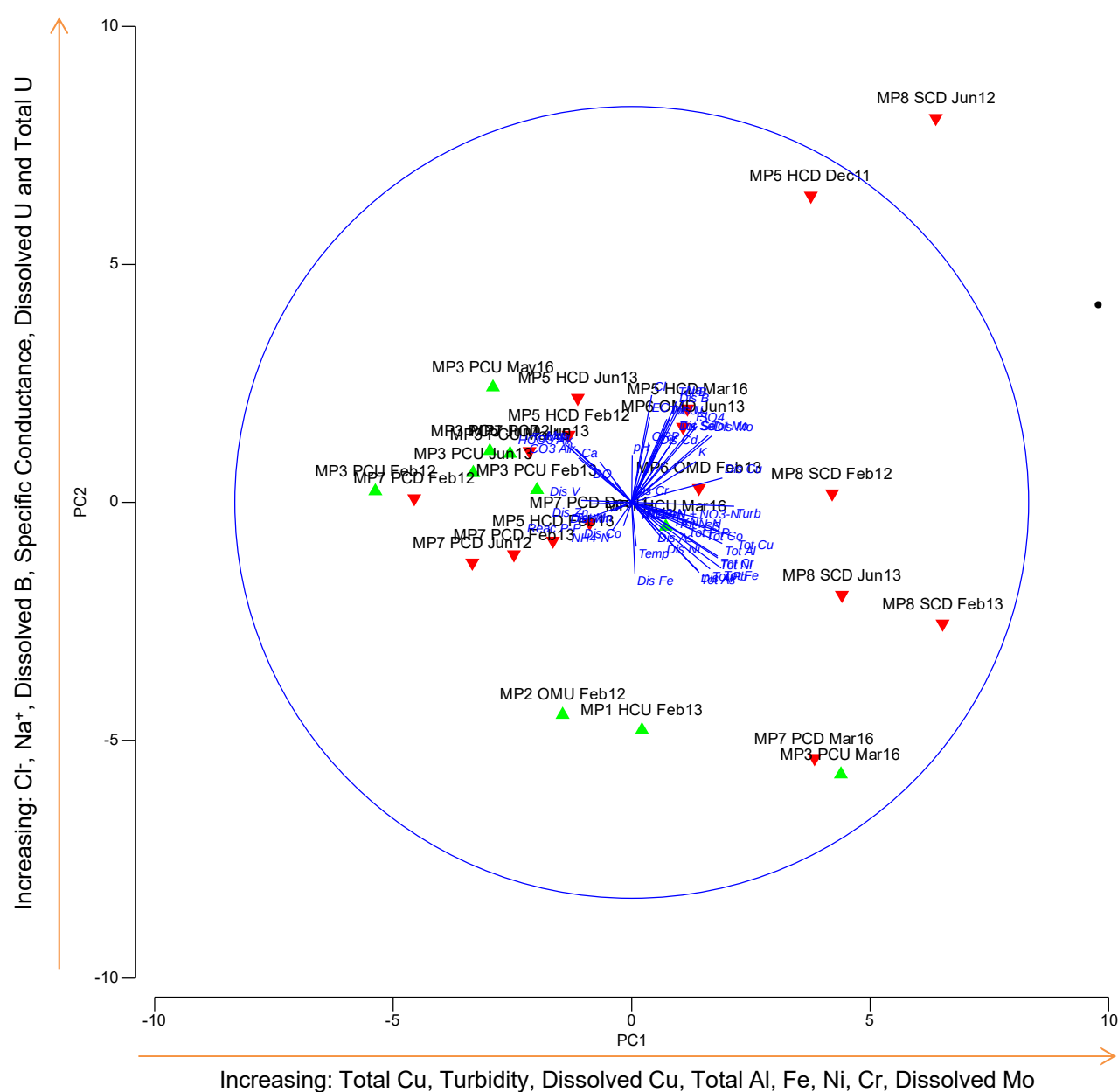


- No clear separation between early and late wet season results.

PCA graph of PC1 and PC2 of Water (2011-2016) by YEAR

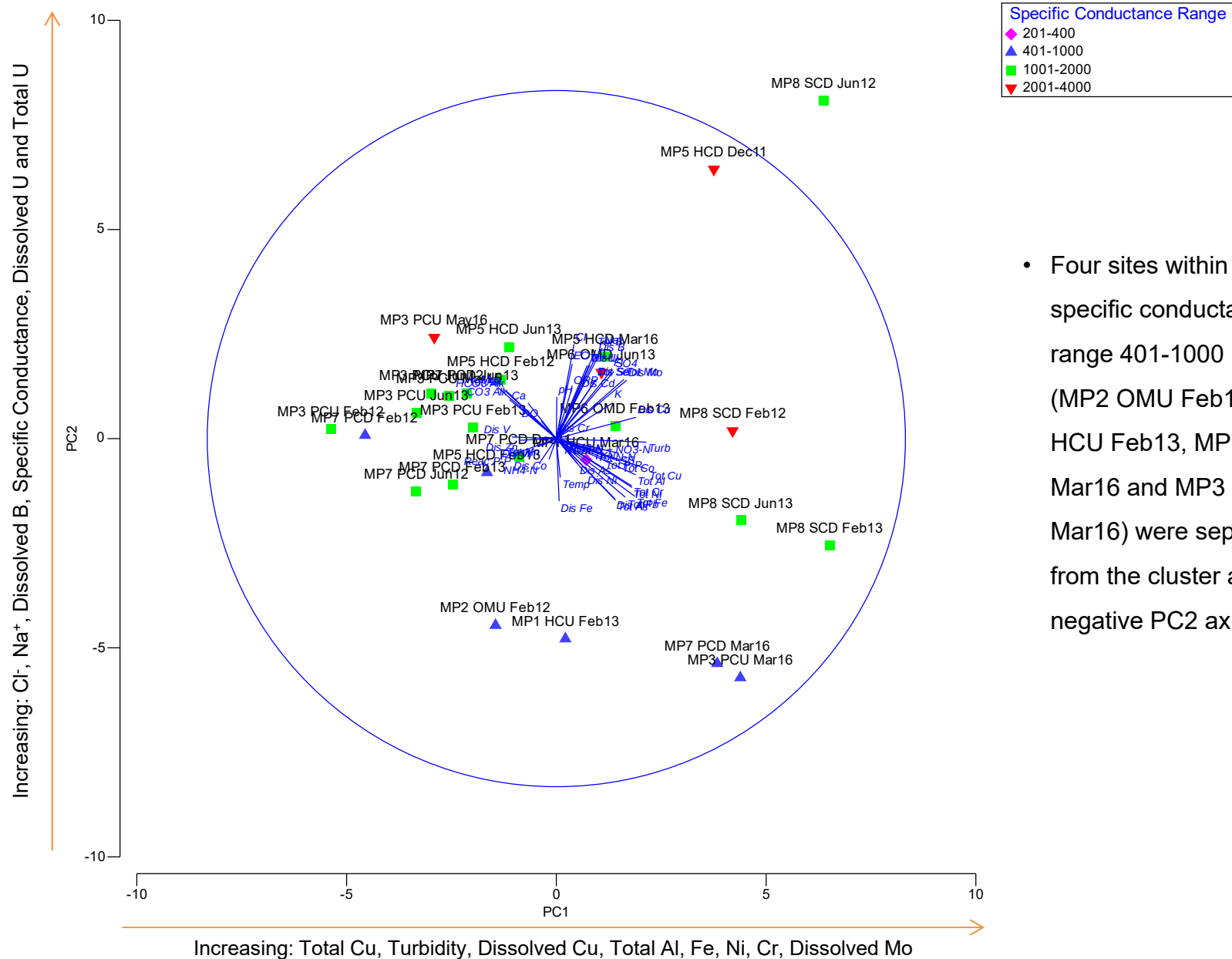


PCA graph of PC1 and PC2 of Water (2011-2016) by LOCATION

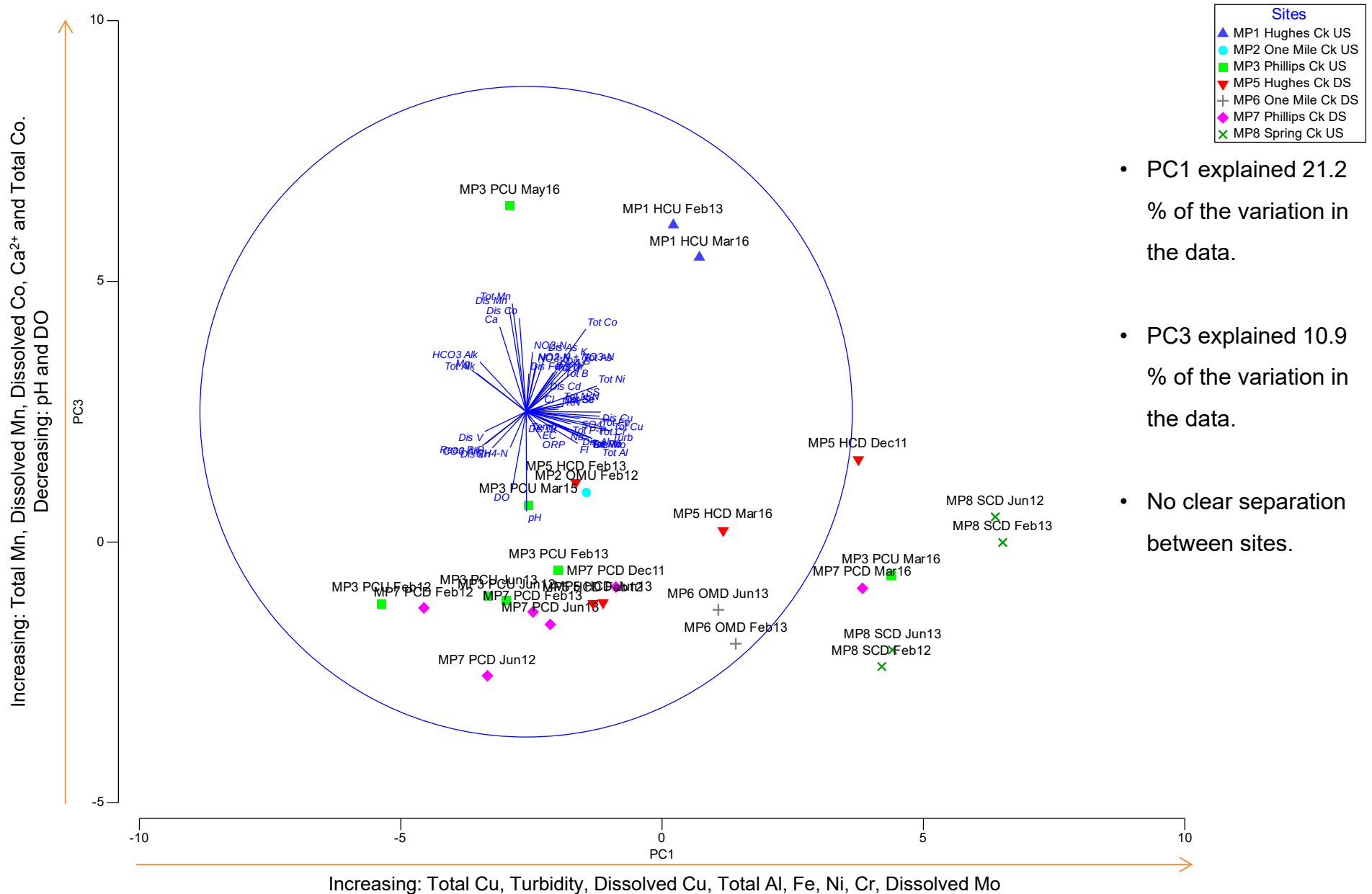


- No clear separation between upstream and downstream sites.

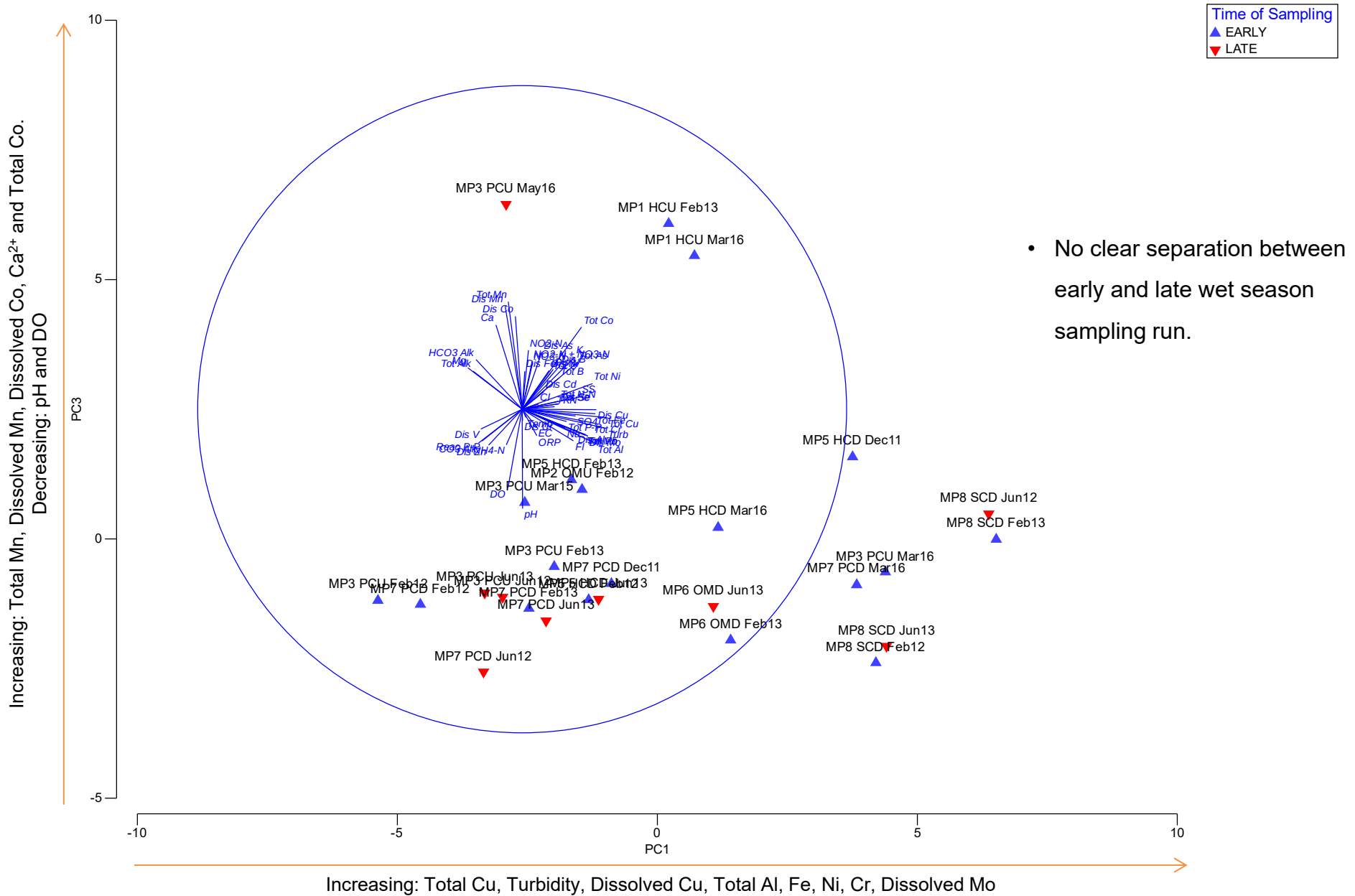
PCA graph of PC1 and PC2 of Water (2011-2016) by SPECIFIC CONDUCTANCE RANGE ($\mu\text{S}/\text{cm}$)



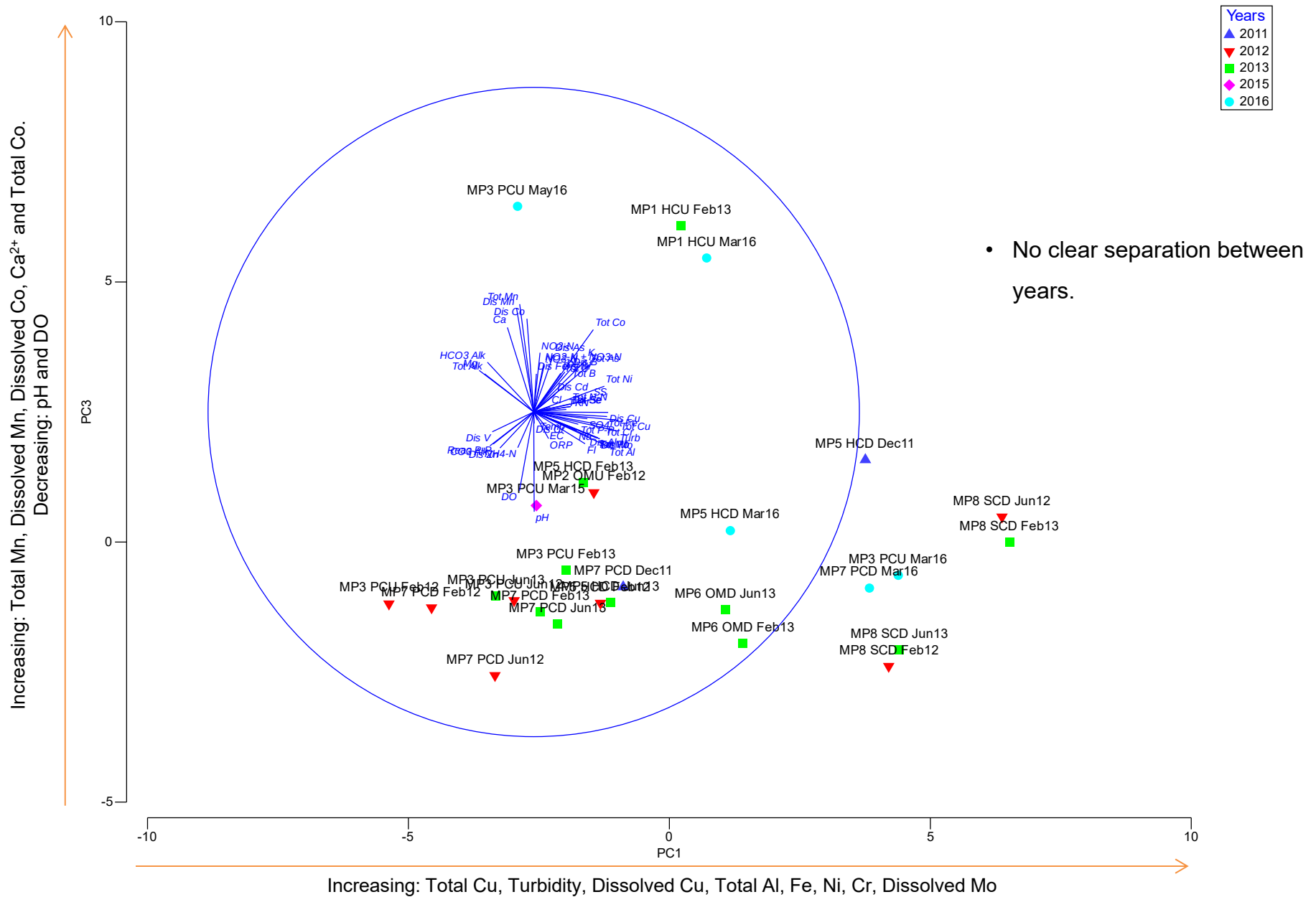
PCA graph of PC1 and PC3 of Water (2011-2016) by SITES



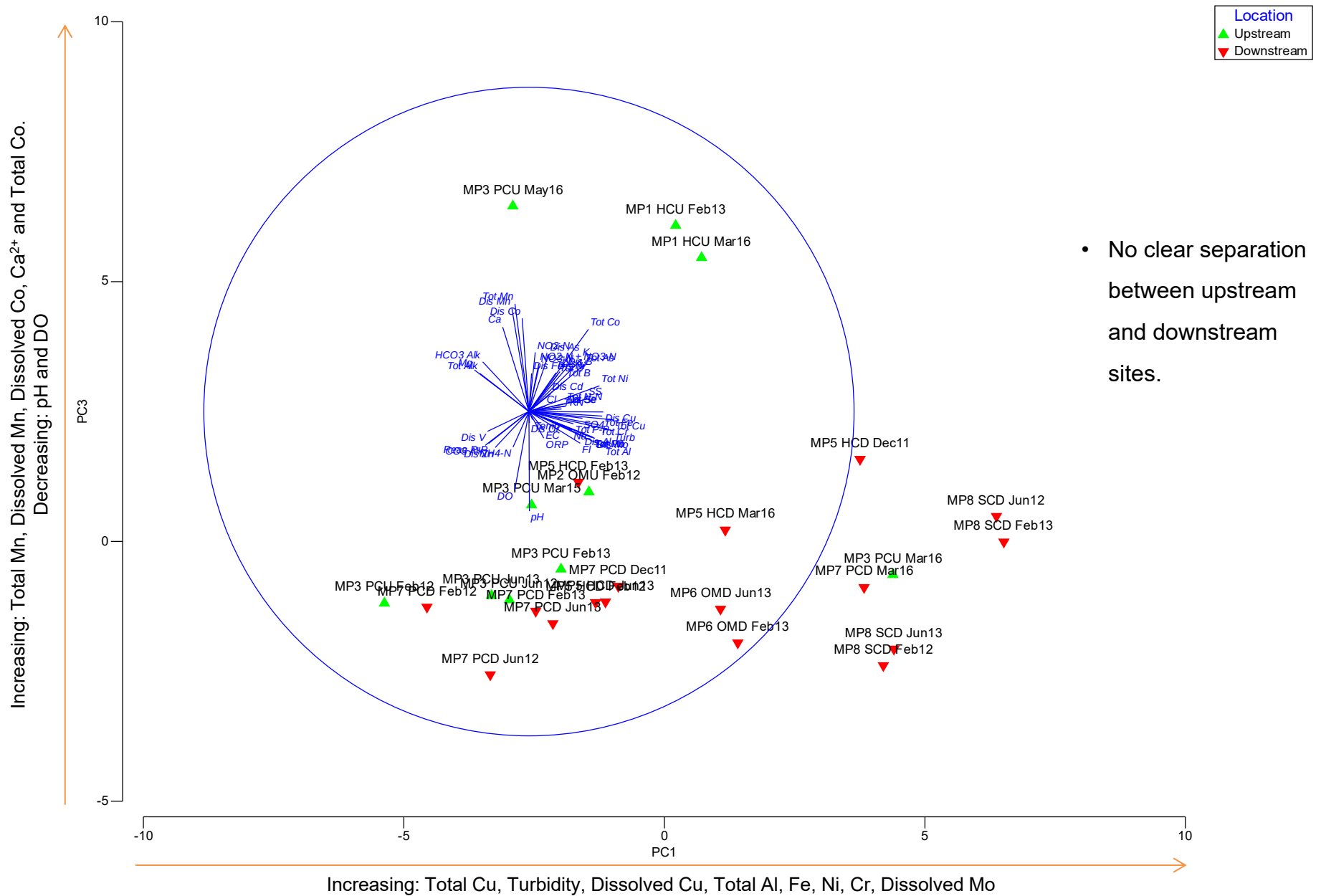
PCA graph of PC1 and PC3 of Water (2011-2016) by TIME



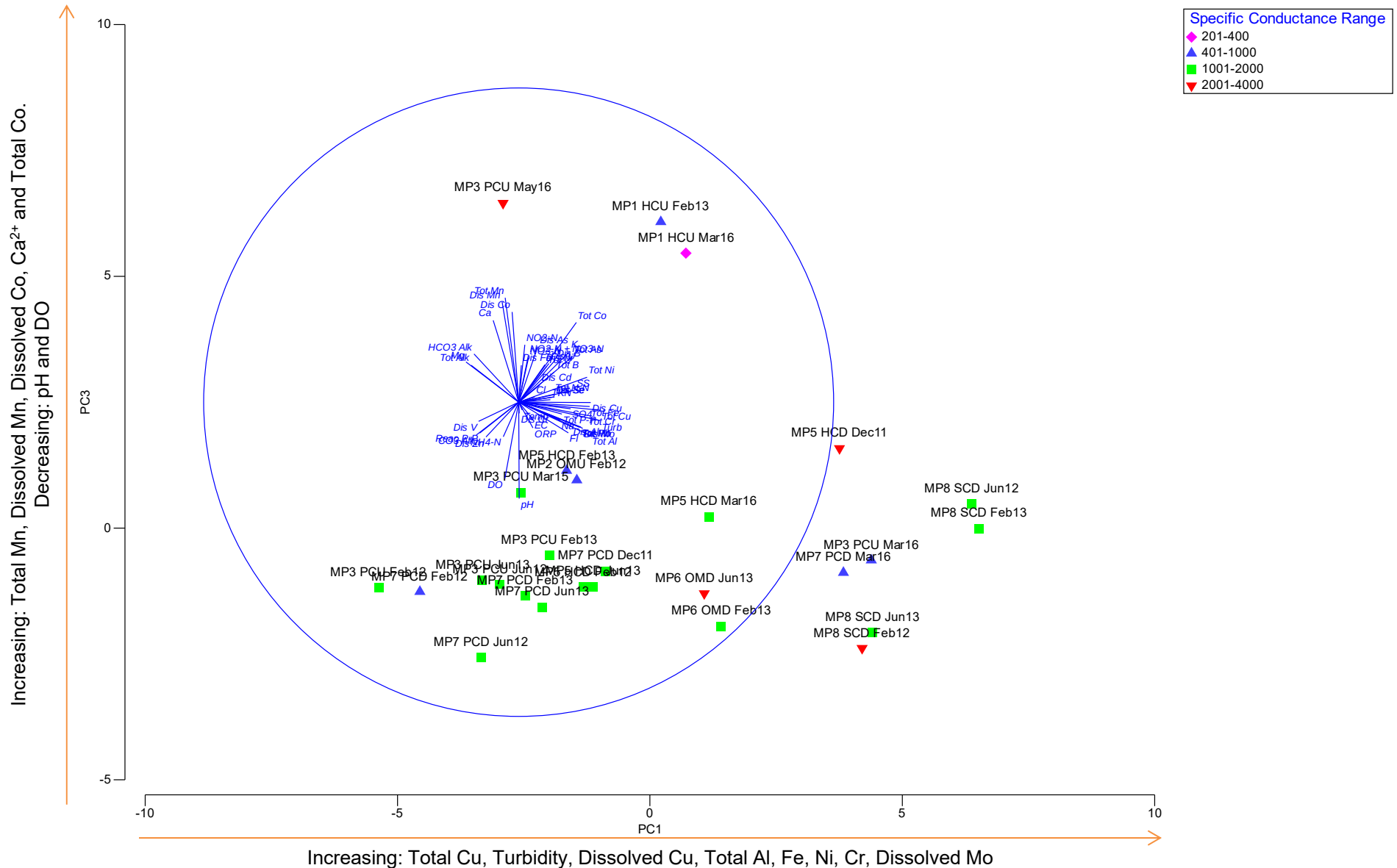
PCA graph of PC1 and PC3 of Water (2011-2016) by YEARS



PCA graph of PC1 and PC3 of Water (2011-2016) by LOCATION



CONDUCTANCE RANGE ($\mu\text{S}/\text{cm}$)



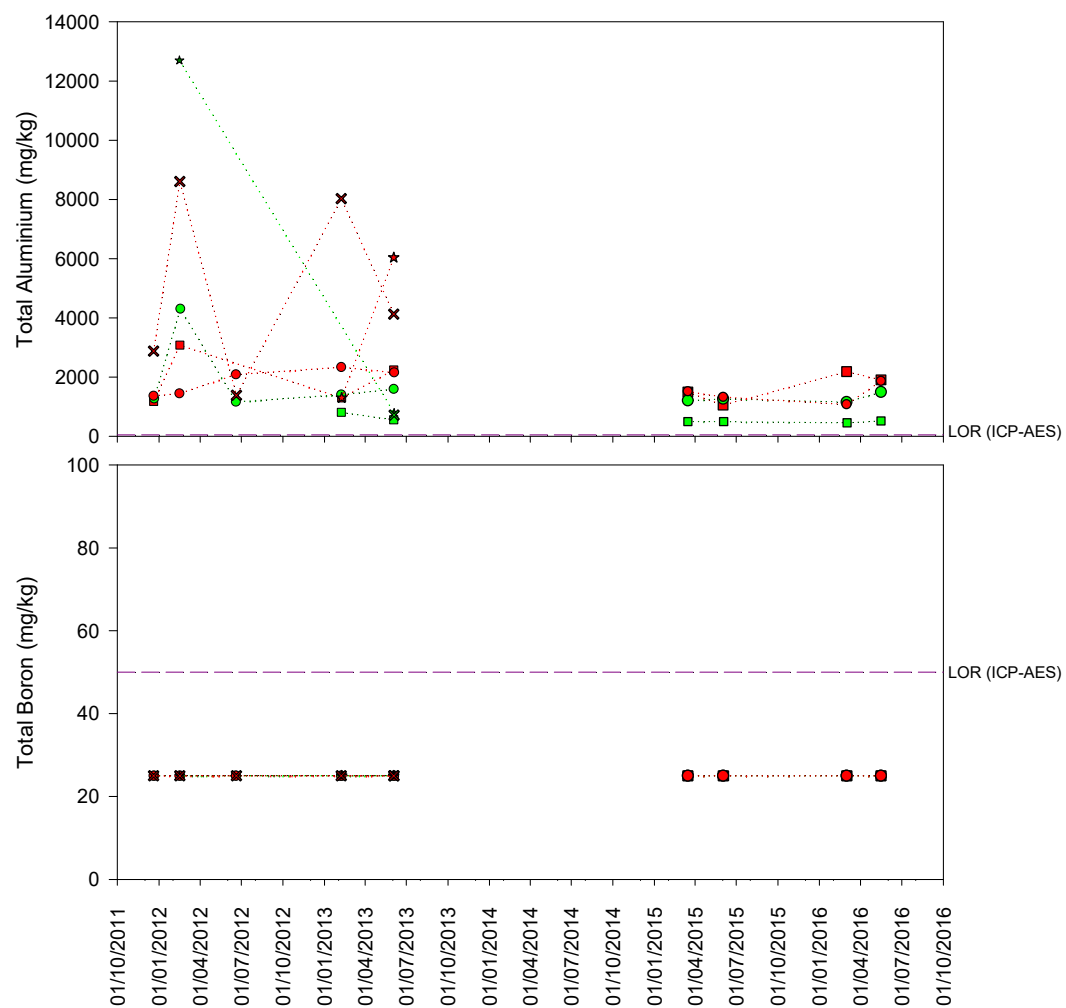
SRM Sediment Results

2011-2016

BE WHAT **YOU** WANT TO BE

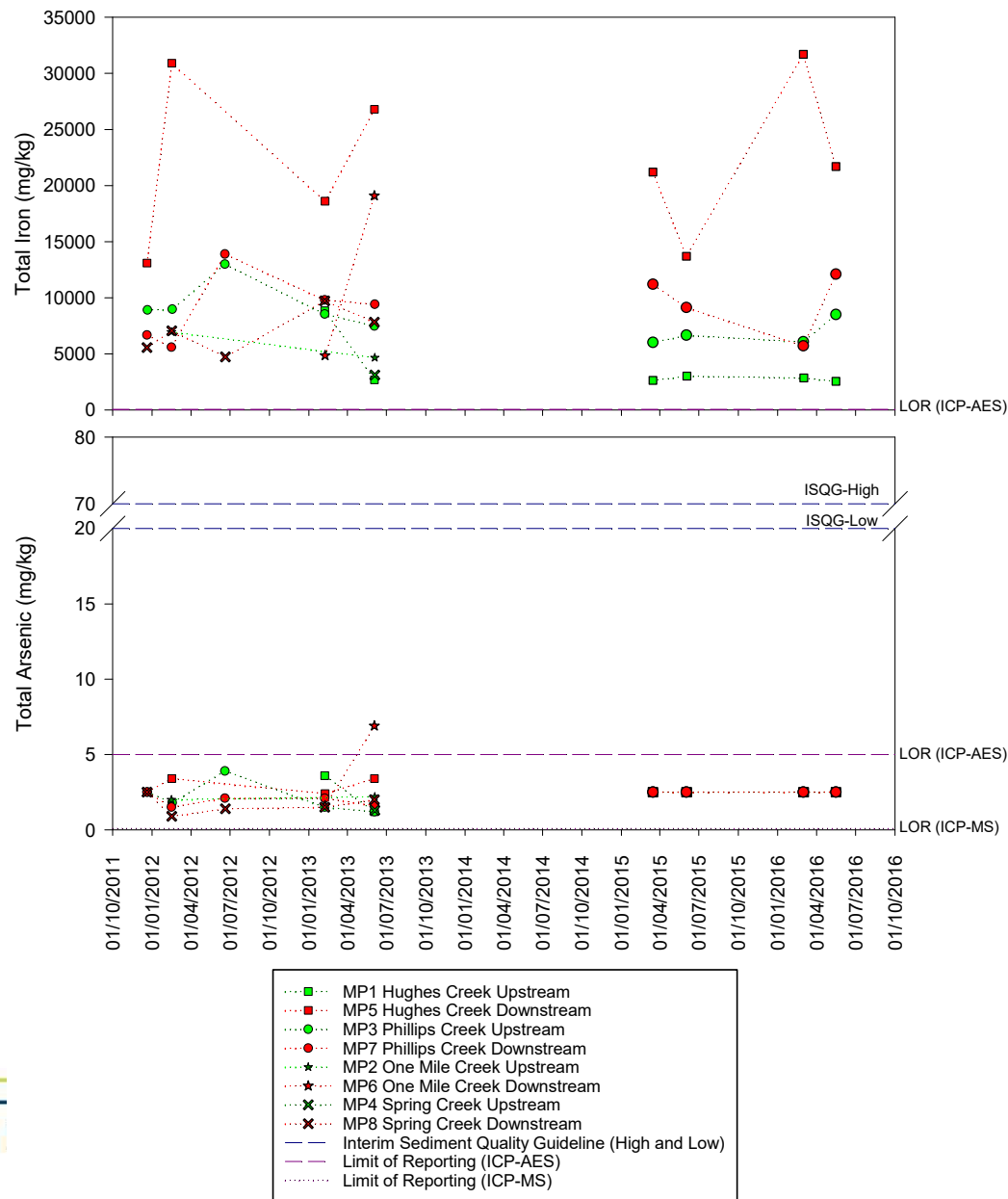


Total Aluminium and Total Boron (mg/kg)



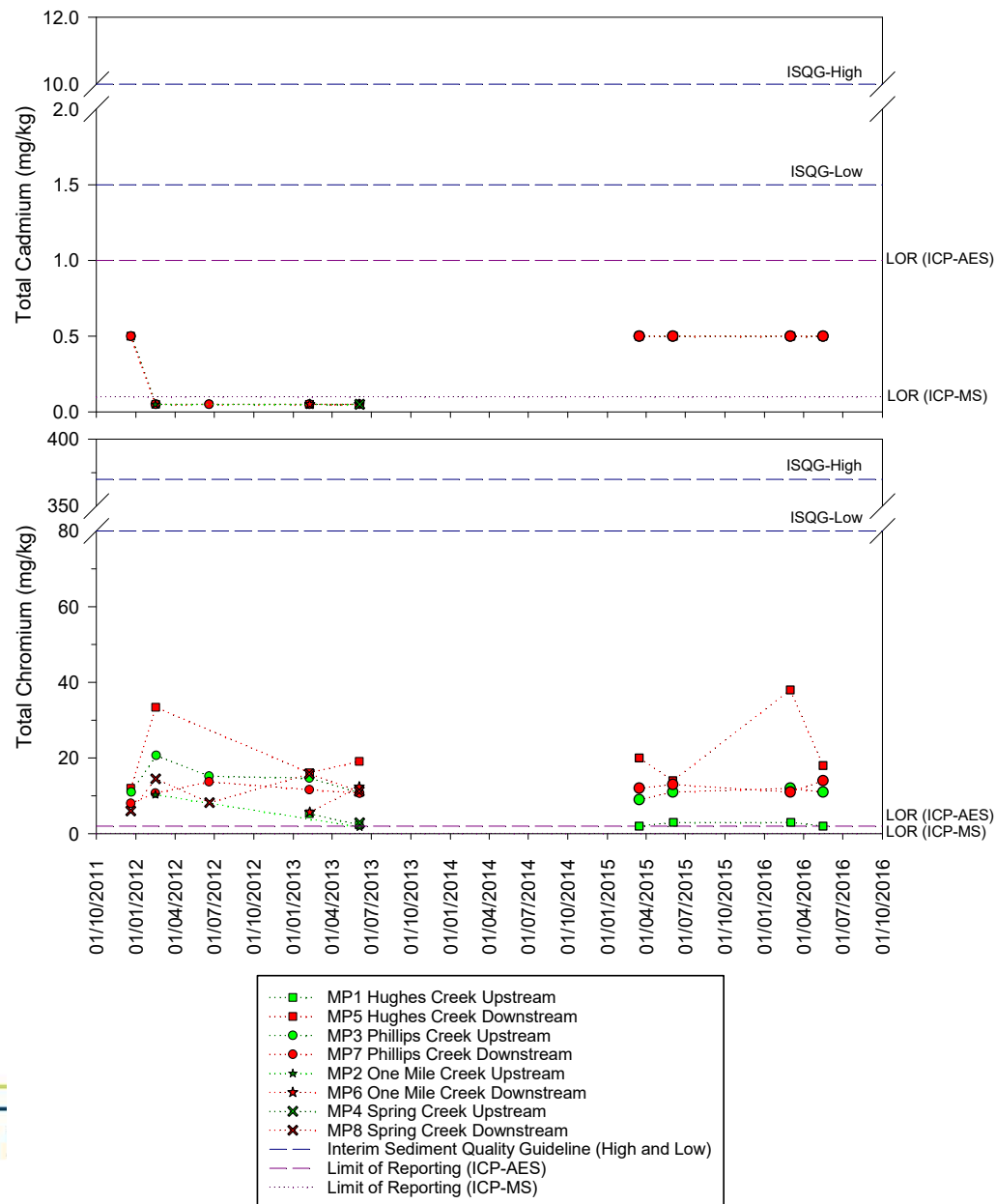
- MP1 Hughes Creek Upstream
- MP5 Hughes Creek Downstream
- MP3 Phillips Creek Upstream
- MP7 Phillips Creek Downstream
- MP2 One Mile Creek Upstream
- MP6 One Mile Creek Downstream
- MP4 Spring Creek Upstream
- MP8 Spring Creek Downstream
- Limit of Reporting (ICP-AES)

Total Iron and Total Arsenic (mg/kg)



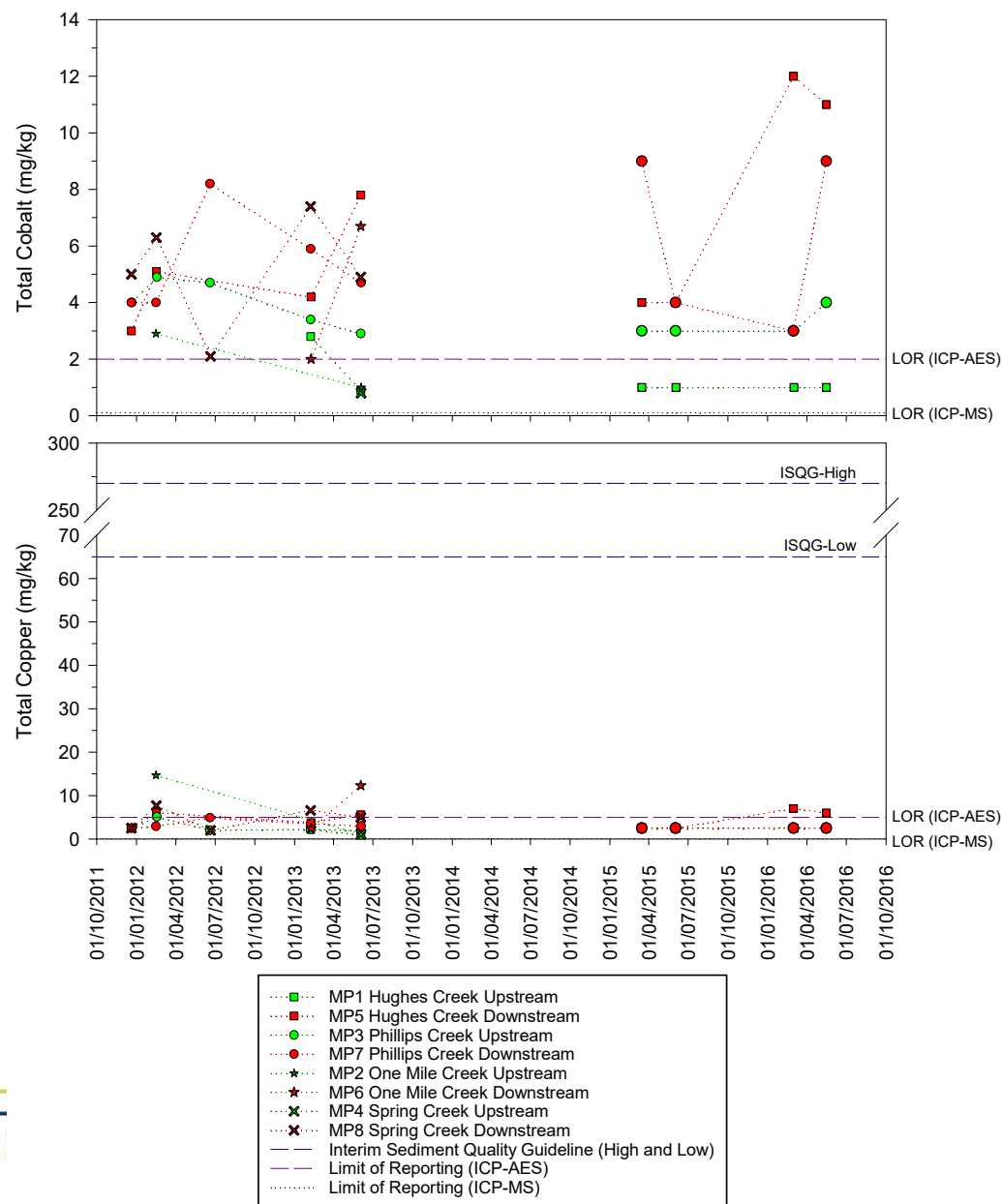
- All concentrations were below the ISQG (high and low) for Total Arsenic in Sediment
- Where concentrations were <LOR, half the LOR has been plotted
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable

Total Cadmium and Total Chromium (mg/kg)



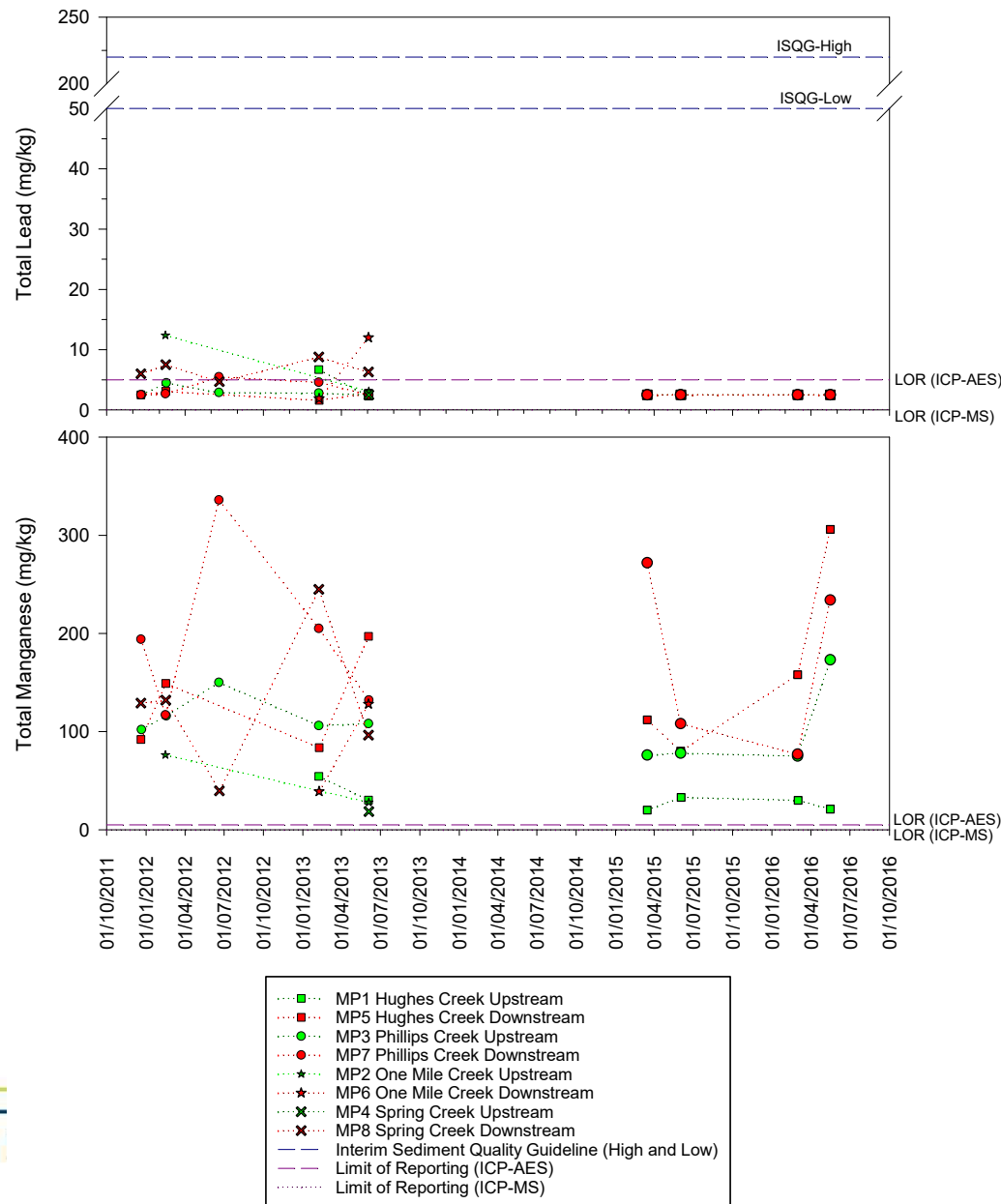
- All results were below the ISQG (high and low) for total cadmium and chromium.
- Where concentrations were <LOR, half the LOR has been plotted.
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable.

Total Cobalt and Total Copper (mg/kg)



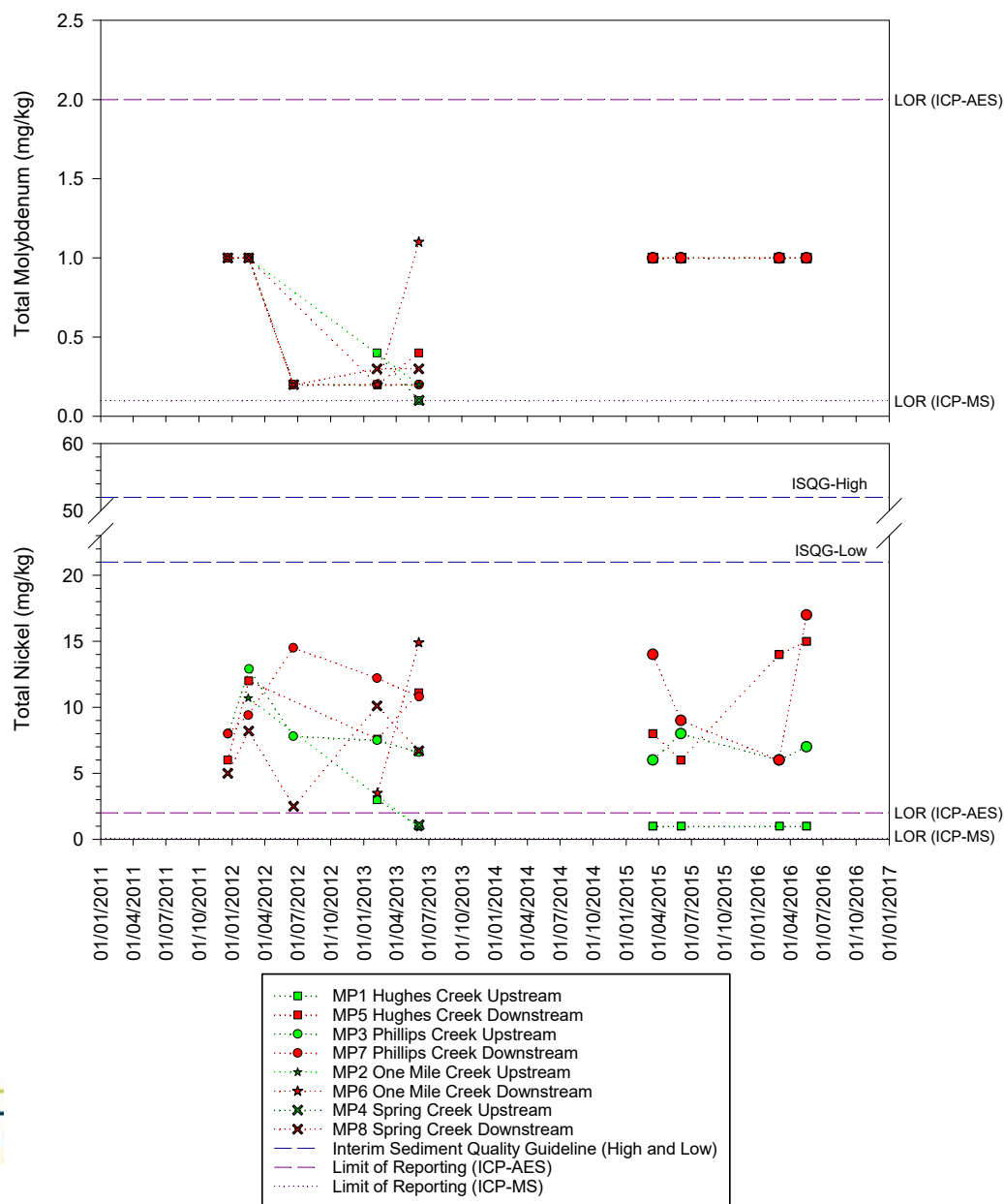
- All results were below the ISQG (high and low) for total copper.
- Where concentrations were <LOR, half the LOR has been plotted.
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable.

Total Lead and Total Manganese (mg/kg)



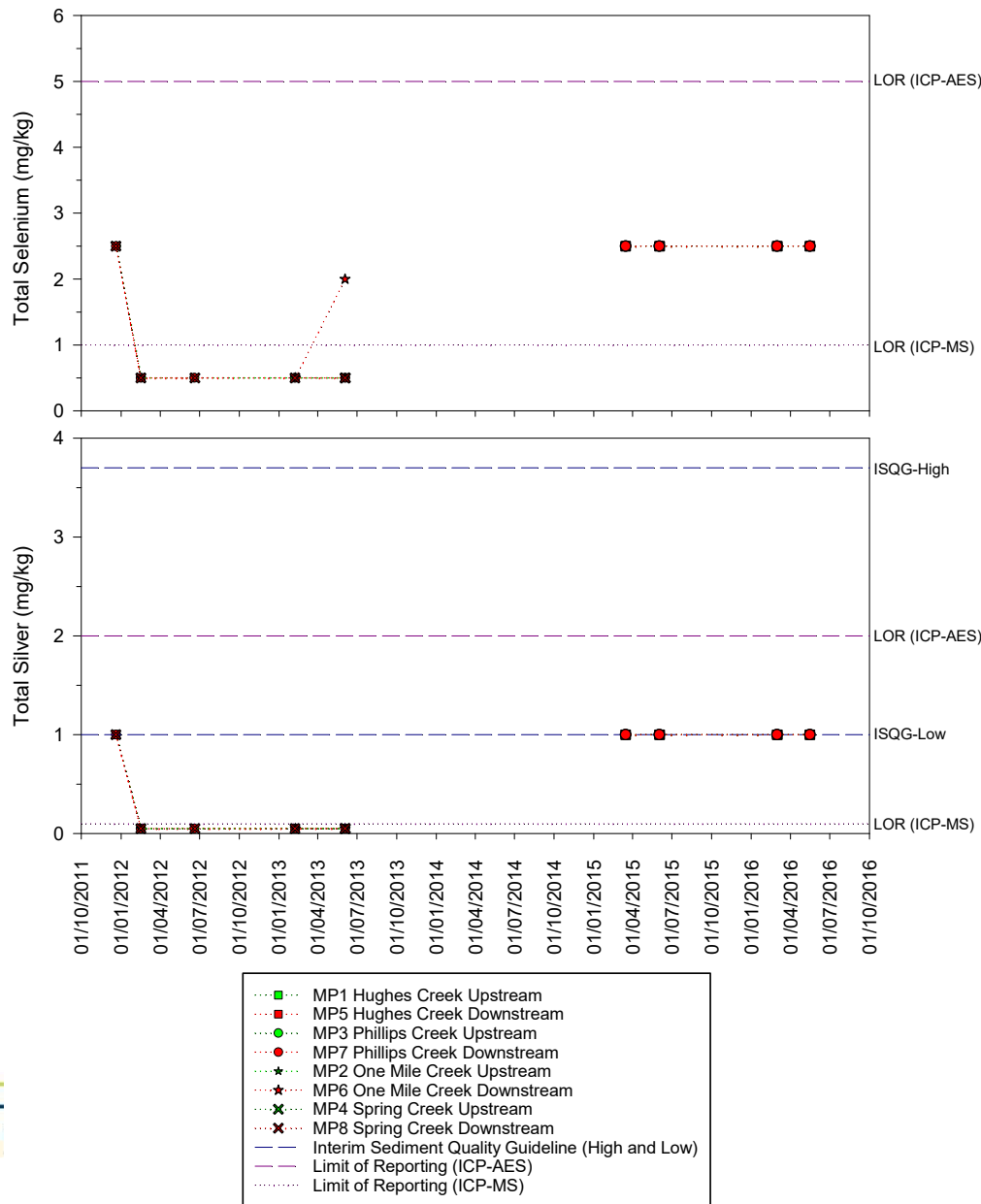
- All results were below the ISQG (high and low) for total lead.
- Where concentrations were <LOR, half the LOR has been plotted.
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable.

Total Molybdenum and Total Nickel (mg/kg)



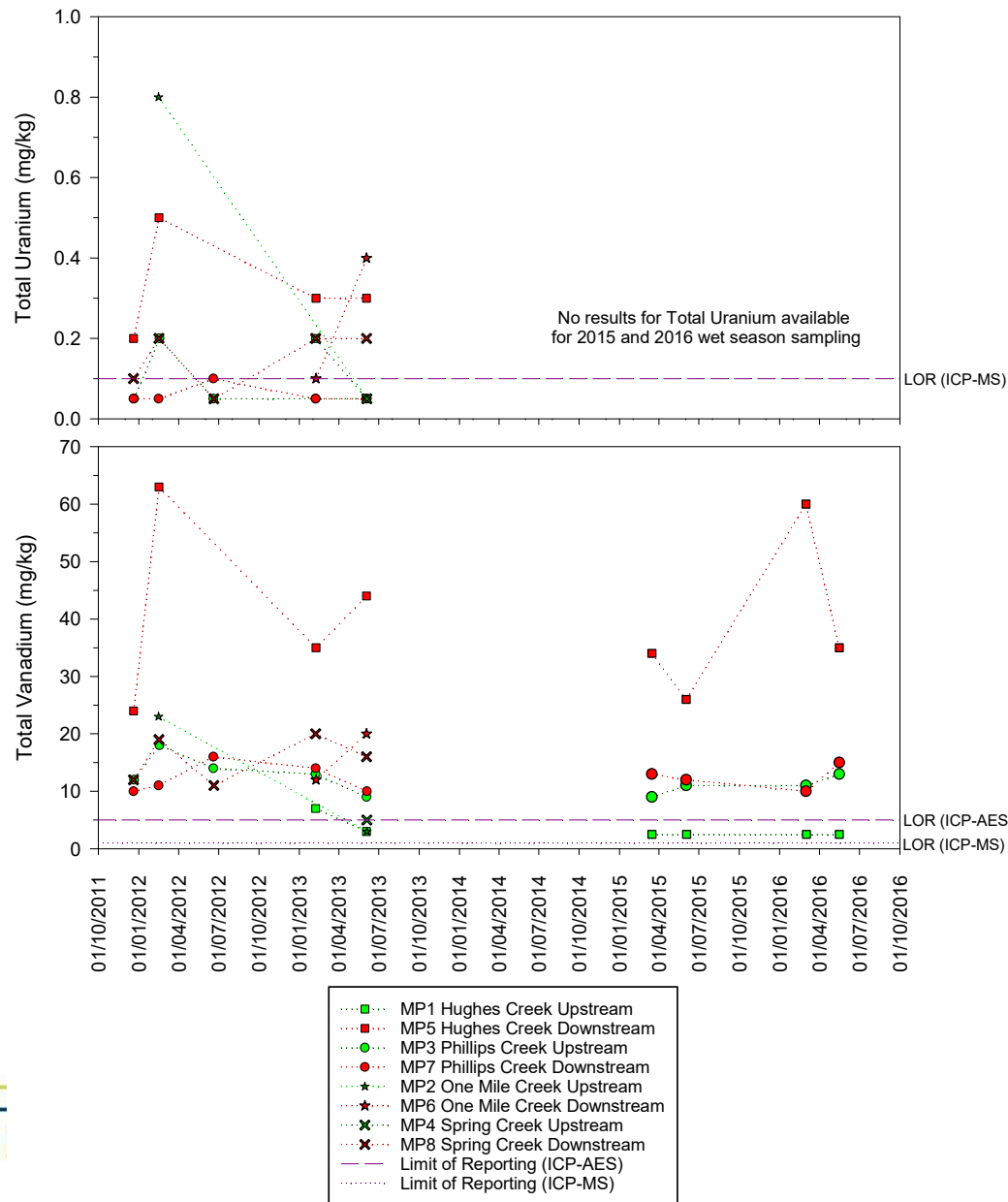
- All concentrations were below the ISQG (high and low) for total nickel in sediment
- Where concentrations were <LOR, half the LOR has been plotted
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable

Total Selenium and Total Silver (mg/kg)



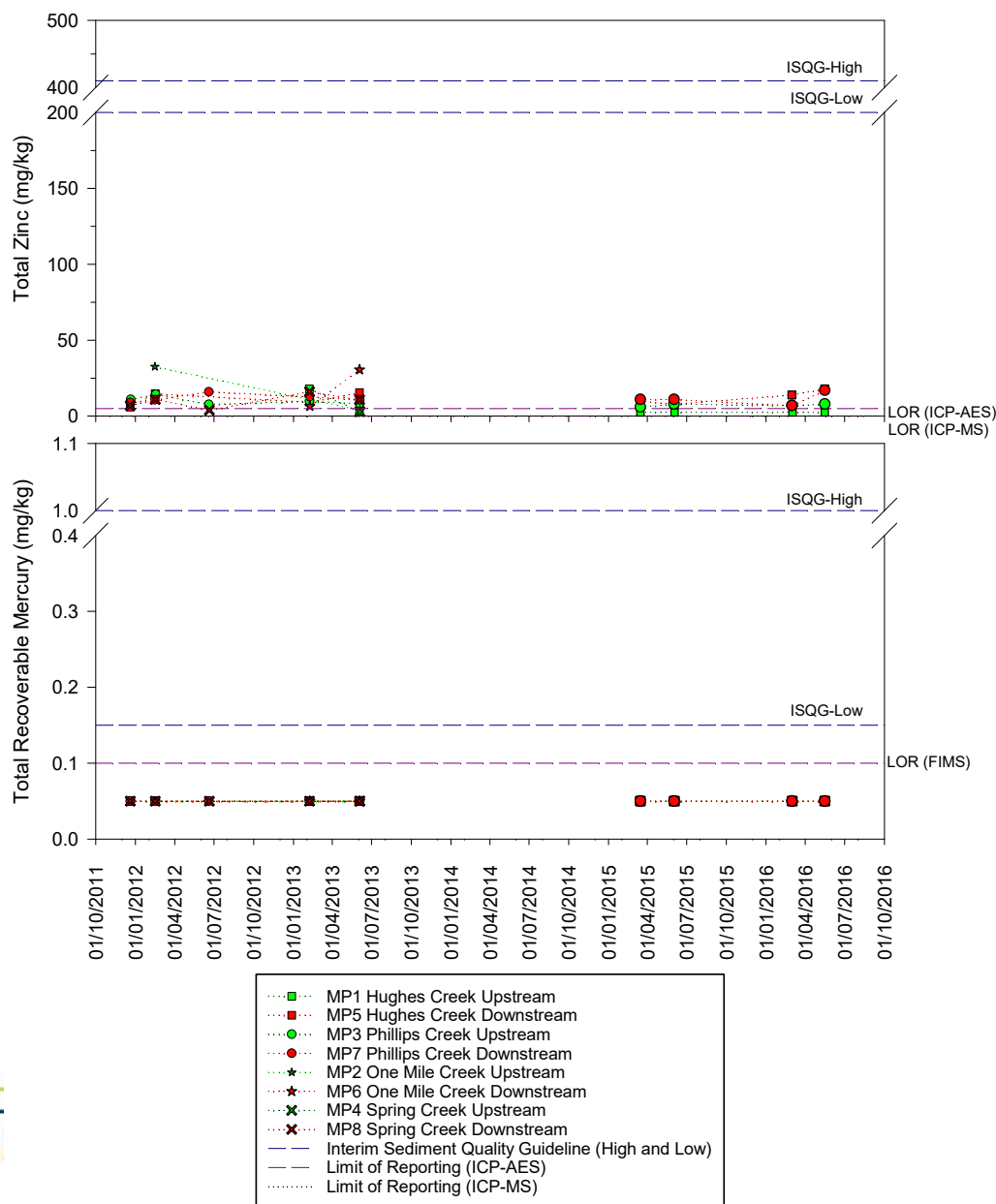
- All concentrations were at or below the ISQG (high and low) for total silver in sediment
- Where concentrations were <LOR , half the LOR has been plotted
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable

Total Uranium and Total Vanadium (mg/kg)



- Where concentrations were <LOR, half the LOR has been plotted
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable

Total Zinc and Total Recoverable Mercury (mg/kg)



- All concentrations were below the ISQG (high and low) for total arsenic in sediment.
- Where concentrations were <LOR, half the LOR has been plotted.
- Two methods have been used for analysis – ICP-AES and ICP-MS and each LOR noted where applicable.

PRINCIPAL COMPONENT ANALYSIS OF SEDIMENT RESULTS 2012-2016

Principal Component Analysis

The Eigenvalues show the percentage of variation in the results that is attributable to each principal component. The particular chemical results that are then correlated with each principal component (trend in the data) are listed on the following page.

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	5.74	52.2	52.2
2	2.72	24.7	76.9
3	1.08	9.8	86.7
4	0.833	7.6	94.3
5	0.195	1.8	96.1

Principal Component Analysis of Sediment Results 2012-2016 showing Eigenvectors

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
Aluminium	0.258	-0.383	0.027	-0.466	0.095
Arsenic	0.153	-0.306	0.042	0.841	0.050
Chromium	0.322	0.292	0.293	-0.093	0.348
Cobalt	0.349	0.214	-0.295	0.027	-0.248
Copper	0.303	-0.362	0.225	-0.107	-0.012
Iron	0.324	0.280	0.325	0.196	-0.310
Lead	0.214	-0.494	-0.026	-0.068	-0.402
Manganese	0.284	0.210	-0.576	-0.048	-0.366
Nickel	0.366	0.123	-0.328	0.063	0.563
Vanadium	0.315	0.251	0.467	-0.073	-0.188
Zinc	0.358	-0.229	-0.100	0.026	0.250

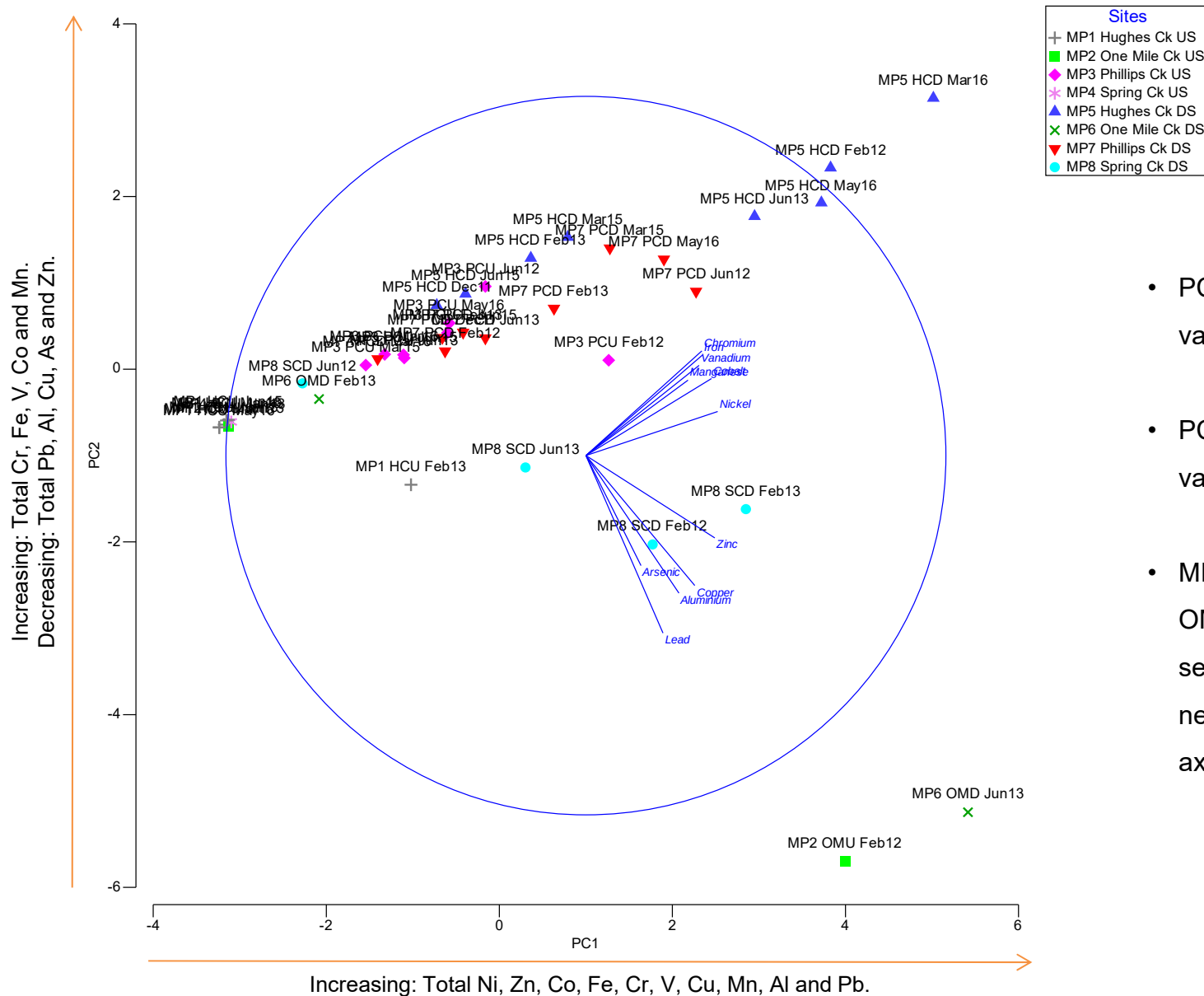
- The highlighted numbers in columns correspond with the parameters that are highly positively or negatively correlated with the first (yellow), second (cyan) and third (green) principal component.
- Where two LOR results from different analytical methods (ICP-AES and ICP-MS) pertained to the one metal, the highest LOR was applied to data used in analysis.
- B, Cd, Mo, Se, Ag and Hg were removed from the PCA as the variation in data was less than the variation resulting from the change in LOR when chemical analysis methods used by ALS varied or no results were detected above the limit of reporting.
- U was removed as a complete data set was not available.

Principal Component Scores of Sediment Results 2012-2016

Principal Component Scores

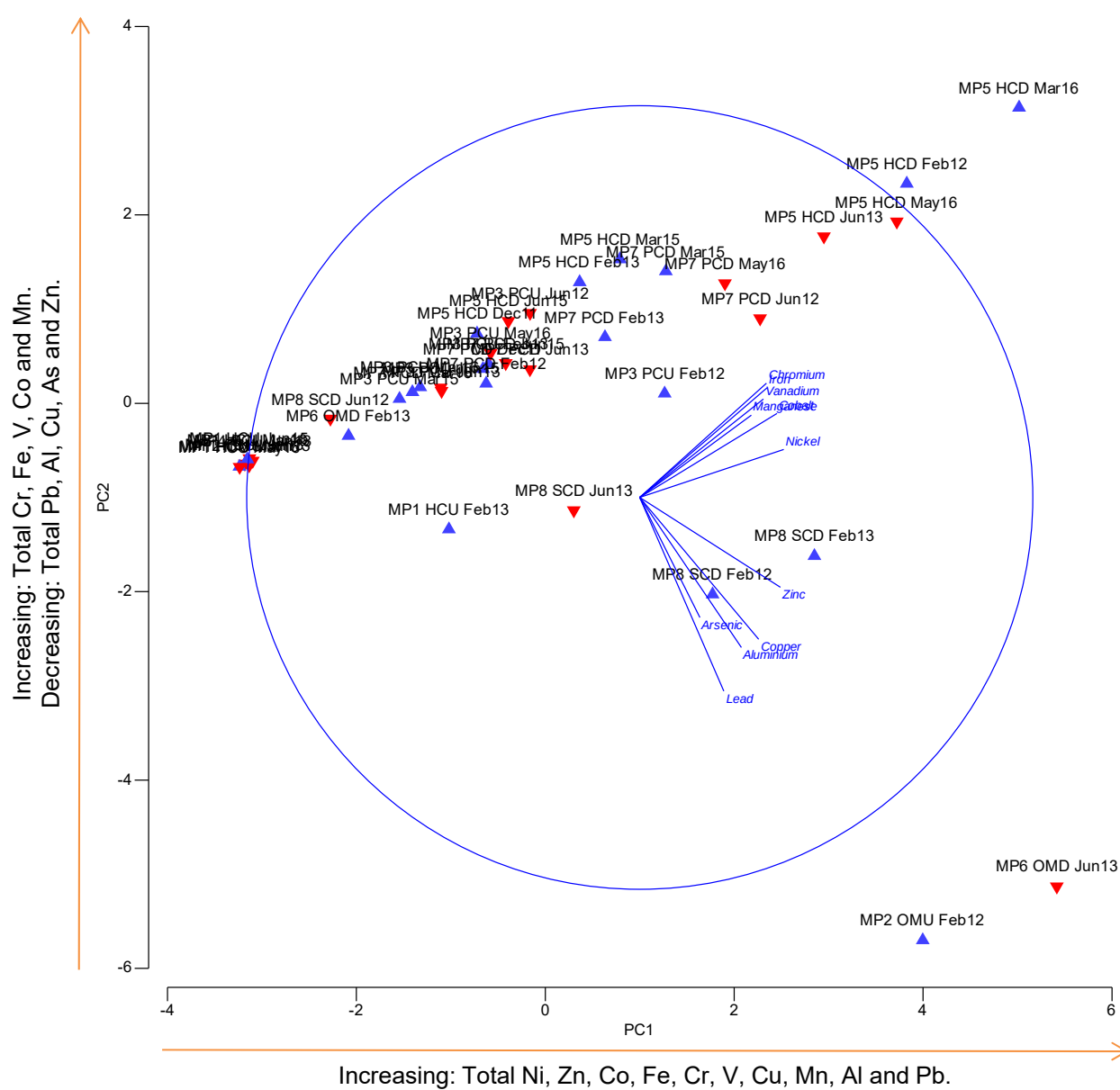
Sample		SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
MP5 HCD	Dec11	-0.722	0.741	0.754	0.142	-0.215
MP7 PCD	Dec11	-0.659	0.365	-1.16	0.0461	-0.139
MP2 OMU	Feb12	4	-5.7	0.813	-2.71	0.422
MP3 PCU	Feb12	1.26	0.104	-0.0278	-0.597	1.42
MP5 HCD	Feb12	3.83	2.33	2.77	-0.248	0.182
MP7 PCD	Feb12	-0.626	0.21	-0.647	0.0365	0.609
MP8 SCD	Feb12	1.77	-2.03	0.0141	-1.69	-0.34
MP3 PCU	Jun12	-0.161	0.959	-0.205	0.166	-0.0643
MP7 PCD	Jun12	2.27	0.901	-2.48	-0.00834	-0.672
MP8 SCD	Jun12	-2.27	-0.164	0.589	-0.0423	-0.101
MP1 HCU	Feb13	-1.02	-1.34	0.0326	0.183	-0.54
MP3 PCU	Feb13	-0.6	0.421	-0.0059	0.0336	0.48
MP5 HCD	Feb13	0.364	1.29	1.29	0.208	-0.151
MP6 OMD	Feb13	-2.08	-0.345	0.414	0.0324	0.0469
MP7 PCD	Feb13	0.631	0.704	-1.38	-0.0333	0.315
MP8 SCD	Feb13	2.85	-1.62	-1.03	-1.53	-0.82
MP1 HCU	Jun13	-3.18	-0.642	0.276	0.15	-0.249
MP2 OMU	Jun13	-3.13	-0.659	0.33	0.176	-0.373
MP3 PCU	Jun13	-1.1	0.131	-0.205	0.0141	0.268
MP4 SCU	Jun13	-3.1	-0.61	0.477	0.119	-0.201
MP5 HCD	Jun13	2.95	1.77	0.784	0.0826	-0.628
MP6 OMD	Jun13	5.42	-5.13	0.283	4.32	0.0606
MP7 PCD	Jun13	-0.162	0.361	-0.786	0.0267	0.527
MP8 SCD	Jun13	0.302	-1.14	0.0774	-0.651	-0.356
MP1 HCU	Mar15	-3.24	-0.672	0.335	0.17	-0.217
MP1 HCU	Jun15	-3.13	-0.585	0.297	0.159	-0.246
MP5 HCD	Mar15	0.791	1.53	1.3	0.185	-0.0919
MP5 HCD	Jun15	-0.391	0.873	0.873	0.17	-0.14
MP3 PCU	Mar15	-1.54	0.0475	-0.0484	0.0738	0.214
MP3 PCU	Jun15	-1.11	0.167	-0.0629	0.0786	0.564
MP7 PCD	Mar15	1.28	1.4	-2.26	0.164	-0.169
MP7 PCD	Jun15	-0.418	0.426	-0.282	0.119	0.55
MP1 HCU	Mar16	-3.15	-0.593	0.31	0.164	-0.227
MP1 HCU	May16	-3.24	-0.676	0.324	0.163	-0.217
MP5 HCD	Mar16	5.02	3.14	2.02	-0.0507	-0.0775
MP5 HCD	May16	3.72	1.93	-1.18	0.0828	-0.575
MP3 PCU	Mar16	-1.32	0.172	0.128	0.0419	0.362
MP3 PCU	May16	-0.578	0.535	-0.631	0.0127	-0.175
MP7 PCD	Mar16	-1.41	0.12	0.0252	0.0634	0.333
MP7 PCD	May16	1.9	1.27	-2.1	0.174	0.633

PCA graph of PC1 and PC2 of Sediments (2012-2016) by SITES



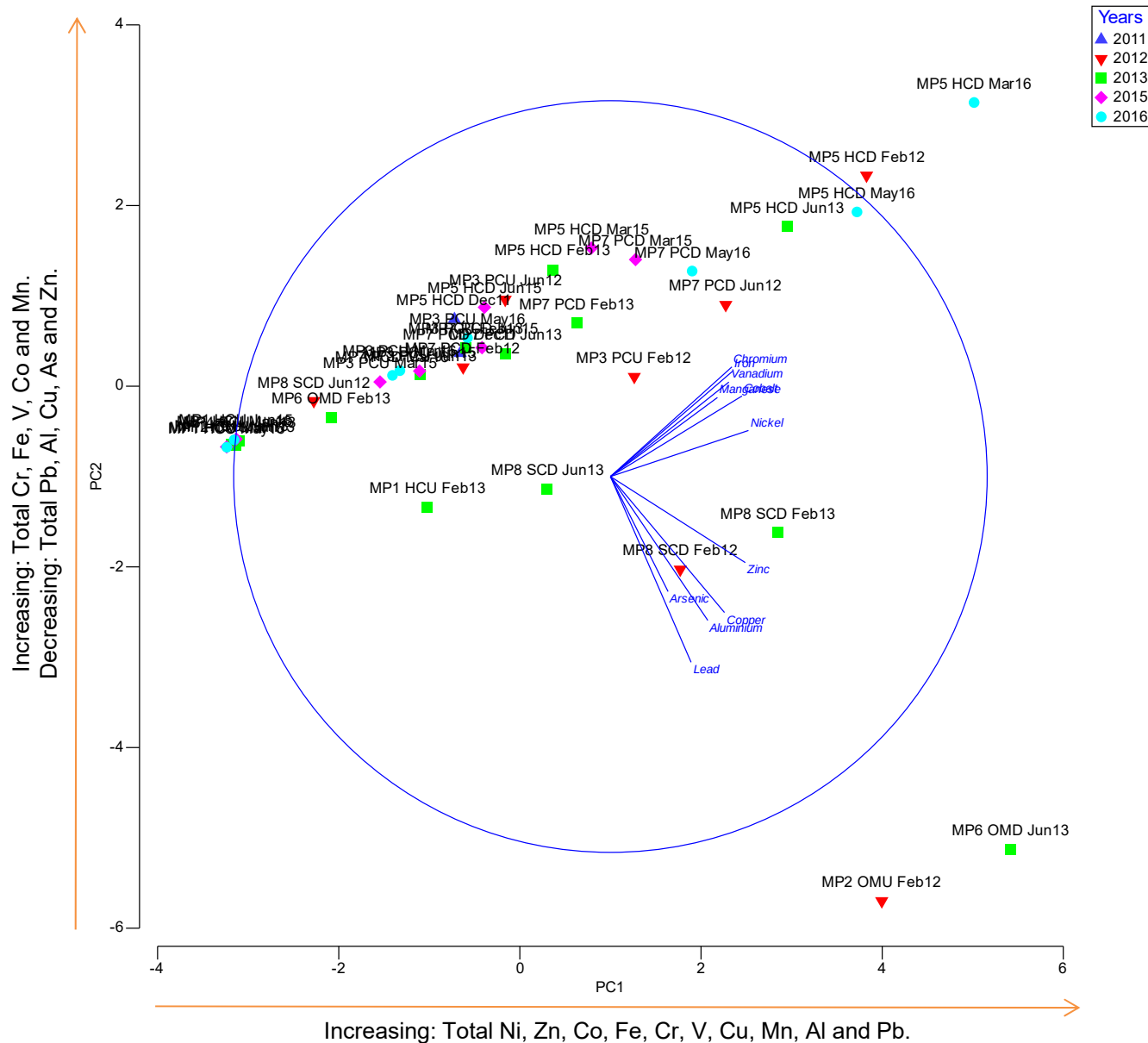
- PC1 explained 52.2 % of the variation in the data.
- PC2 explains 24.7 % of variation in the data.
- MP2 OMU Feb 12 and MP6 OMD Jun 13 were separated from the cluster negatively along the PC2 axis.

PCA graph of PC1 and PC2 of Sediments (2012-2016) by TIME



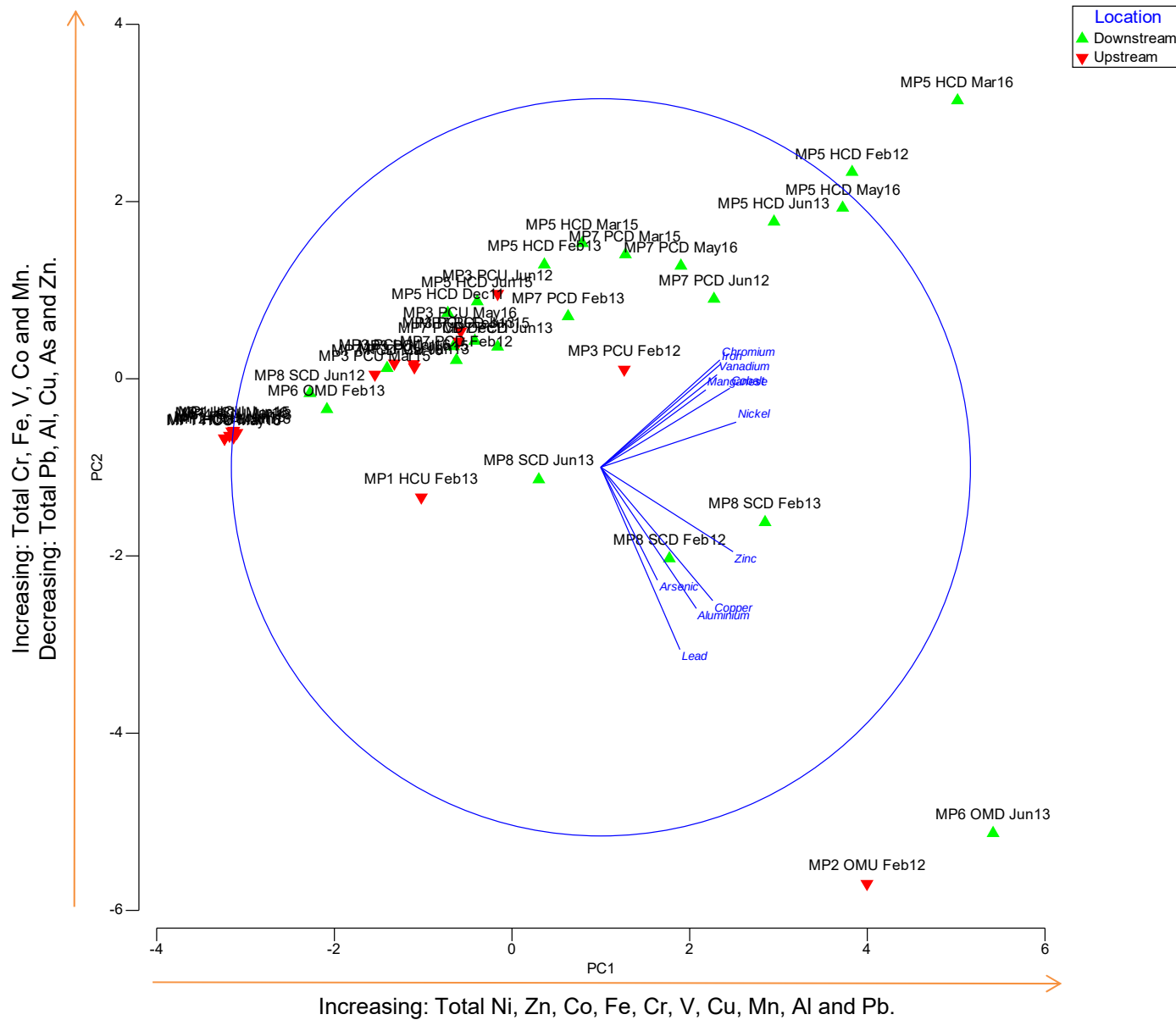
- There is no clear separation between sampling times

PCA graph of PC1 and PC2 of Sediments (2012-2016) by YEAR

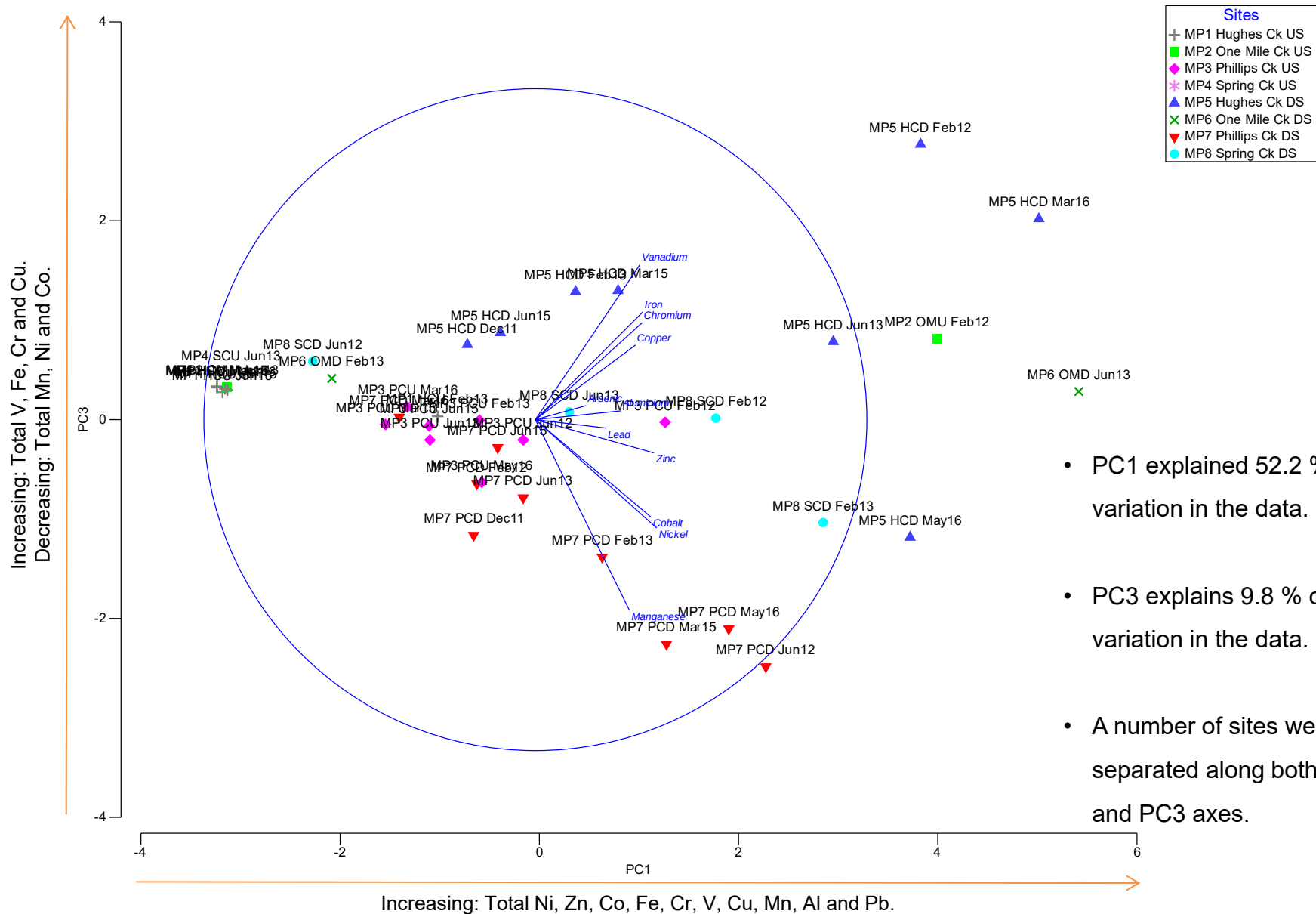


- There is no clear separation between years

PCA graph of PC1 and PC2 of Sediments (2012-2016) by LOCATION

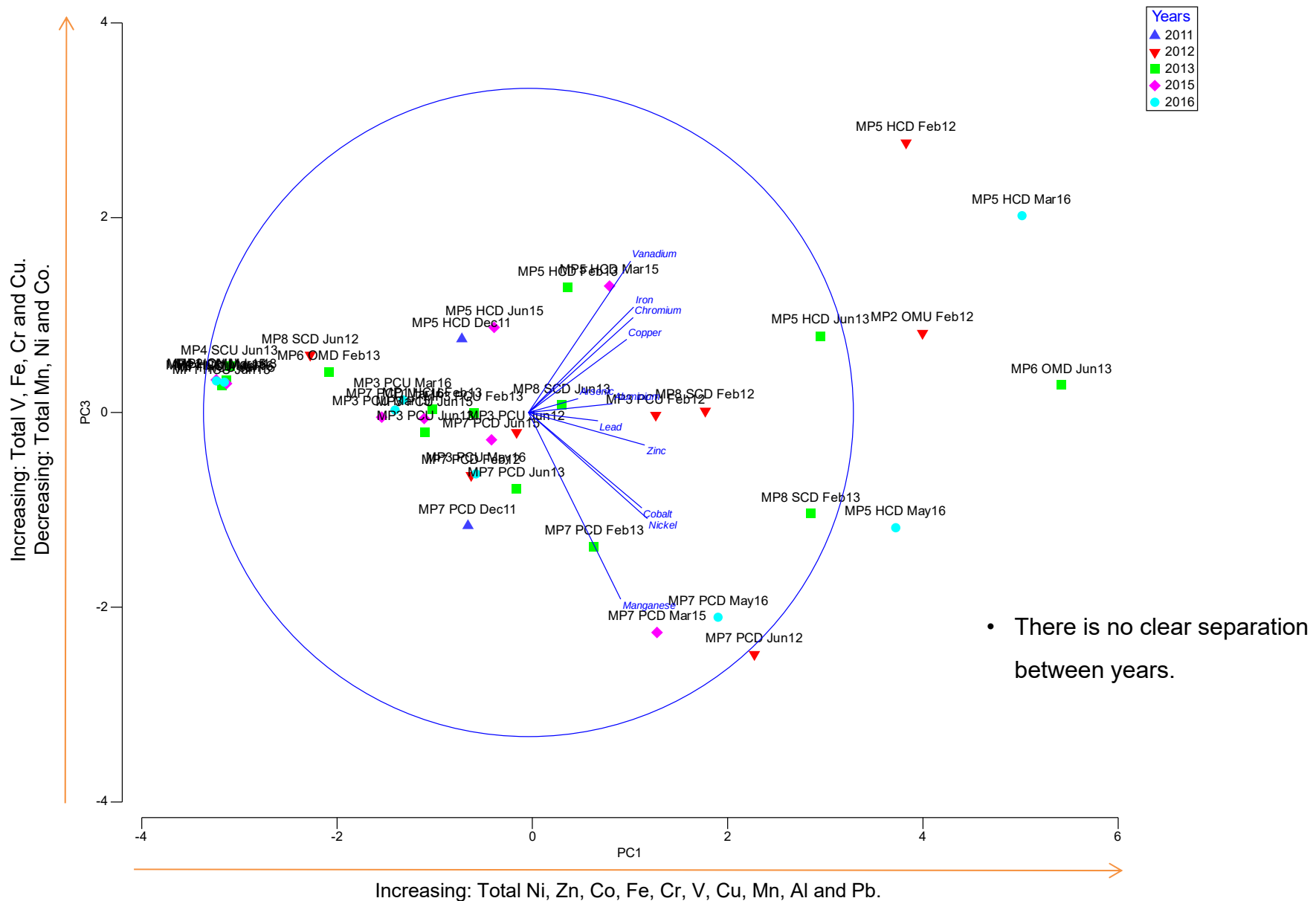


PCA graph of PC1 and PC3 of Sediments (2012-2016) by SITES

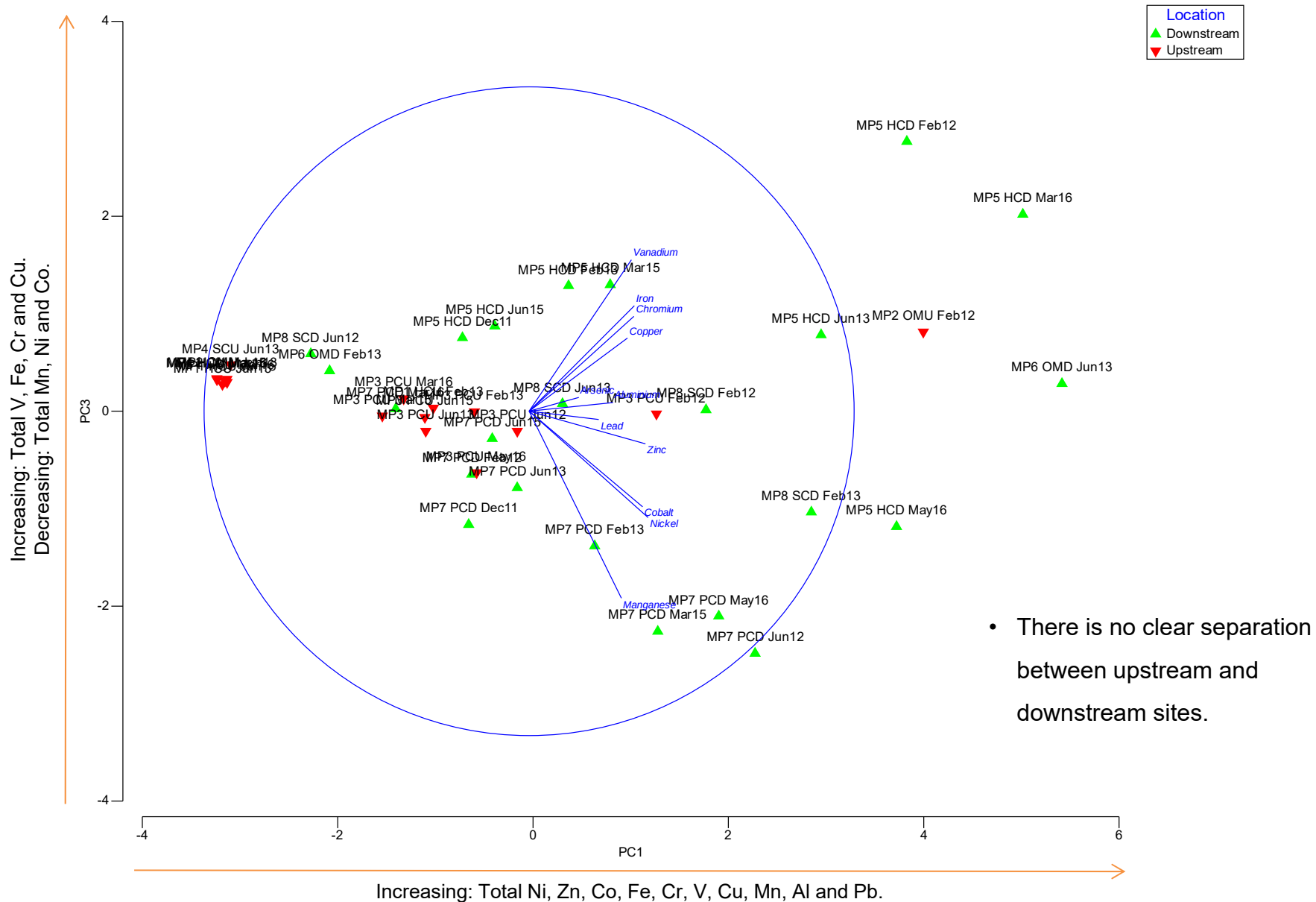


- PC1 explained 52.2 % of the variation in the data.
- PC3 explains 9.8 % of the variation in the data.
- A number of sites were separated along both the PC1 and PC3 axes.

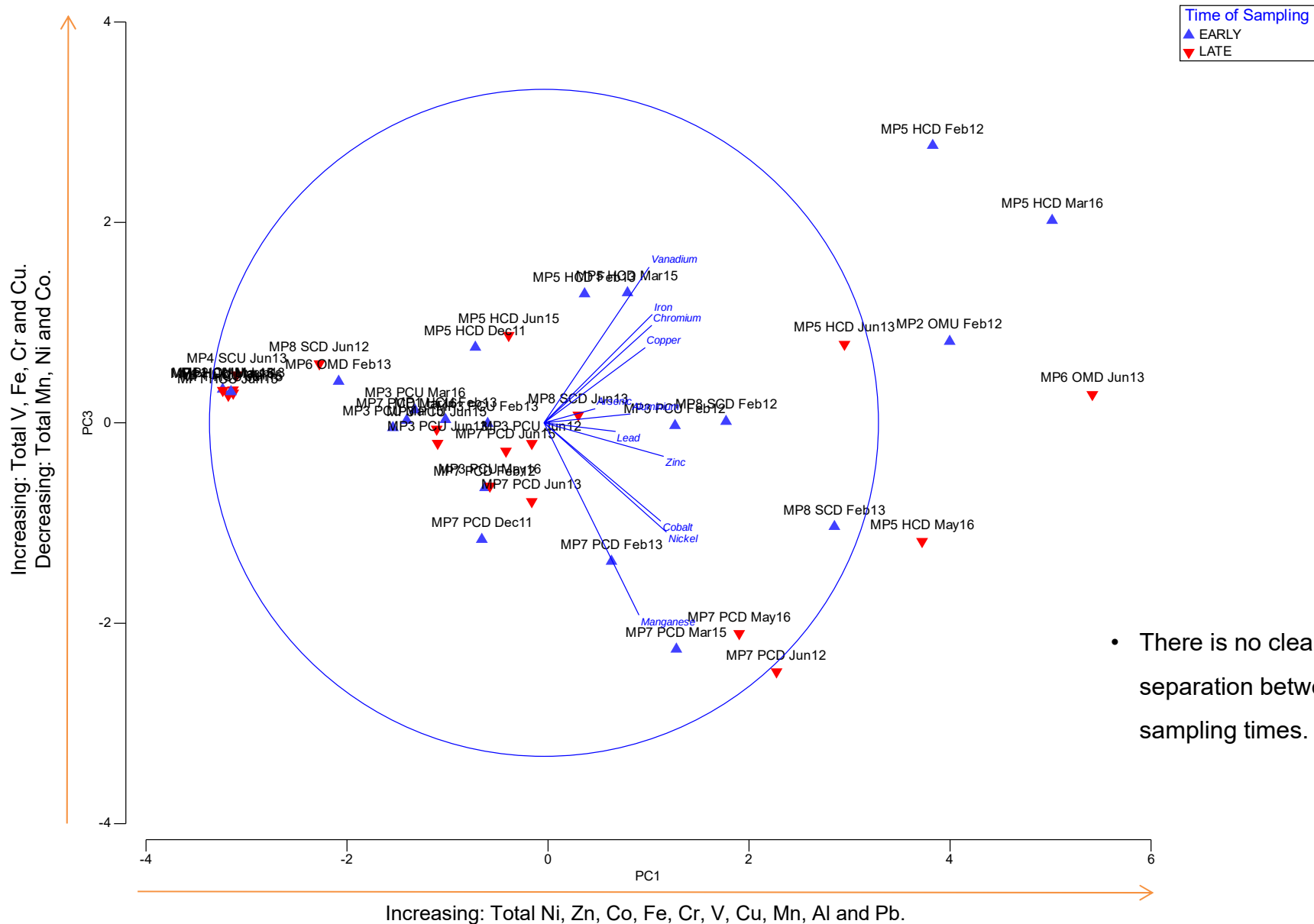
PCA graph of PC1 and PC3 of Sediments (2012-2016) by YEAR



PCA graph of PC1 and PC3 of Sediments (2012-2016) by LOCATION



PCA graph of PC1 and PC3 of Sediments (2012-2016) by TIME



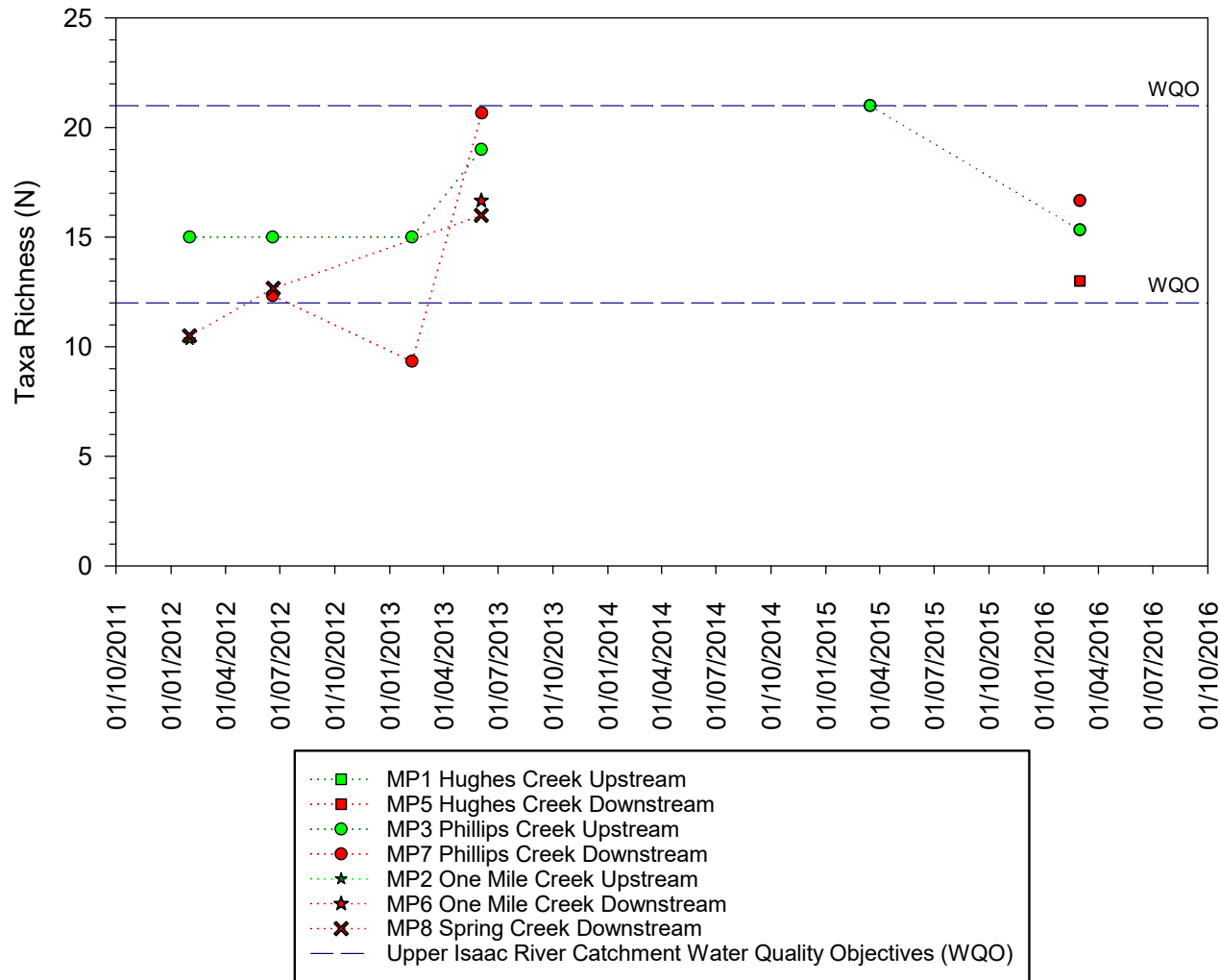
- There is no clear separation between sampling times.

SRM Macroinvertebrate Results (2012-2016)

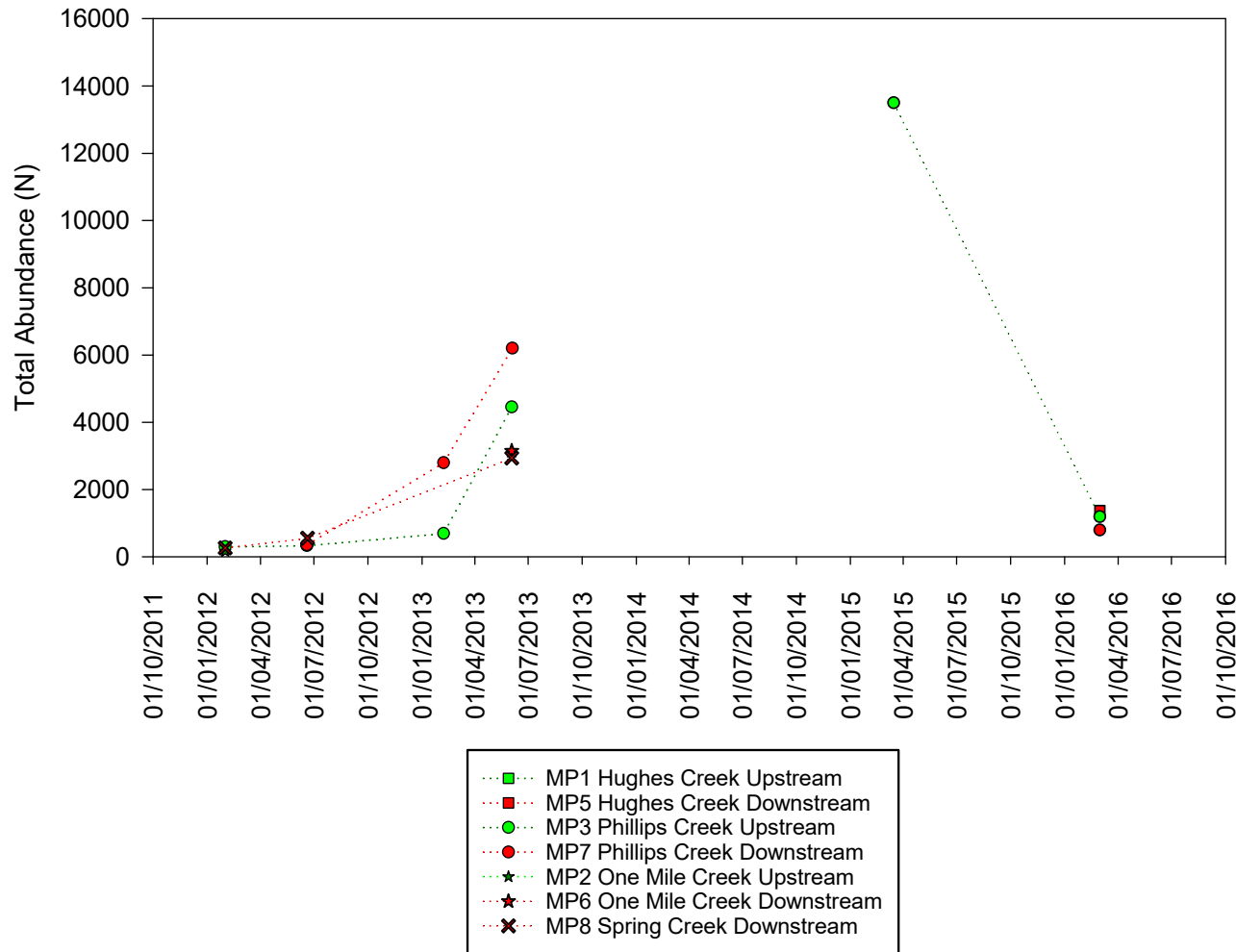
BE WHAT **YOU** WANT TO BE



Macroinvertebrate Results for Taxa Richness (2012-2016)

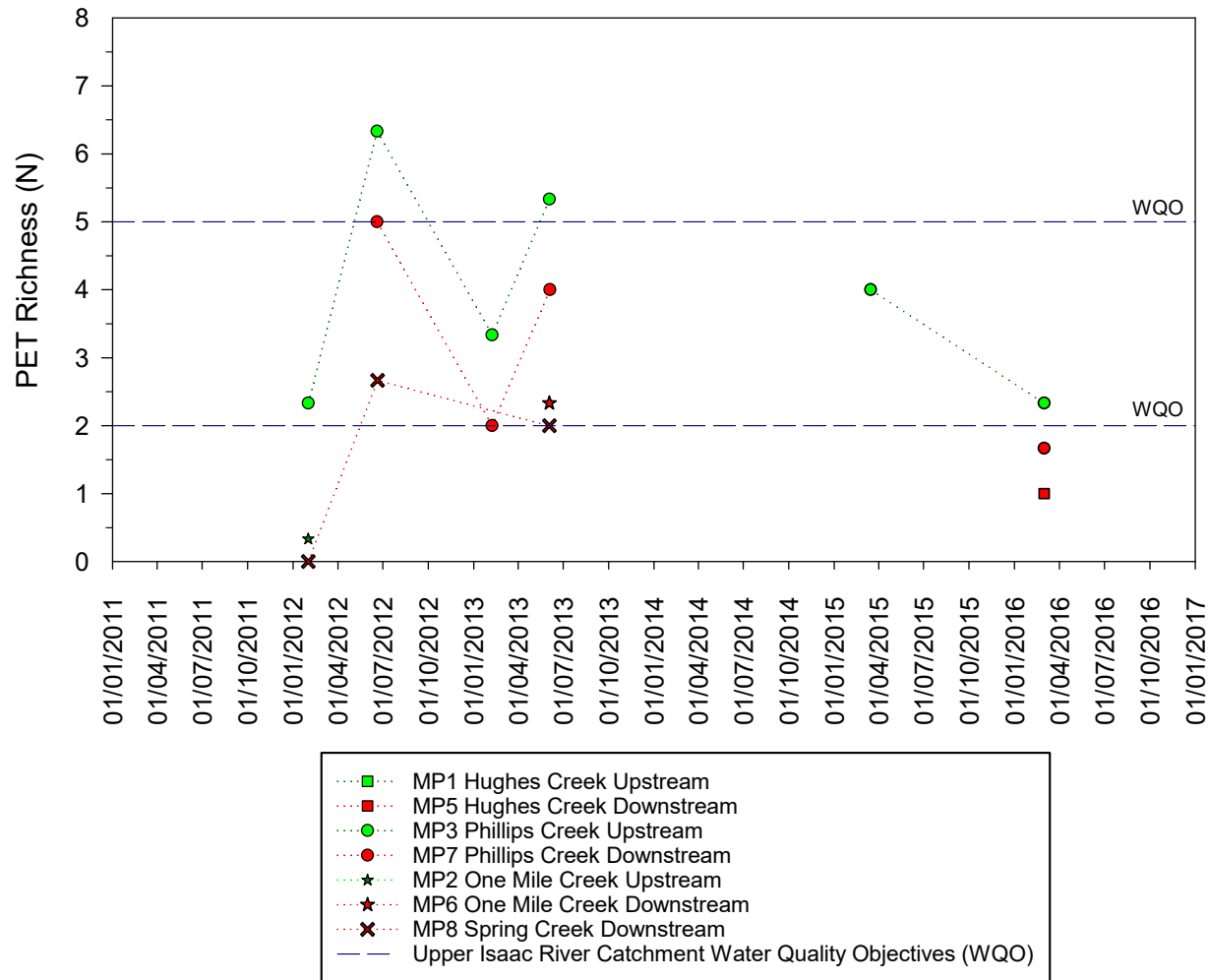


Macroinvertebrate Results for Total Abundance (2012-2016)

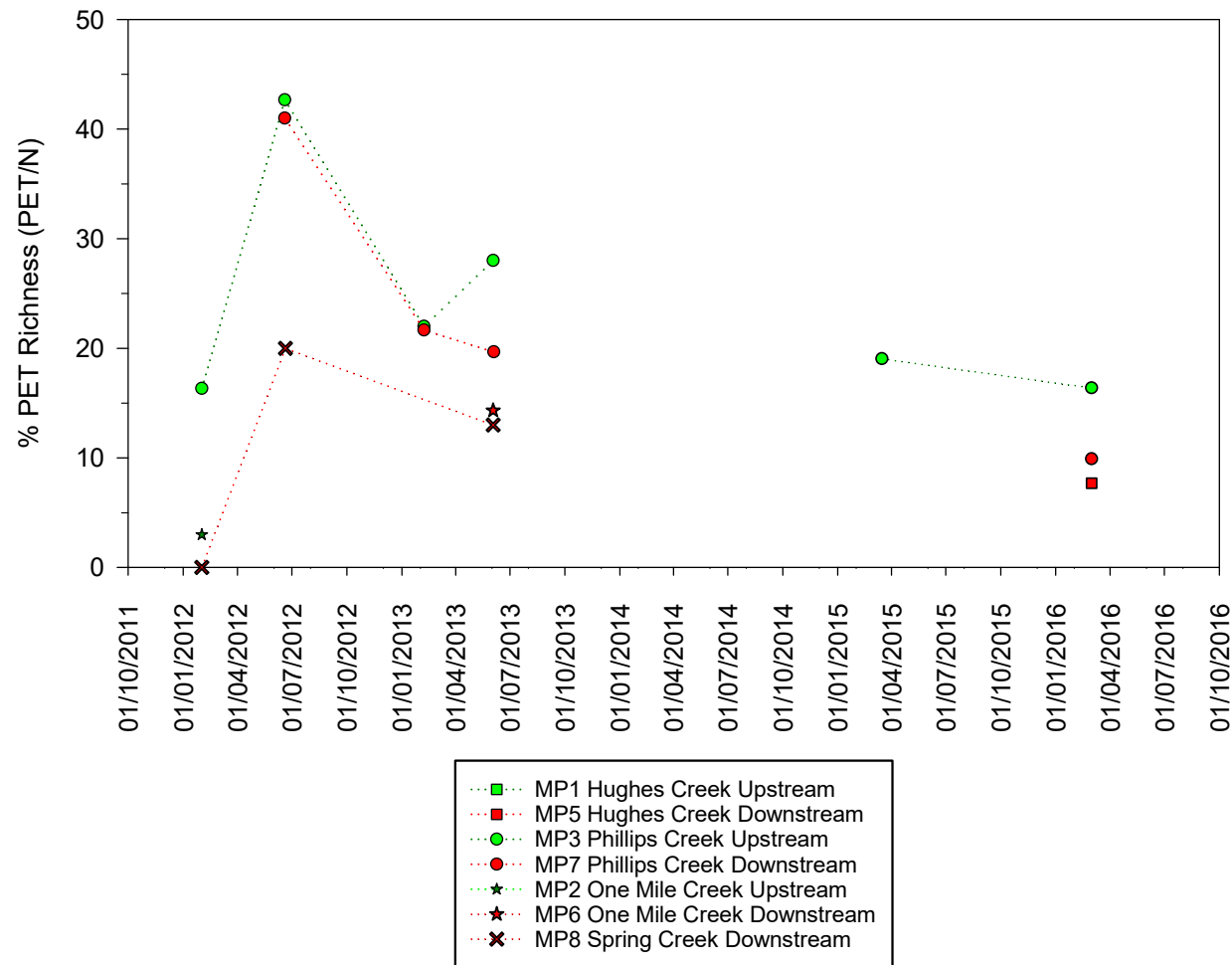


BE WHAT YOU WANT TO BE

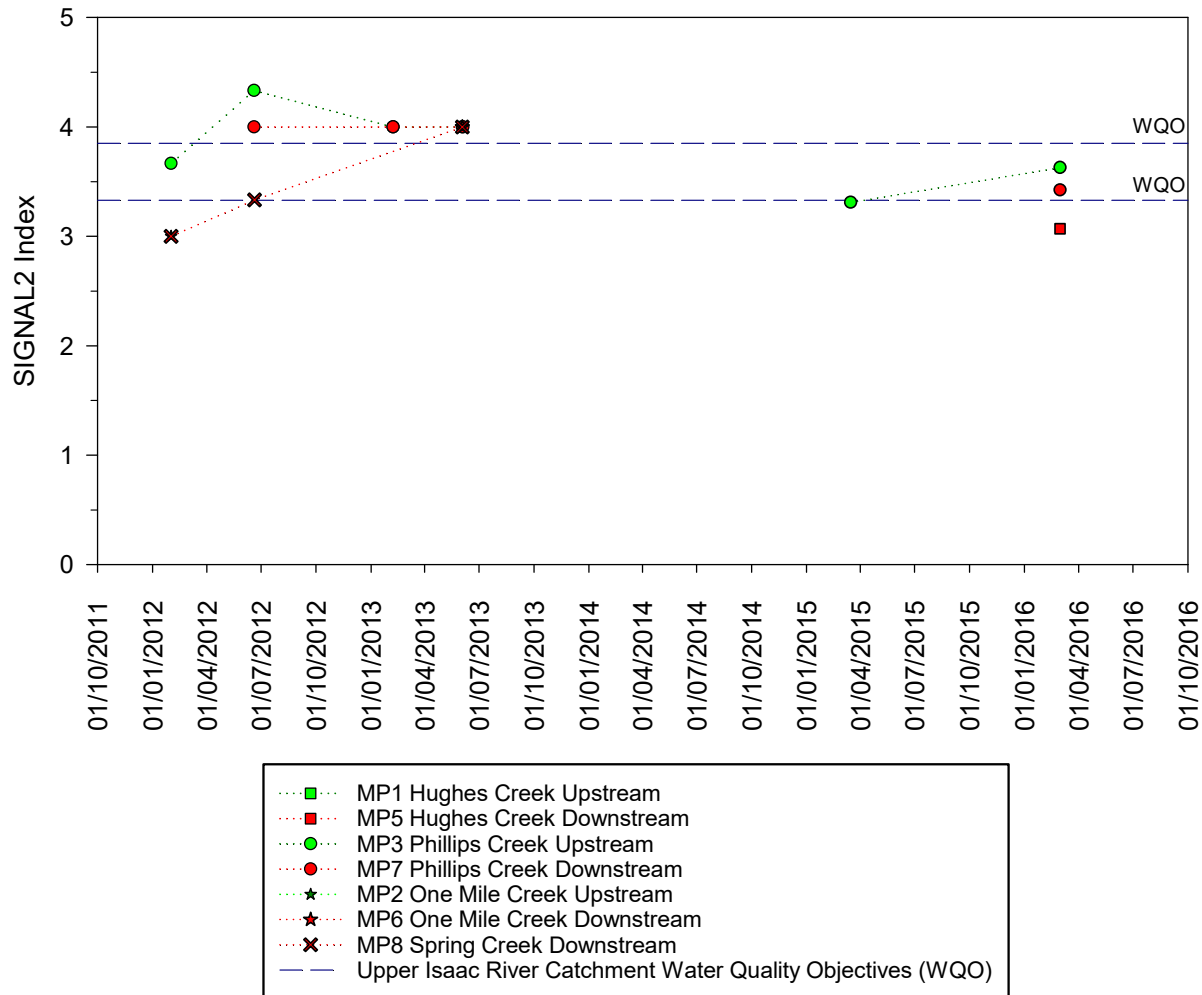
Macroinvertebrate Results for PET Index (2012-2016)



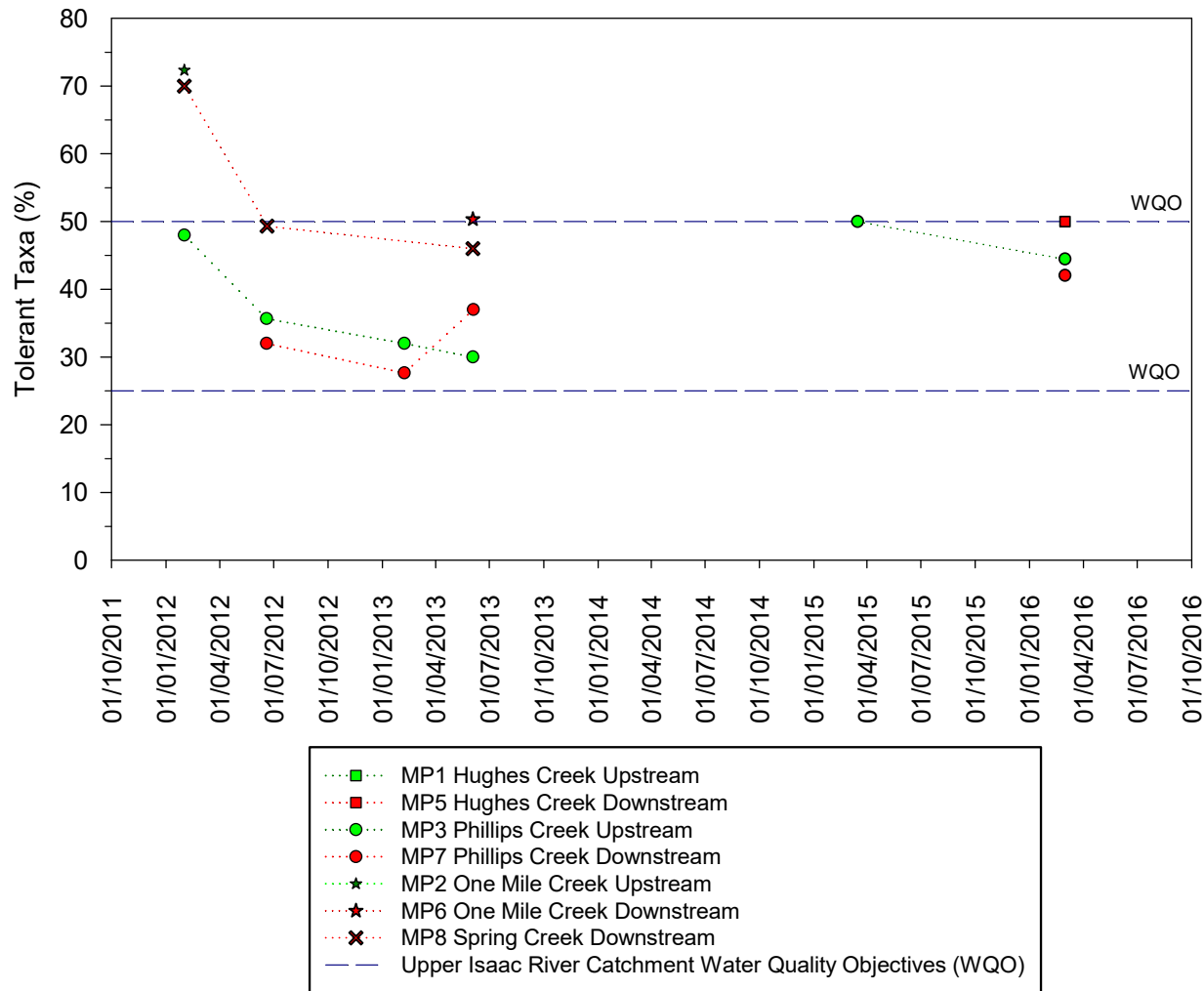
Macroinvertebrate Results for PET/N (2012-2016)



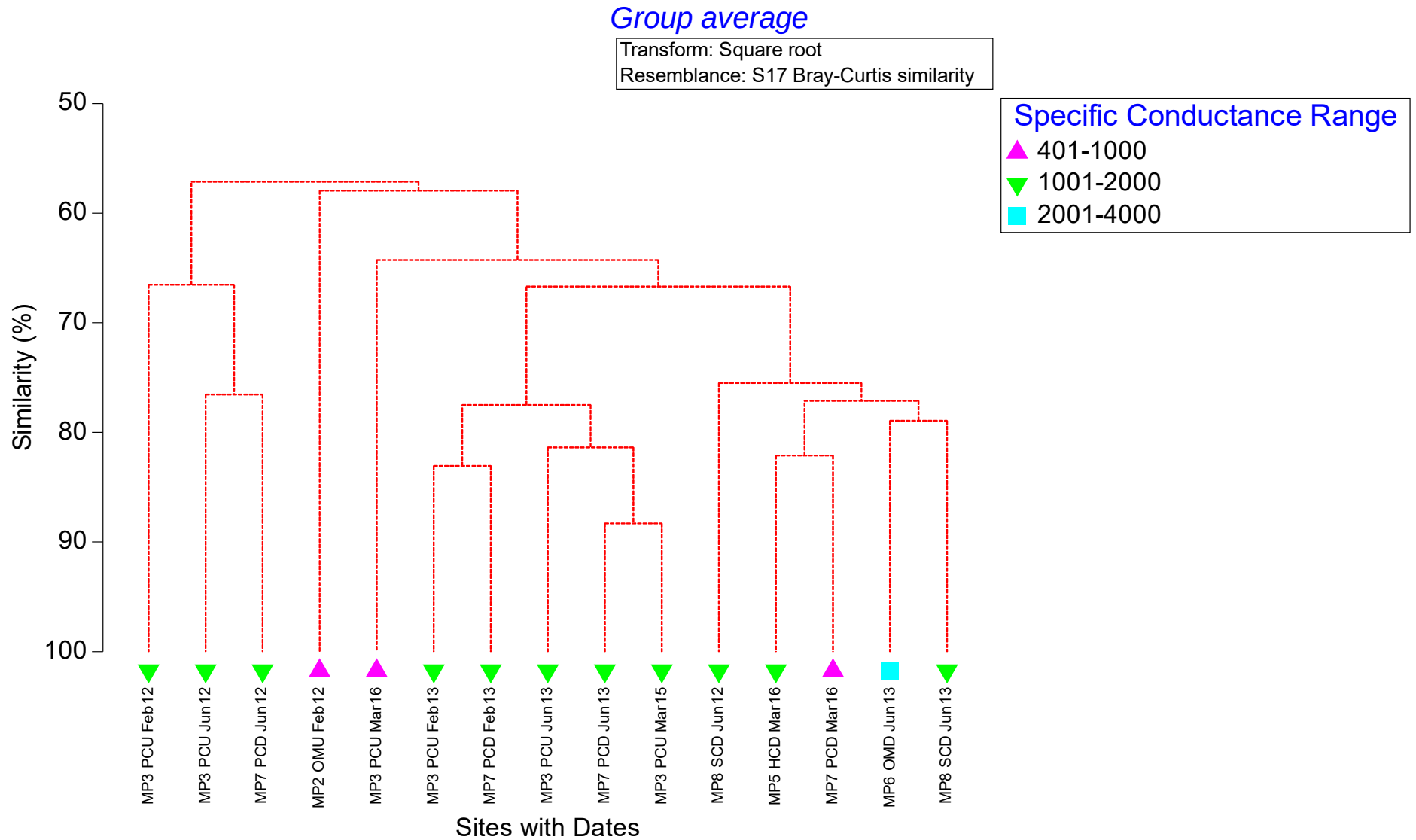
Macroinvertebrate Results for SIGNAL2 Score (2012-2016)



Macroinvertebrate Results for % Tolerant Taxa (2012-2016)



Dendrogram Based on Hierarchical Agglomerative Clustering of Results of Macroinvertebrate Community Composition at Sites (2012-2016)

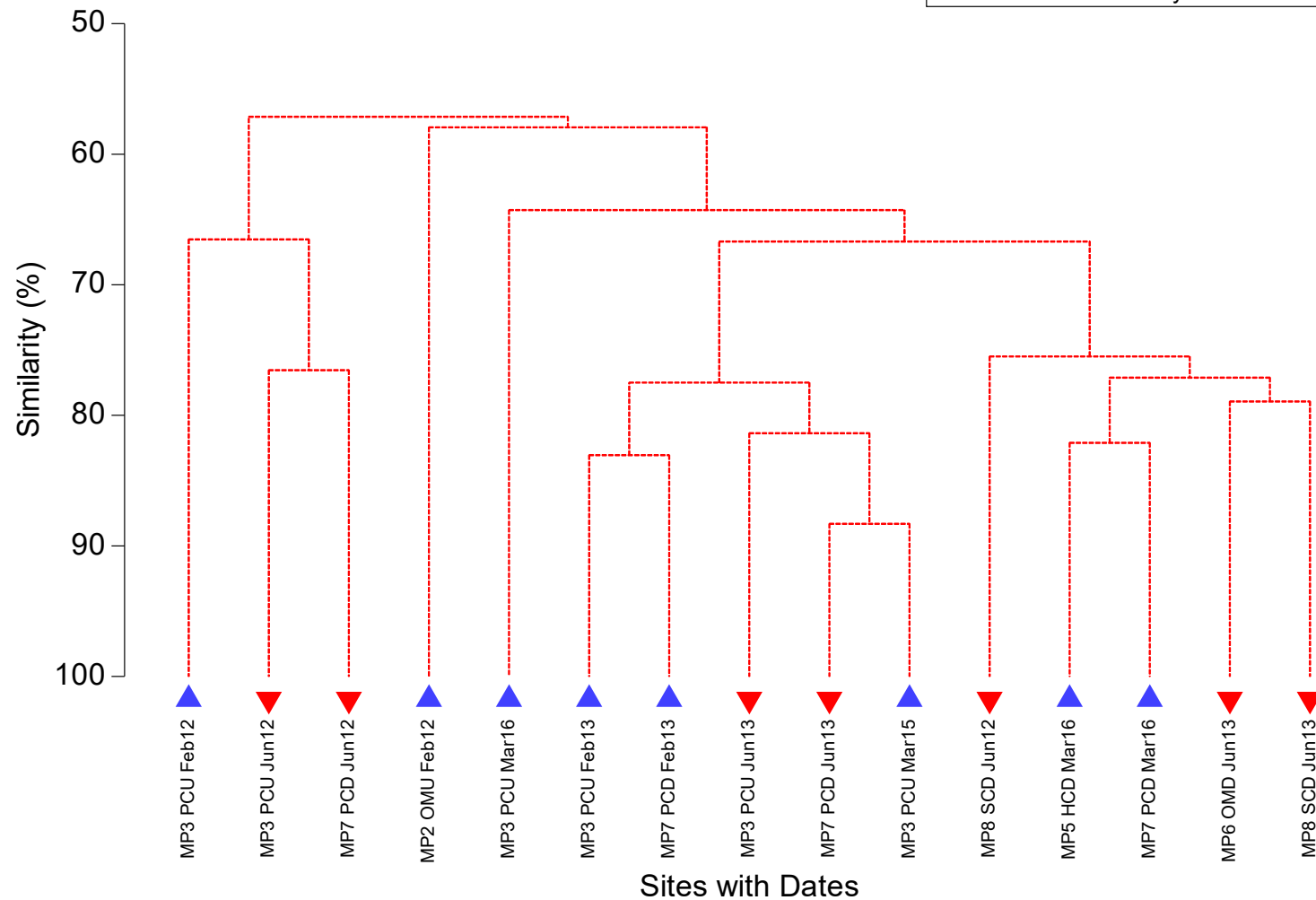


Dendrogram Based on Hierarchical Agglomerative Clustering of Results of Macroinvertebrate Community Composition at Sites (2012-2016)

Group average

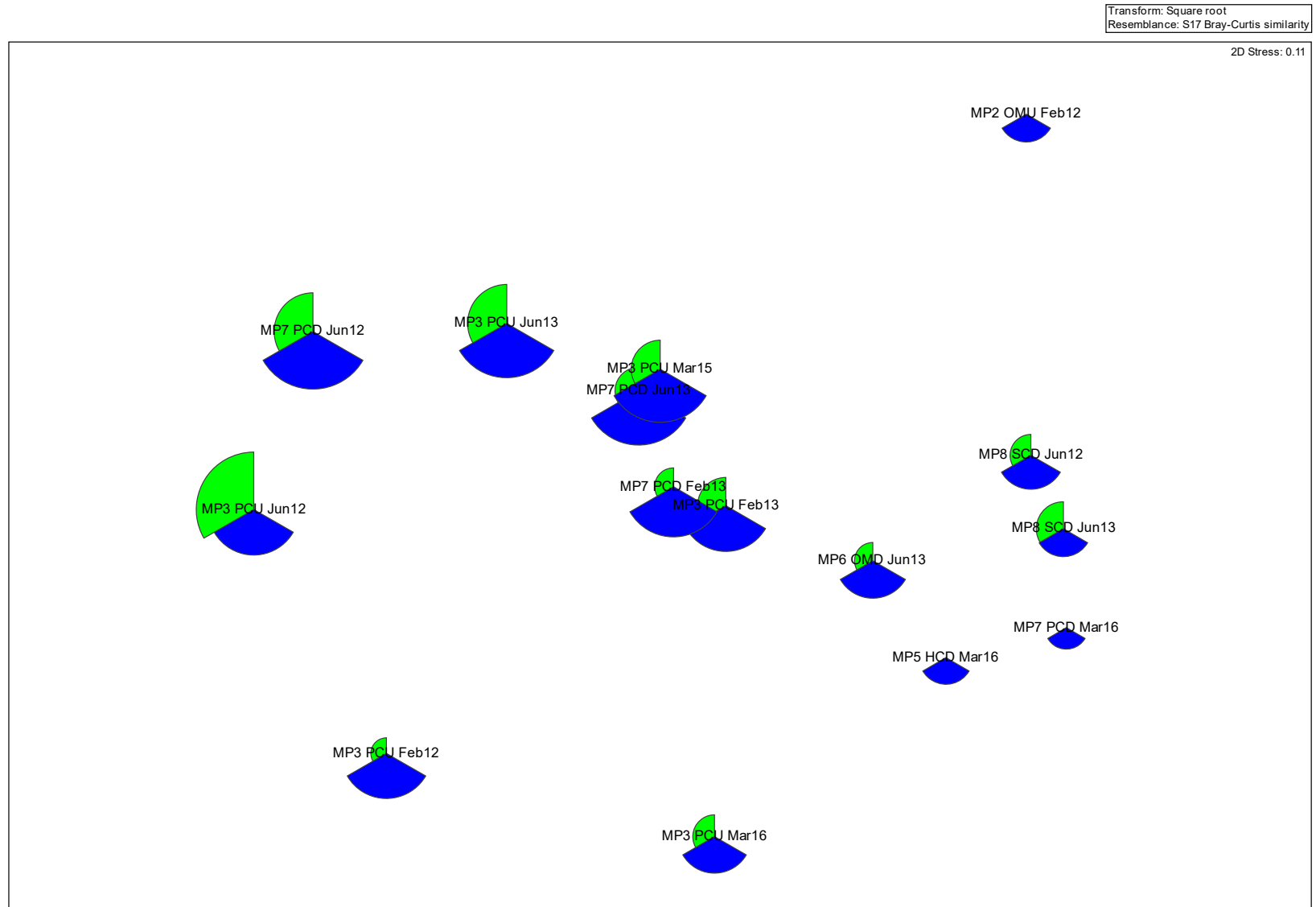
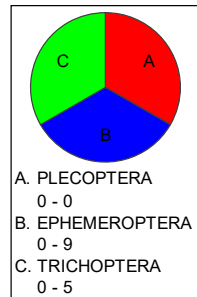
Transform: Square root
Resemblance: S17 Bray-Curtis similarity

Time of Sampling
▲ EARLY
▼ LATE

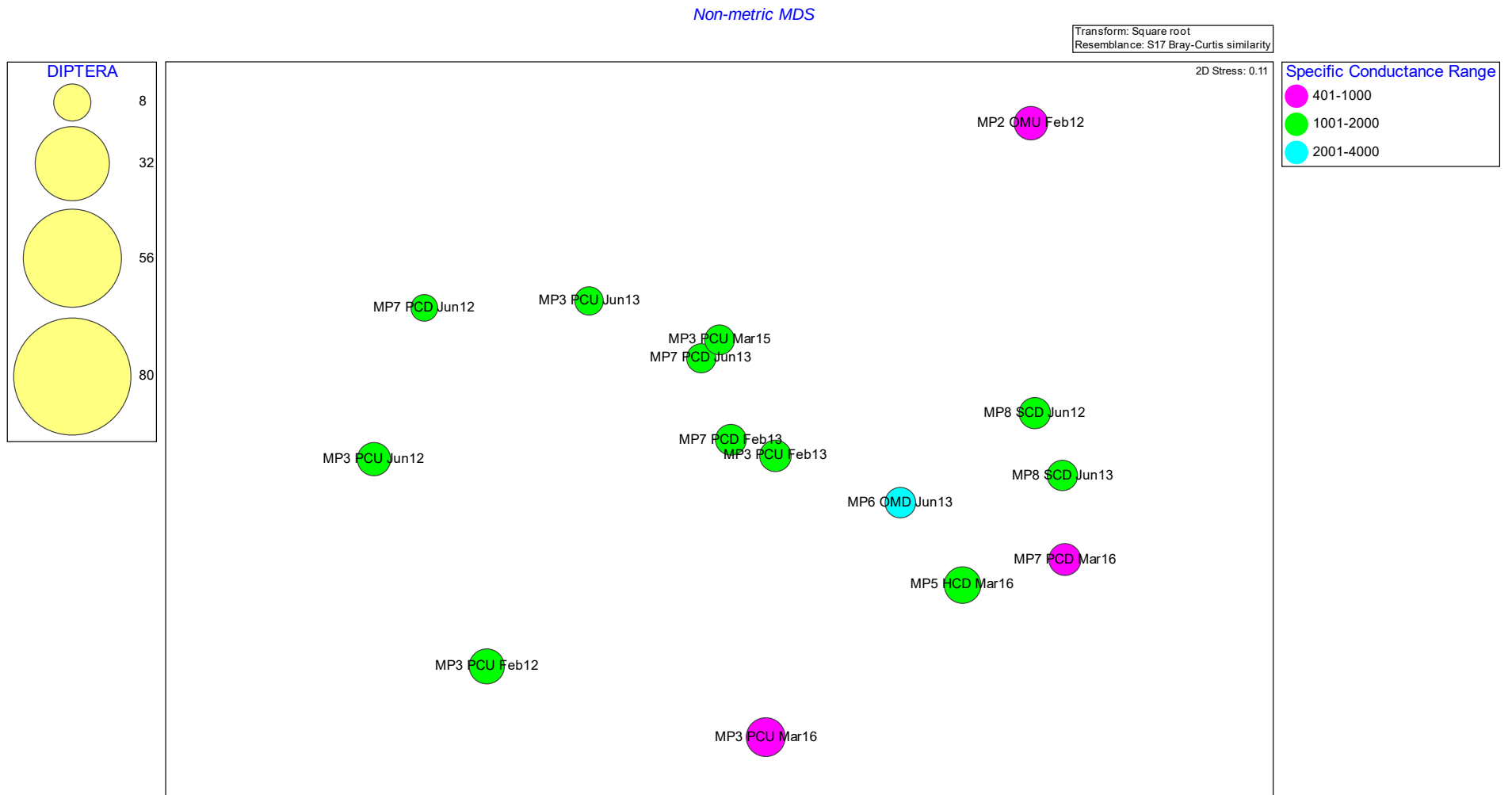


MDS Plot of Macroinvertebrate Community Composition showing square root of PET abundances at various Specific Conductance Ranges (2012-2016)

Non-metric MDS

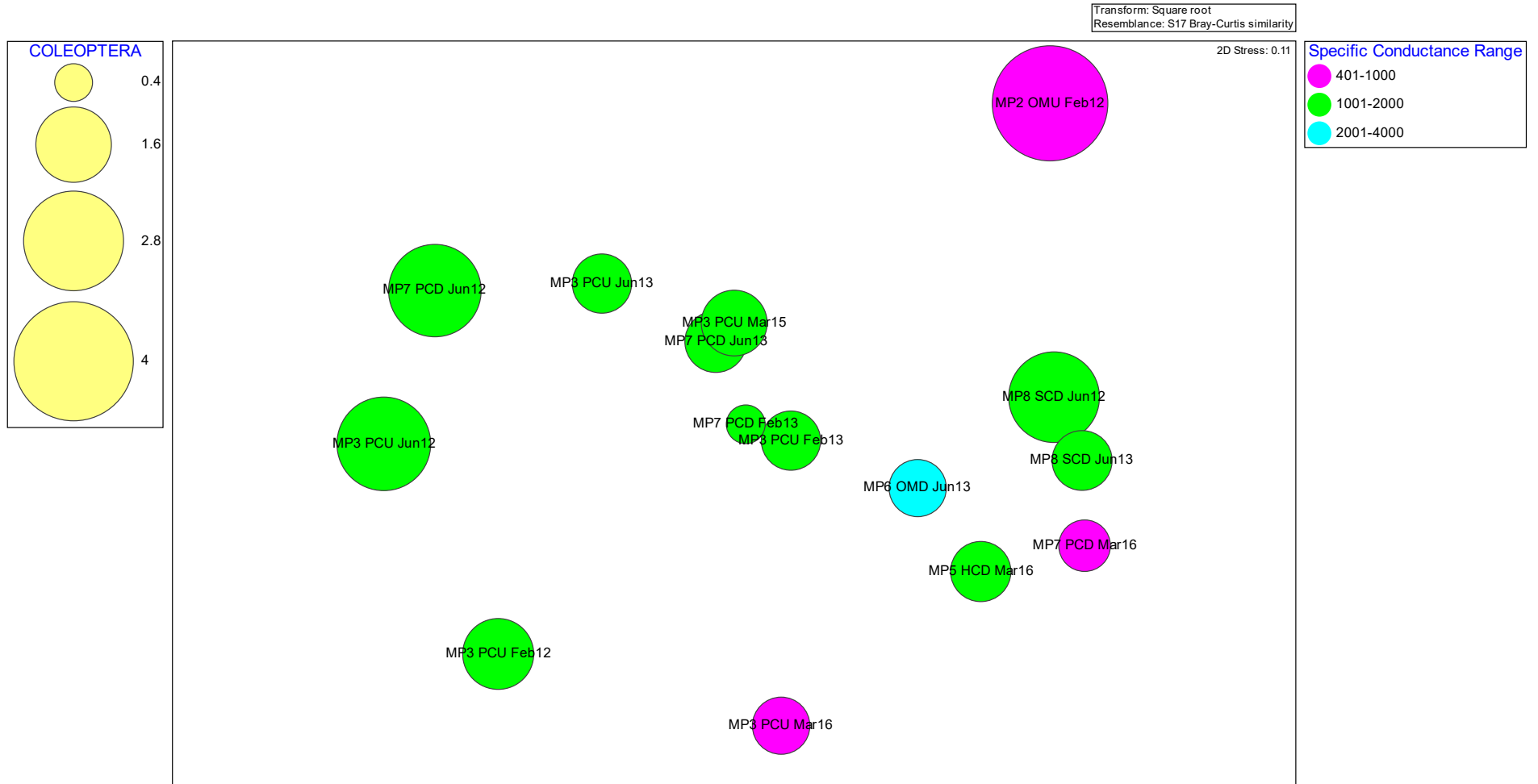


MDS Plot of Macroinvertebrate Community Composition showing square root of DIPTERA abundances at various Specific Conductance Ranges (2012-2016)

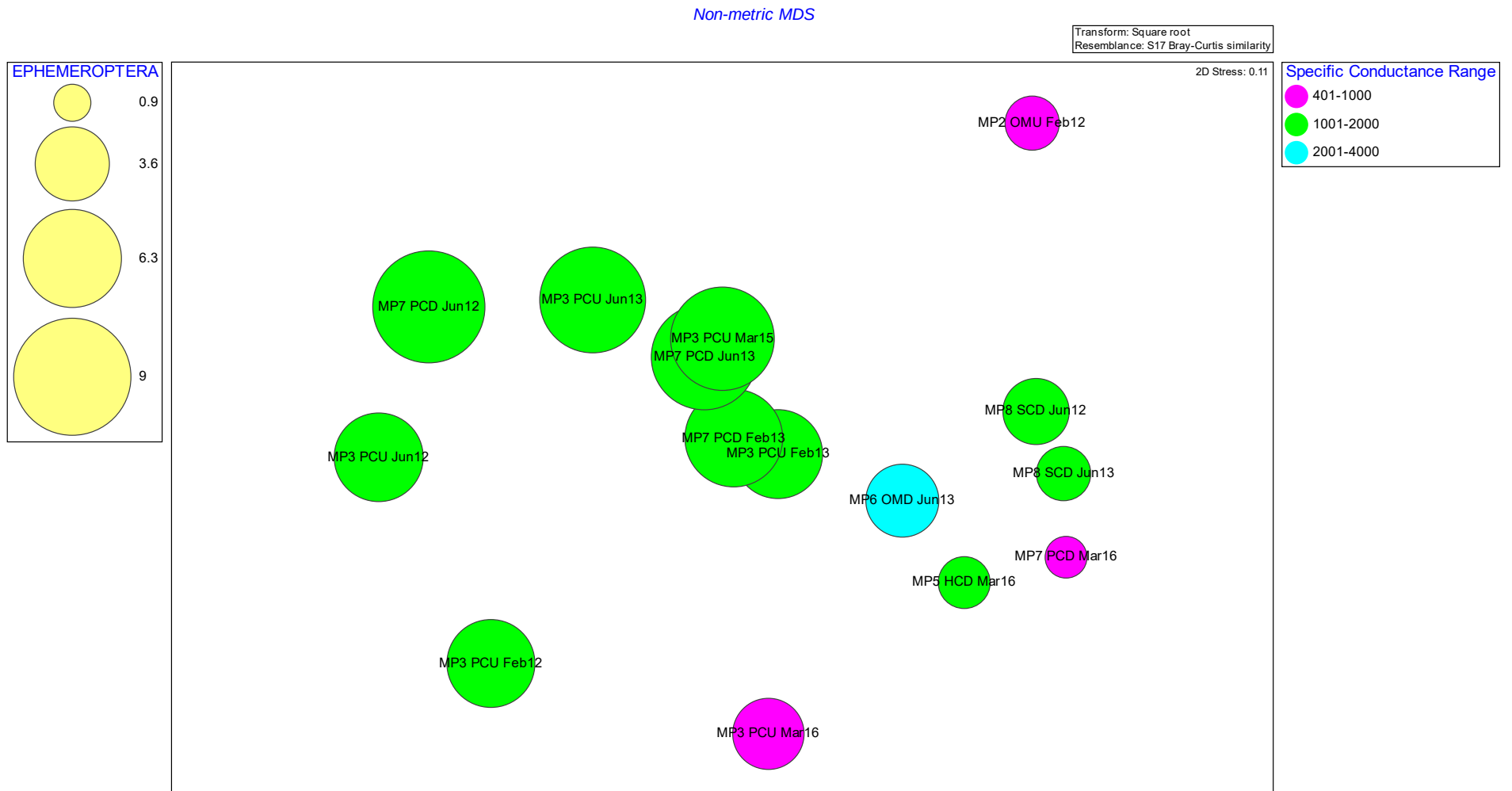


MDS Plot of Macroinvertebrate Community Composition showing square root of COLEOPTERA abundances at various Specific Conductance Ranges (2012-2016)

Non-metric MDS

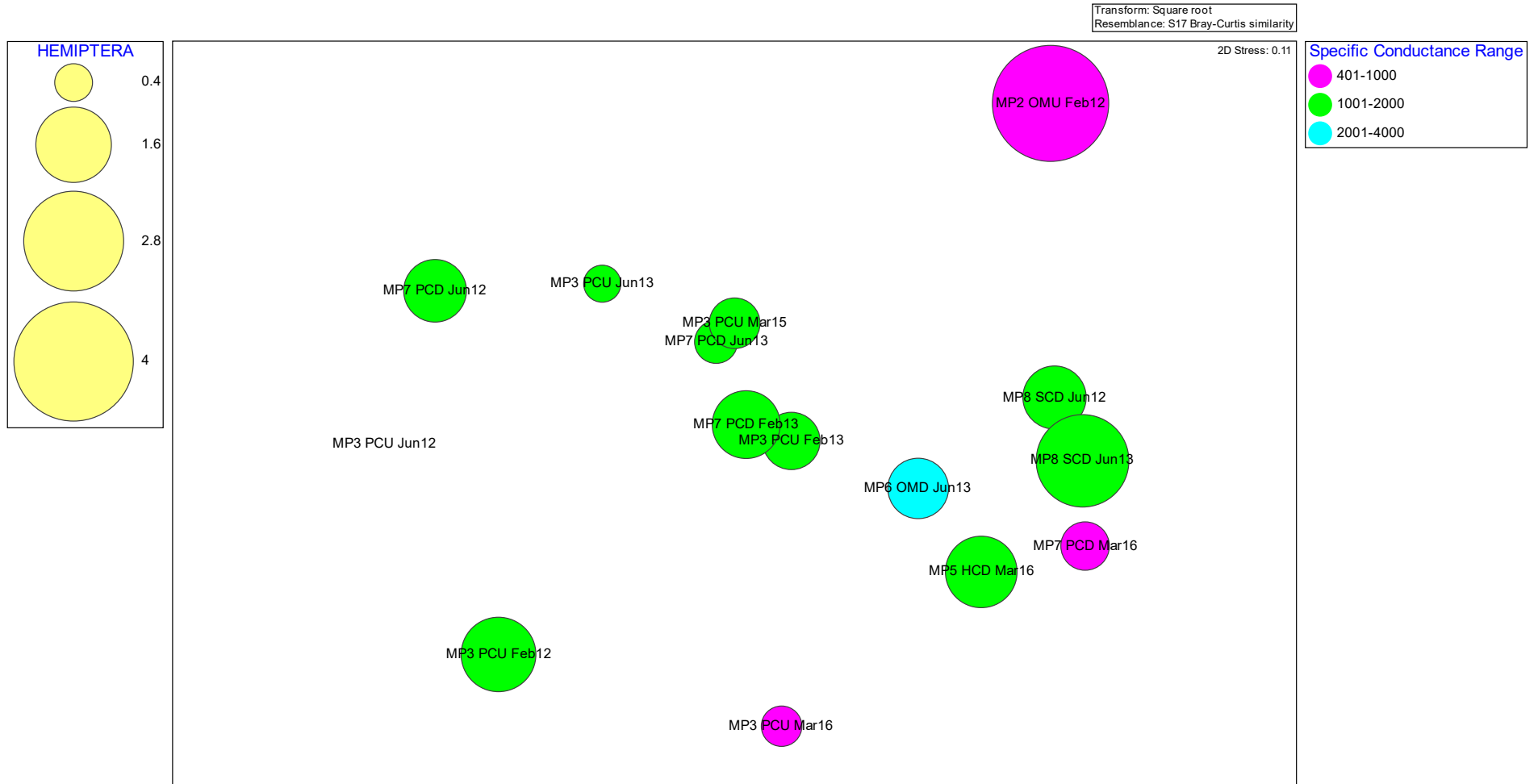


MDS Plot of Macroinvertebrate Community Composition showing square root of EPHEMEROPTERA abundance at various Specific Conductance Ranges (2012-2016)

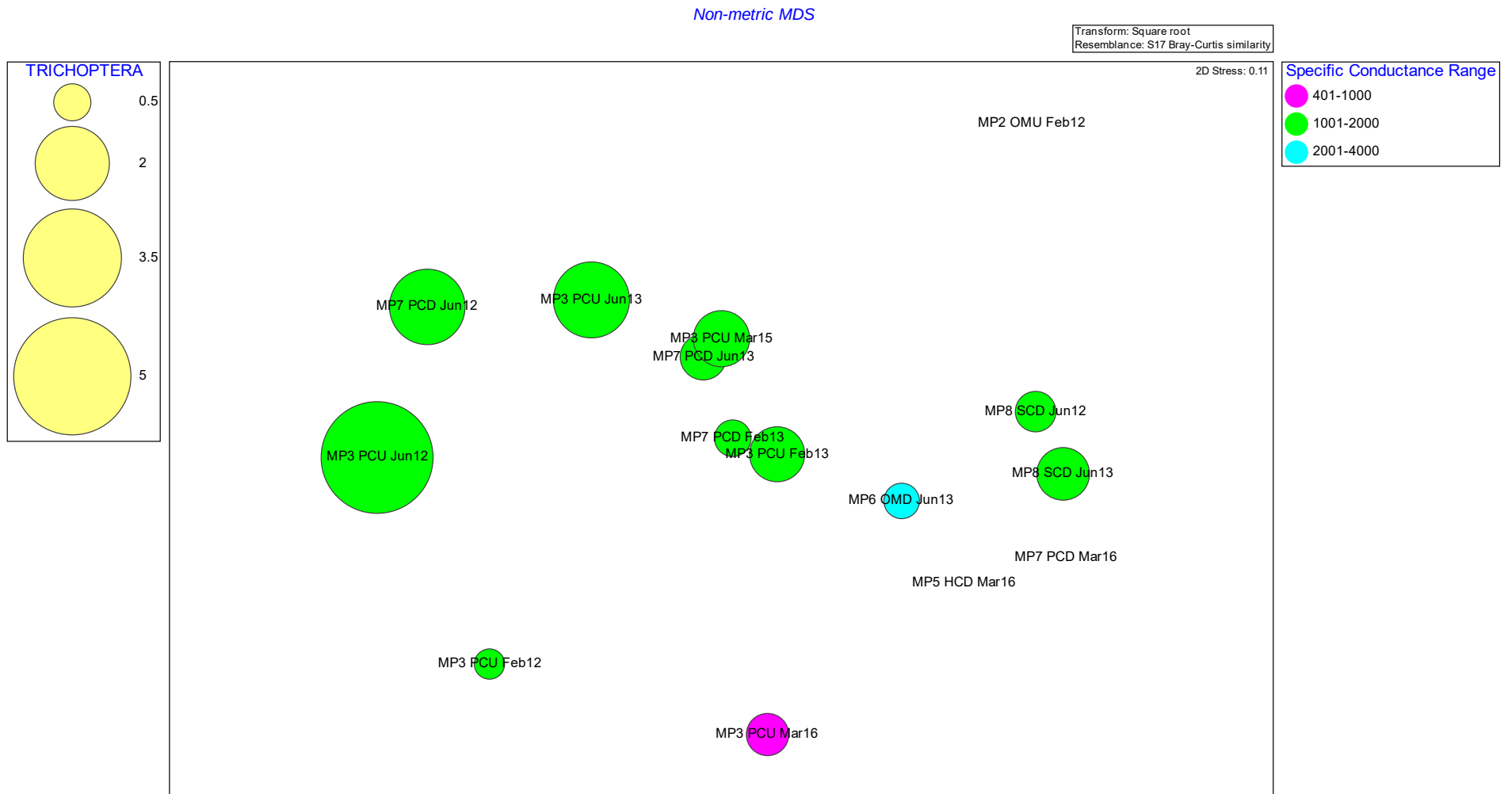


MDS Plot of Macroinvertebrate Community Composition showing square root of HEMIPTERA abundances at various Specific Conductance Ranges (2012-2016)

Non-metric MDS

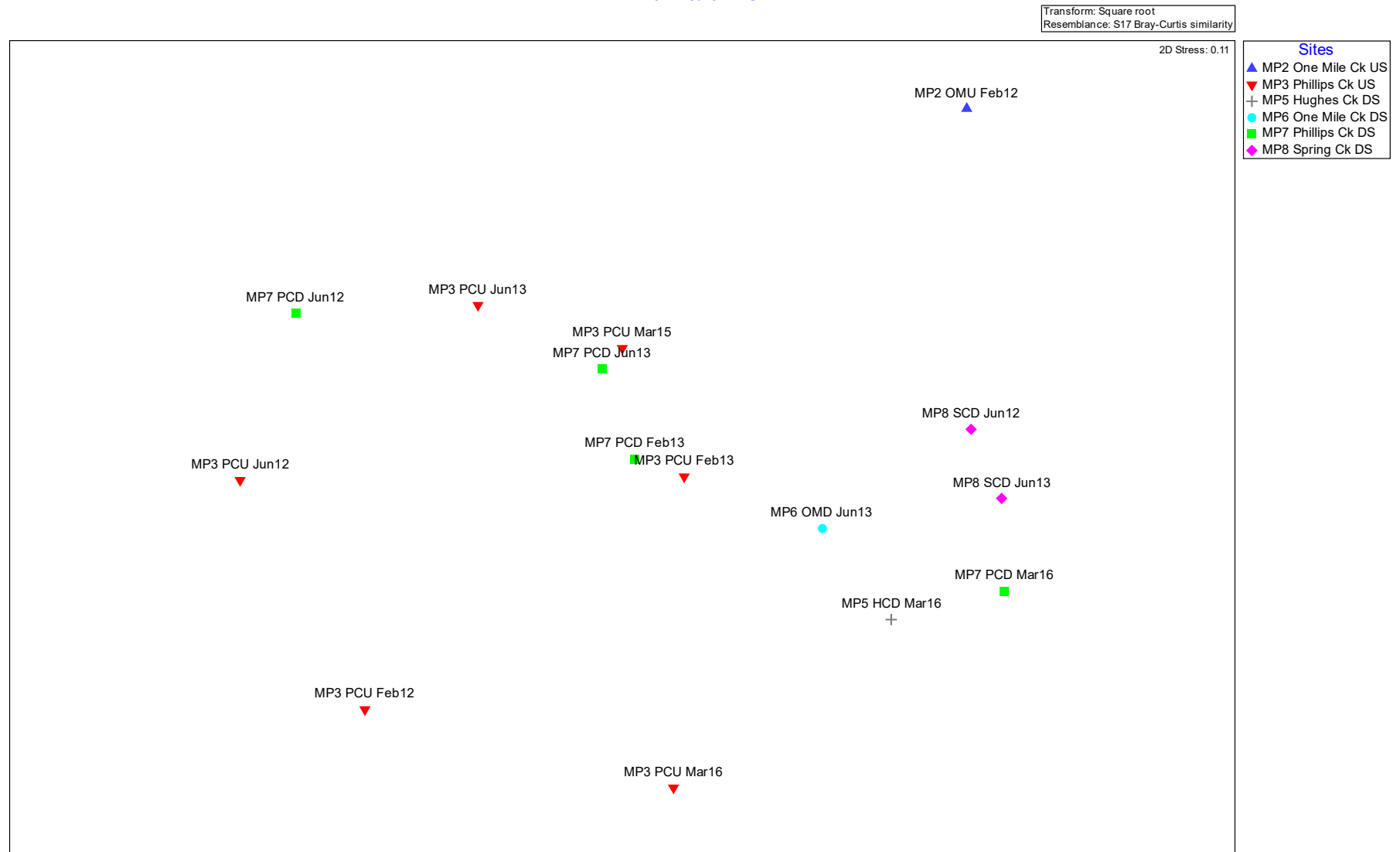


MDS Plot of Macroinvertebrate Community Composition showing square root of TRICHOPTERA abundances at various Specific Conductance Ranges (2012-2016)



MDS Plot of Macroinvertebrate Community Composition between SITES (2012-2016)

Non-metric MDS

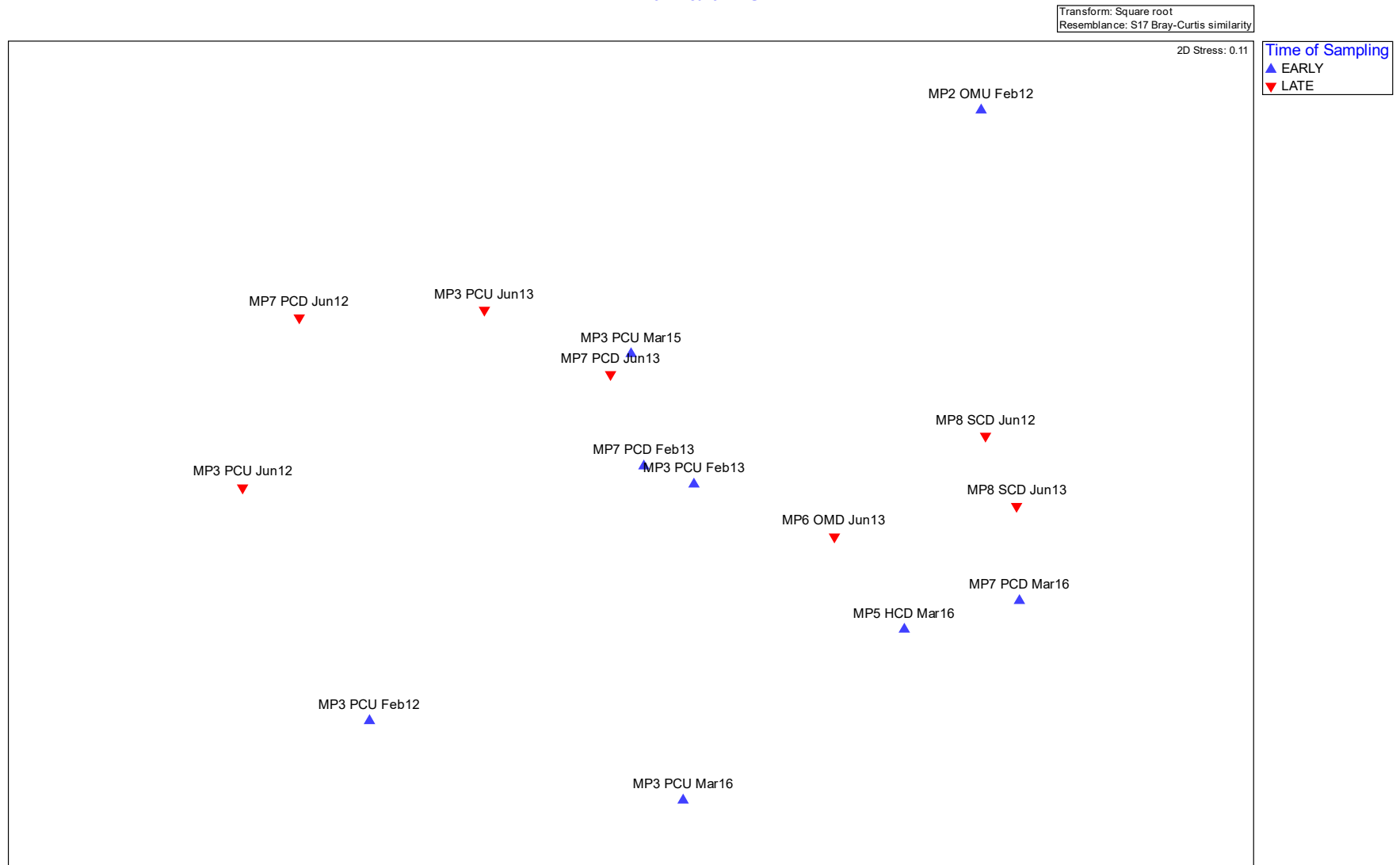


No clear separation of sites in MDS.

ANOSIM – one-way showed no significant difference between sites ($R = 0.125$, $P = 23.2\%$).

MDS Plot of Macroinvertebrate Community Composition by TIME (2012-2016)

Non-metric MDS

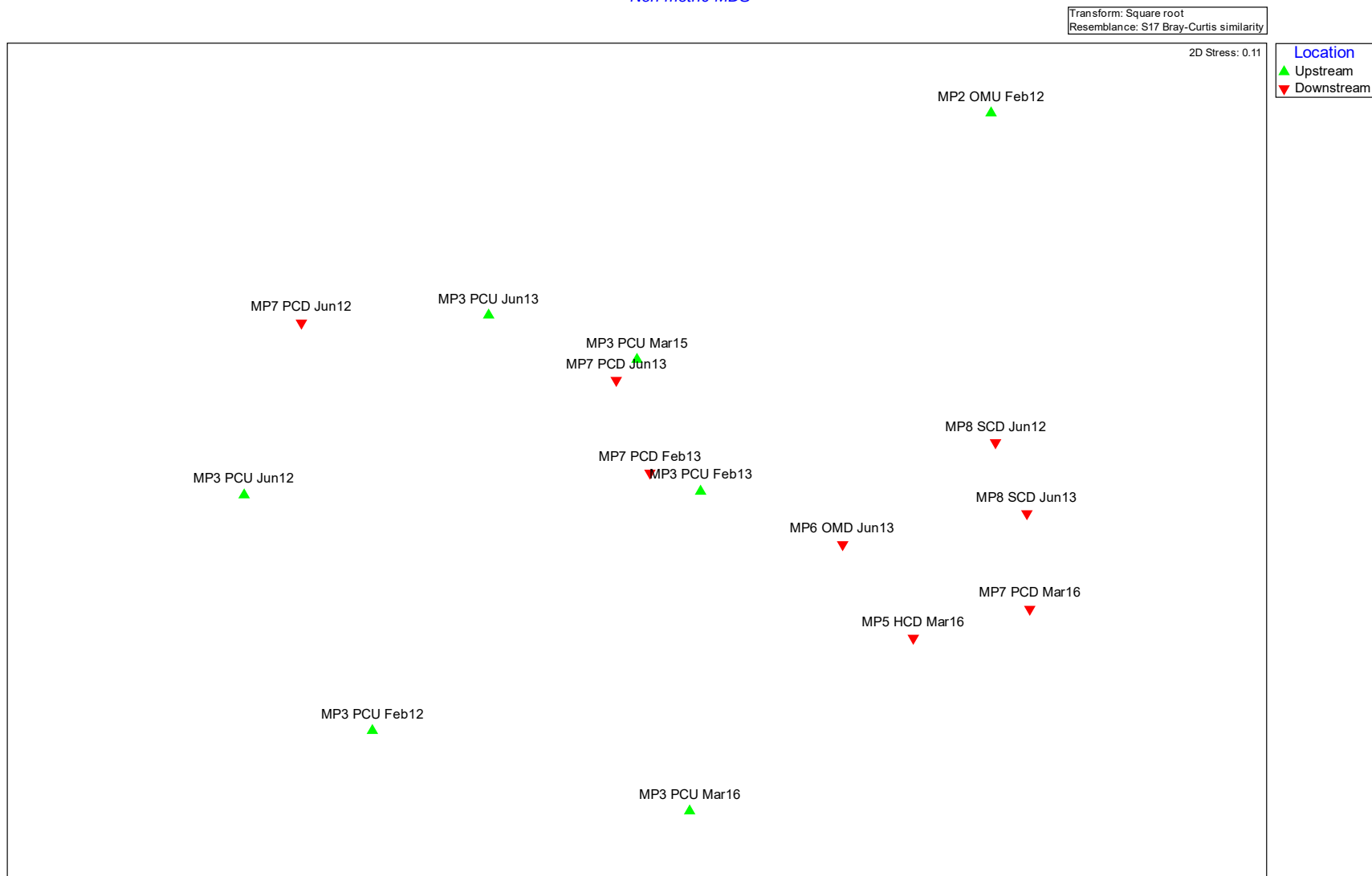


No clear separation of sampling times in MDS.

ANOSIM – (one-way) showed no significant difference between sampling time ($R = -0.009$, $P = 45.8\%$).

MDS Plot of Macroinvertebrate Community Composition between LOCATIONS (2012-2016)

Non-metric MDS

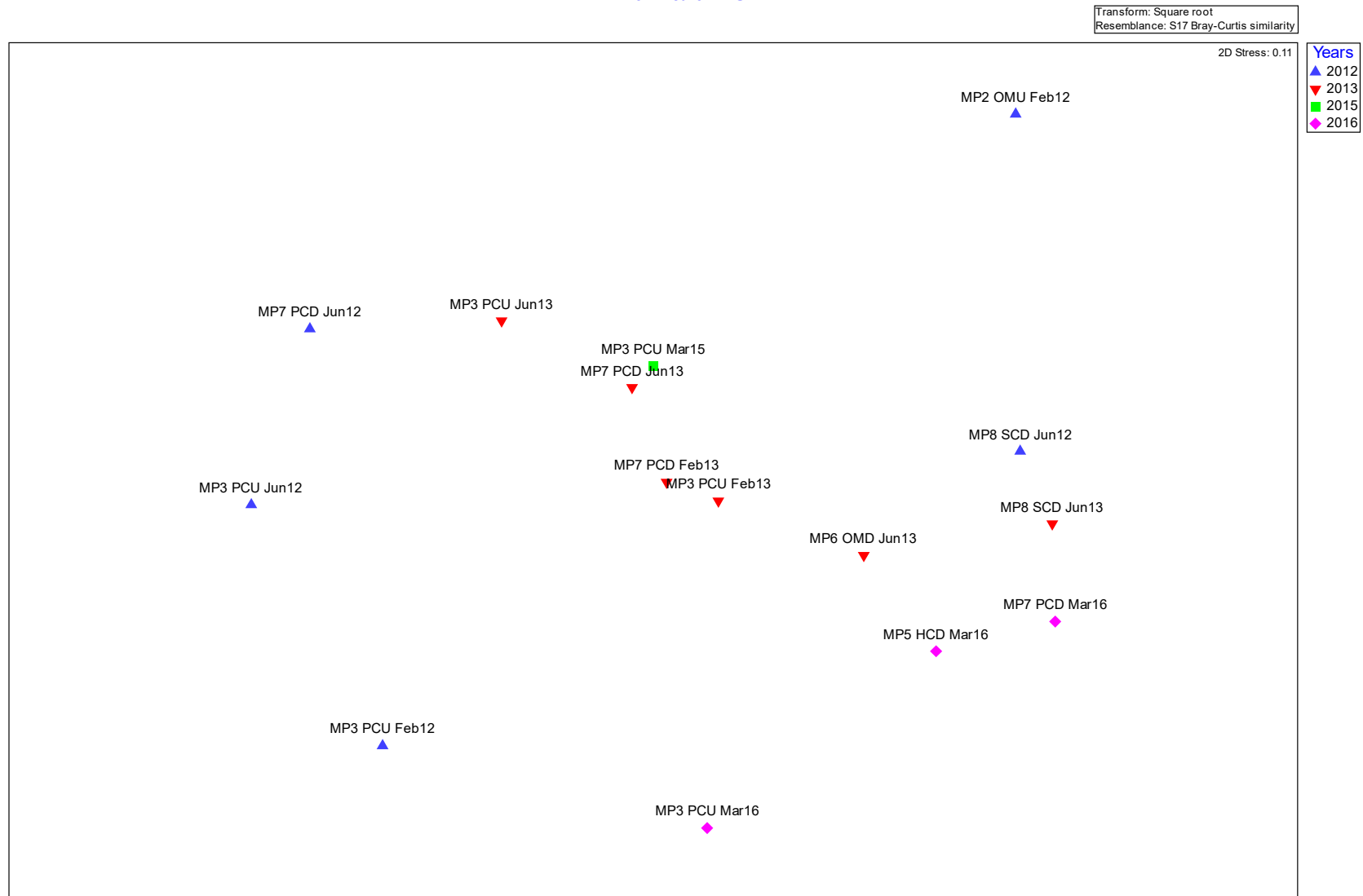


No clear separation between locations in MDS.

ANOSIM – (one-way) showed no significant difference between locations ($R = 0.136$, $P = 9.7\%$).

MDS Plot of Macroinvertebrate Community Composition between YEARS (2012-2016)

Non-metric MDS



No clear separation of years in MDS.

ANOSIM – (one-way) showed no significant difference between years ($R = 0.239$, $P = 3.4\%$).

ANOSIM of SRM Macroinvertebrate Results 2012-2016

Global Test (TIME)

Sample statistic (R): -0.009

Significance level of sample statistic: 45.8%

Number of permutations: 999 (Random sample from 6435)

Number of permuted statistics greater than or equal to R: 457

NO SIGNIFICANT DIFFERENCE BETWEEN SAMPLING TIMES

Global Test (YEAR)

Sample statistic (R): 0.239

Significance level of sample statistic: 3.4%

Number of permutations: 999 (Random sample from 2522520)

Number of permuted statistics greater than or equal to R: 33

NO SIGNIFICANT DIFFERENCE BETWEEN YEARS

Global Test (LOCATION)

Sample statistic (R): 0.136

Significance level of sample statistic: 9.7%

Number of permutations: 999 (Random sample from 6435)

Number of permuted statistics greater than or equal to R: 96

NO SIGNIFICANT DIFFERENCE BETWEEN LOCATION

ONE-WAY SIMPER ANALYSIS Macroinvertebrate Results

Comparing Early and Late Wet Season Sampling (2012-2016)

Groups **EARLY & LATE**

Average dissimilarity = 35.55

Species	Group EARLY Av. Abund	Group LATE Av. Abund	Av. Diss	Diss/SD	Contrib%	Cum. %
MICRO-CRUSTACEANS	4.01	4.02	7.01	1.45	19.73	19.73
EPHEMEROPTERA	3.96	5.19	6.20	1.37	17.43	37.15
DIPTERA	6.58	5.24	3.40	1.24	9.58	46.73
TRICHOPTERA	0.47	1.65	2.99	0.99	8.41	55.14
COLEOPTERA	1.31	1.59	2.07	1.16	5.83	60.98
HEMIPTERA	1.36	0.94	2.06	1.09	5.80	66.78
ODONATA	1.71	1.40	1.99	1.33	5.60	72.38

ONE-WAY SIMPER ANALYSIS Macroinvertebrate Results

Comparing Upstream and Downstream Sites (2012-2016)

Groups *Upstream & Downstream*

Average dissimilarity = 36.34

Species	Group Upstream Av. Abund	Group Downstream Av. Abund	Av. Diss	Diss/SD	Contrib%	Cum. %
MICRO-CRUSTACEANS	2.47	5.37	8.08	1.60	22.22	22.22
EPHEMEROPTERA	5.00	4.13	6.14	1.56	16.90	39.12
DIPTERA	6.36	5.60	3.18	1.26	8.75	47.87
TRICHOPTERA	1.41	0.68	2.71	0.92	7.45	55.32
HEMIPTERA	1.12	1.20	2.18	1.18	5.99	61.31
COLEOPTERA	1.68	1.24	2.02	1.04	5.55	66.86
ODONATA	1.65	1.49	1.97	1.40	5.42	72.28

ONE-WAY SIMPER ANALYSIS Macroinvertebrate Results

2012-2013, 2012-2015 and 2012-2016

Groups 2012 & 2013

Average dissimilarity = 38.46

Species	Group 2012 Av.Abund	Group 2013 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
MICRO-CRUSTACEANS	2.12	5.10	8.55	1.72	22.24	22.24
EPHEMEROPTERA	4.65	5.25	5.50	1.46	14.29	36.53
COLEOPTERA	2.47	0.90	3.44	2.09	8.95	45.48
TRICHOPTERA	1.51	0.99	3.01	1.05	7.83	53.31
DIPTERA	5.99	5.28	2.57	2.05	6.67	59.98
HEMIPTERA	1.52	1.09	2.39	1.17	6.23	66.21
ODONATA	1.47	1.81	2.30	1.43	5.98	72.18

Groups 2012 & 2015

Average dissimilarity = 36.84

Species	Group 2012 Av.Abund	Group 2015 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
MICRO-CRUSTACEANS	2.12	4.01	6.94	2.06	18.83	18.83
EPHEMEROPTERA	4.65	7.01	6.13	1.79	16.63	35.46
TRICHOPTERA	1.51	1.15	3.00	1.16	8.15	43.61
OLIGOCHAETA	0.51	1.78	2.81	2.17	7.64	51.25
COLEOPTERA	2.47	1.22	2.71	1.60	7.35	58.60
DIPTERA	5.99	5.15	2.70	2.48	7.32	65.91
HEMIPTERA	1.52	0.72	2.29	1.00	6.23	72.14

Groups 2012 & 2016

Average dissimilarity = 43.54

Species	Group 2012 Av.Abund	Group 2016 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
MICRO-CRUSTACEANS	2.12	5.01	9.58	1.53	22.01	22.01
EPHEMEROPTERA	4.65	2.08	6.78	1.26	15.58	37.59
DIPTERA	5.99	7.50	4.30	1.42	9.87	47.46
COLEOPTERA	2.47	0.90	3.66	2.16	8.40	55.86
TRICHOPTERA	1.51	0.22	3.45	0.86	7.92	63.78
HEMIPTERA	1.52	0.85	2.48	1.12	5.70	69.48
ODONATA	1.47	1.47	2.14	2.31	4.92	74.40

ONE-WAY SIMPER ANALYSIS Macroinvertebrate Results

2013-2015, 2013-2016 and 2015-2016

Groups **2013 & 2015**

Average dissimilarity = 22.47

Species	Group 2013 Av.Abund	Group 2015 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
EPHEMEROPTERA	5.25	7.01	4.19	1.01	18.63	18.63
MICRO-CRUSTACEANS	5.10	4.01	3.24	1.13	14.43	33.07
OLIGOCHAETA	0.31	1.78	3.16	3.84	14.07	47.13
ODONATA	1.81	0.90	2.01	1.20	8.95	56.08
NEMATODA	0.33	0.61	1.57	2.37	7.01	63.09
BIVALVIA	0.68	0.00	1.44	0.60	6.42	69.51
HYDRA	0.27	0.54	1.36	2.83	6.07	75.58

Groups **2013 & 2016**

Average dissimilarity = 32.23

Species	Group 2013 Av.Abund	Group 2016 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
EPHEMEROPTERA	5.25	2.08	7.69	1.64	23.87	23.87
MICRO-CRUSTACEANS	5.10	5.01	5.68	1.54	17.61	41.48
DIPTERA	5.28	7.50	5.05	1.77	15.68	57.16
TRICHOPTERA	0.99	0.22	1.86	1.36	5.77	62.93
NEMATODA	0.33	0.63	1.70	1.15	5.29	68.21
BIVALVIA	0.68	0.00	1.55	0.64	4.80	73.01

Groups **2015 & 2016**

Average dissimilarity = 36.00

Species	Group 2015 Av.Abund	Group 2016 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
EPHEMEROPTERA	7.01	2.08	11.25	4.04	31.25	31.25
MICRO-CRUSTACEANS	4.01	5.01	5.66	2.13	15.73	46.98
DIPTERA	5.15	7.50	5.30	1.65	14.72	61.70
OLIGOCHAETA	1.78	0.12	3.78	9.19	10.51	72.21

BEST Results for Macroinvertebrate Community Composition and Water (2012-2016)

BEST

Biota and/or Environment matching

Resemblance worksheet

Name: Resem1

Data type: Similarity

Selection: All

Data worksheet

Name: Data6

Data type: Environmental

Sample selection: All

Variable selection: All

Parameters

Correlation method: Spearman rank

Method: BIOENV

Maximum number of variables: 5

Analyse between: Samples

Resemblance measure: D1 Euclidean distance

VARIABLES

pH	pH	Trial
EC	EC	Trial
DO	DO	Trial
OR	ORP	Trial
Tu	Turb	Trial
Te	Temp	Trial
SS	SS	Trial
CO	CO3 Alk	Trial
HC	HC03 Alk	Trial
Tot Alk	Tot Alk	Trial
SO	SO4	Trial
Cl	Cl	Trial
Ca	Ca	Trial
Mg	Mg	Trial
Na	Na	Trial
K	K	Trial
Dis Al	Dis Al	Trial
Dis As	Dis As	Trial
Dis B	Dis B	Trial
Dis Cr	Dis Cr	Trial
Dis Cu	Dis Cu	Trial
Dis F	Dis Fe	Trial
Dis Mn	Dis Mn	Trial
Dis Mo	Dis Mo	Trial
Dis N	Dis Ni	Trial
Dis S	Dis Se	Trial
Dis U	Dis U	Trial
Dis V	Dis V	Trial
Dis Z	Dis Zn	Trial
Tot Al	Tot Al	Trial
Tot As	Tot As	Trial
Tot B	Tot B	Trial
Tot Cr	Tot Cr	Trial
Tot Co	Tot Co	Trial
Tot Cu	Tot Cu	Trial
Tot F	Tot Fe	Trial
Tot Pb	Tot Pb	Trial
Tot Mn	Tot Mn	Trial
Tot Mo	Tot Mo	Trial
Tot Ni	Tot Ni	Trial
Tot S	Tot Se	Trial
Tot U	Tot U	Trial
Fl	Fl	Trial
NH	NH4-N	Trial
N02-N	N02-N	Trial
N03	N03-N	Trial
N02-N	N02-N + N03-N	Trial
TK	TKN	Trial
Tot N-	Tot N-N	Trial
Tot P-	Tot P-P	Trial
Re	Reac P-P	Trial

Best result for each number of variables

No.Vars	Corr.	Selections
1	0.445	Tot As
2	0.532	Dis F, Tot Co
3	0.658	CO, Dis F, Tot Co
4	0.701	CO, Dis F, Dis Z, Tot Co
5	0.727	CO, Dis F, Dis Z, Tot Co, Tot P-

Best results

No.Vars	Corr.	Selections
5	0.727	CO, Dis F, Dis Z, Tot Co, Tot P-
4	0.701	CO, Dis F, Dis Z, Tot Co
5	0.700	CO, Dis F, Dis Z, Tot As, Tot Co
5	0.685	CO, Tot Alk, Dis F, Dis Z, Tot Co
5	0.683	CO, Dis F, Tot Co, NH, Tot P-
5	0.681	Tu, CO, Dis F, Dis Z, Tot Co
5	0.679	Tu, CO, Dis F, Dis Z, Tot P-
5	0.676	CO, HC, Dis F, Dis Z, Tot Co
5	0.675	CO, Dis F, Tot Co, Tot P-, Re
5	0.674	pH, CO, Dis Z, Tot Co, Tot P-

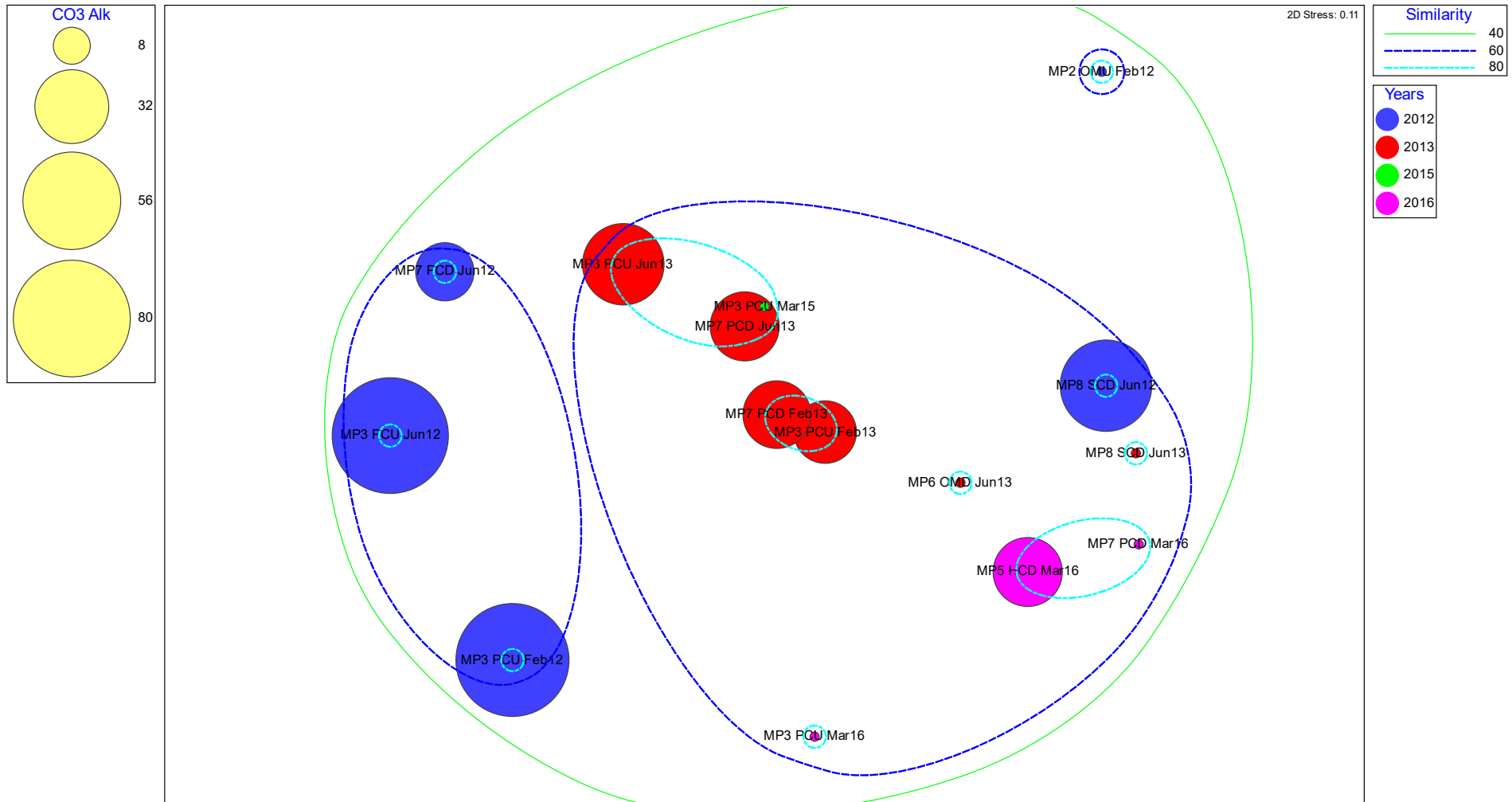
- CO₃²⁻ alkalinity, dissolved Fe, dissolved Zn, total Co and total P provide the best matching of the biotic patterns identified in the MDS.

MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of CO₃²⁻ Alkalinity (mg/L)

Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity

2D Stress: 0.11

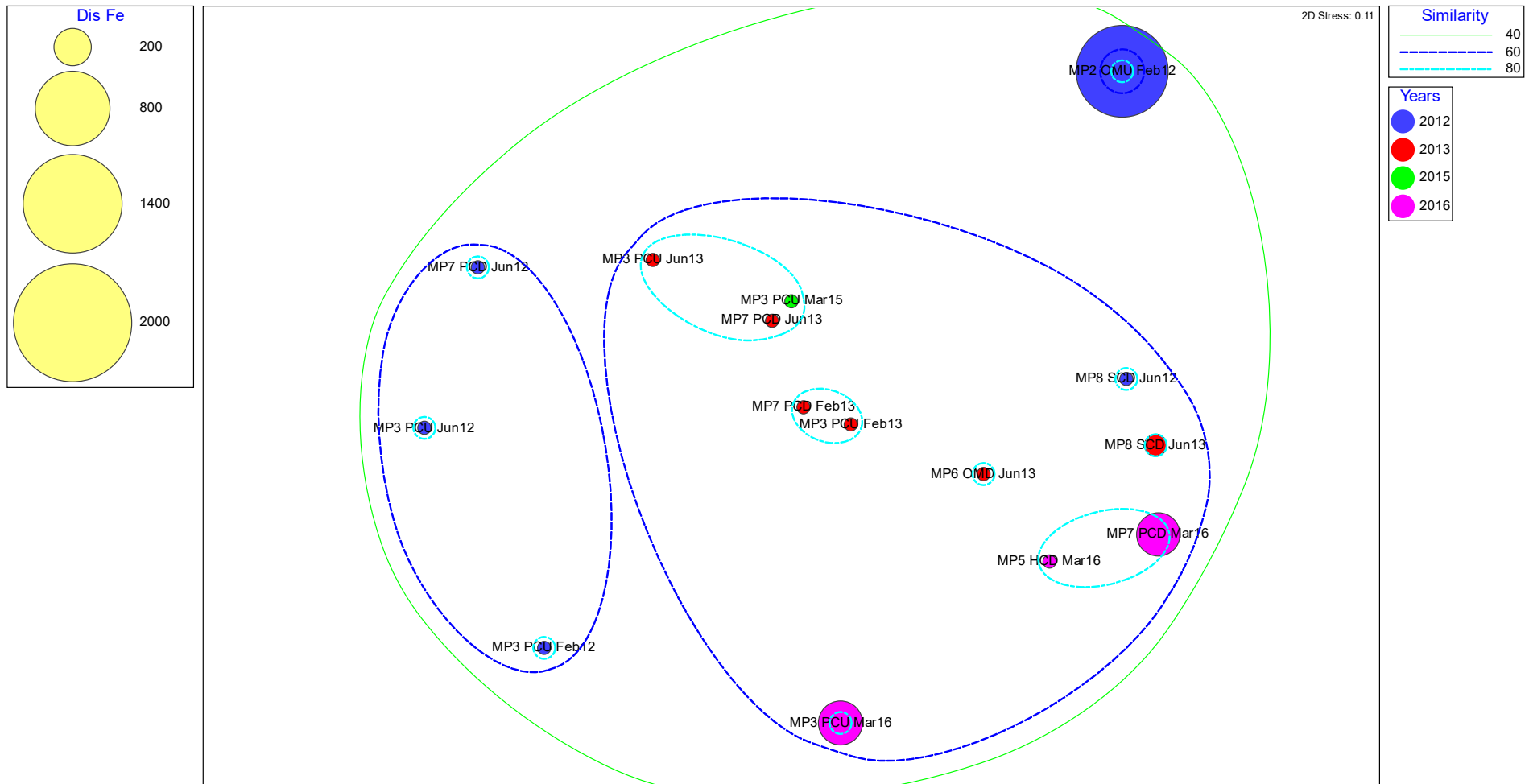


MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Dissolved Iron ($\mu\text{g/L}$)

Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity

2D Stress: 0.11

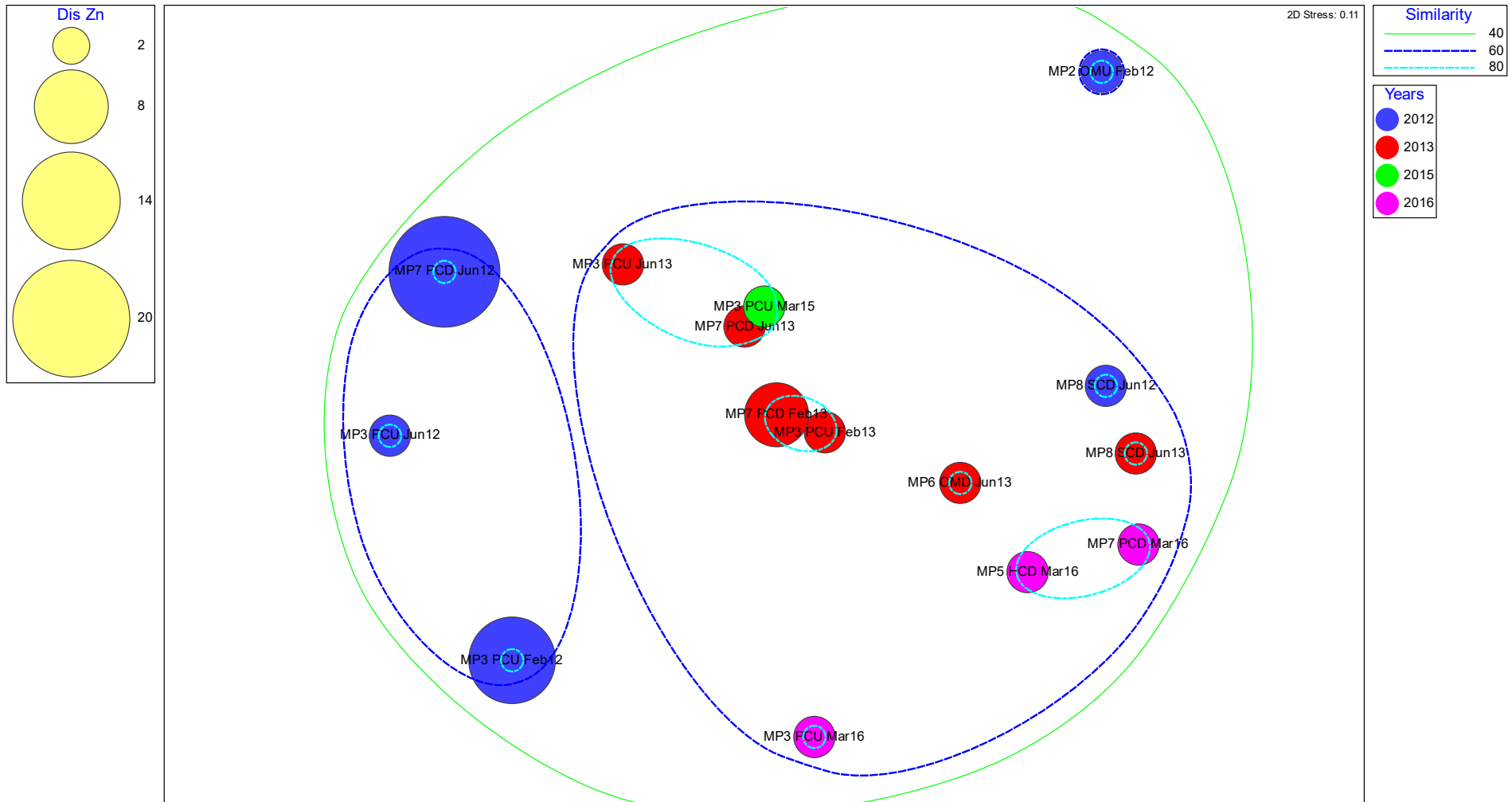


MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Dissolved Zinc ($\mu\text{g/L}$)

Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity

2D Stress: 0.11

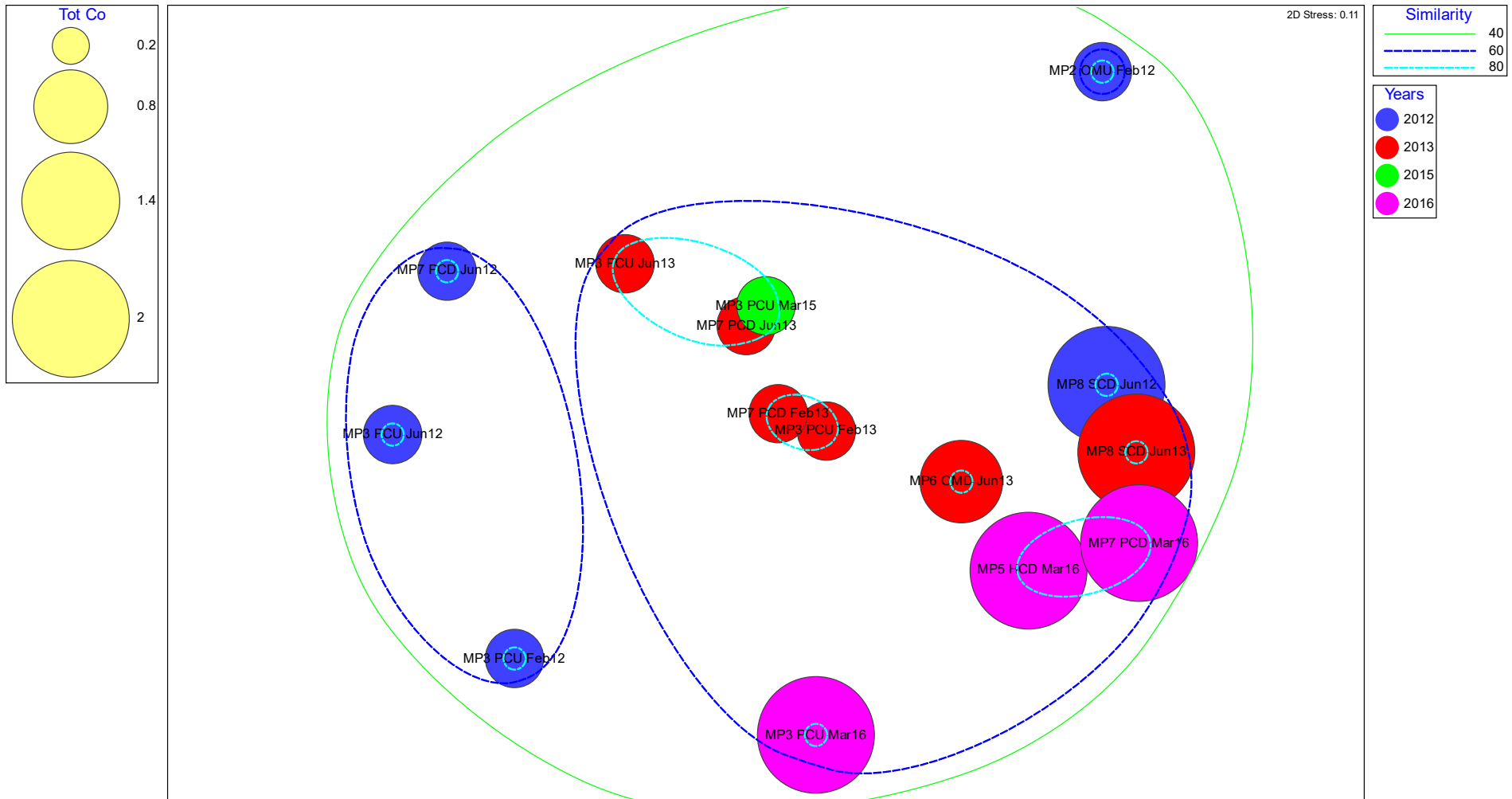


MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Total Cobalt ($\mu\text{g/L}$)

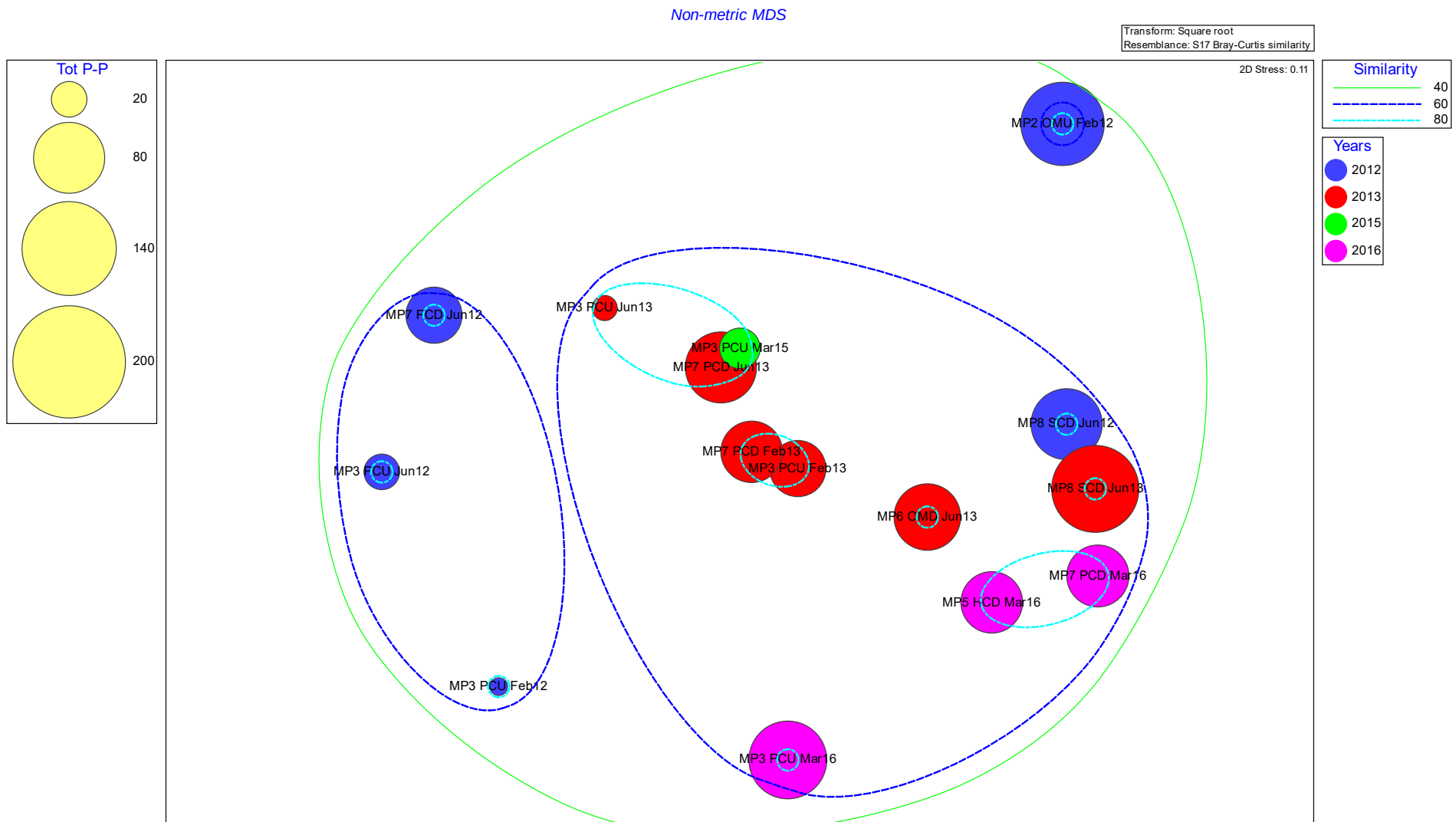
Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity

2D Stress: 0.11



MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Total Phosphorus ($\mu\text{g/L}$)



BEST Results of Macroinvertebrate Community Composition and Sediment (2012-2016)

BEST

Biota and/or Environment matching

Resemblance worksheet

Name: Resem1

Data type: Similarity

Selection: All

Data worksheet

Name: Data5

Data type: Environmental

Sample selection: All

Variable selection: All

Parameters

Correlation method: Spearman rank

Method: BIOENV

Maximum number of variables: 5

Analyse between: Samples

Resemblance measure: D1 Euclidean distance

VARIABLES

Al	Al	Trial
As	As	Trial
Cr	Cr	Trial
Co	Co	Trial
Cu	Cu	Trial
Fe	Fe	Trial
Pb	Pb	Trial
Mn	Mn	Trial
Ni	Ni	Trial
V	V	Trial
Zn	Zn	Trial

Best result for each number of variables

No.Vars	Corr.	Selections
1	0.179	Cu
2	0.246	Al, Fe
3	0.240	Al, Cu, Fe
4	0.226	Al, Cr, Cu, Mn
5	0.220	Al, Cr, Cu, Fe, Pb

Best results

No.Vars	Corr.	Selections
2	0.246	Al, Fe
3	0.240	Al, Cu, Fe
3	0.231	Al, Cr, Mn
4	0.226	Al, Cr, Cu, Mn
2	0.223	Al, Cr
3	0.223	Al, Cr, Fe
4	0.222	Al, Cr, Pb, Mn
5	0.220	Al, Cr, Cu, Fe, Pb
3	0.219	Al, Pb, Mn
2	0.218	Al, Mn

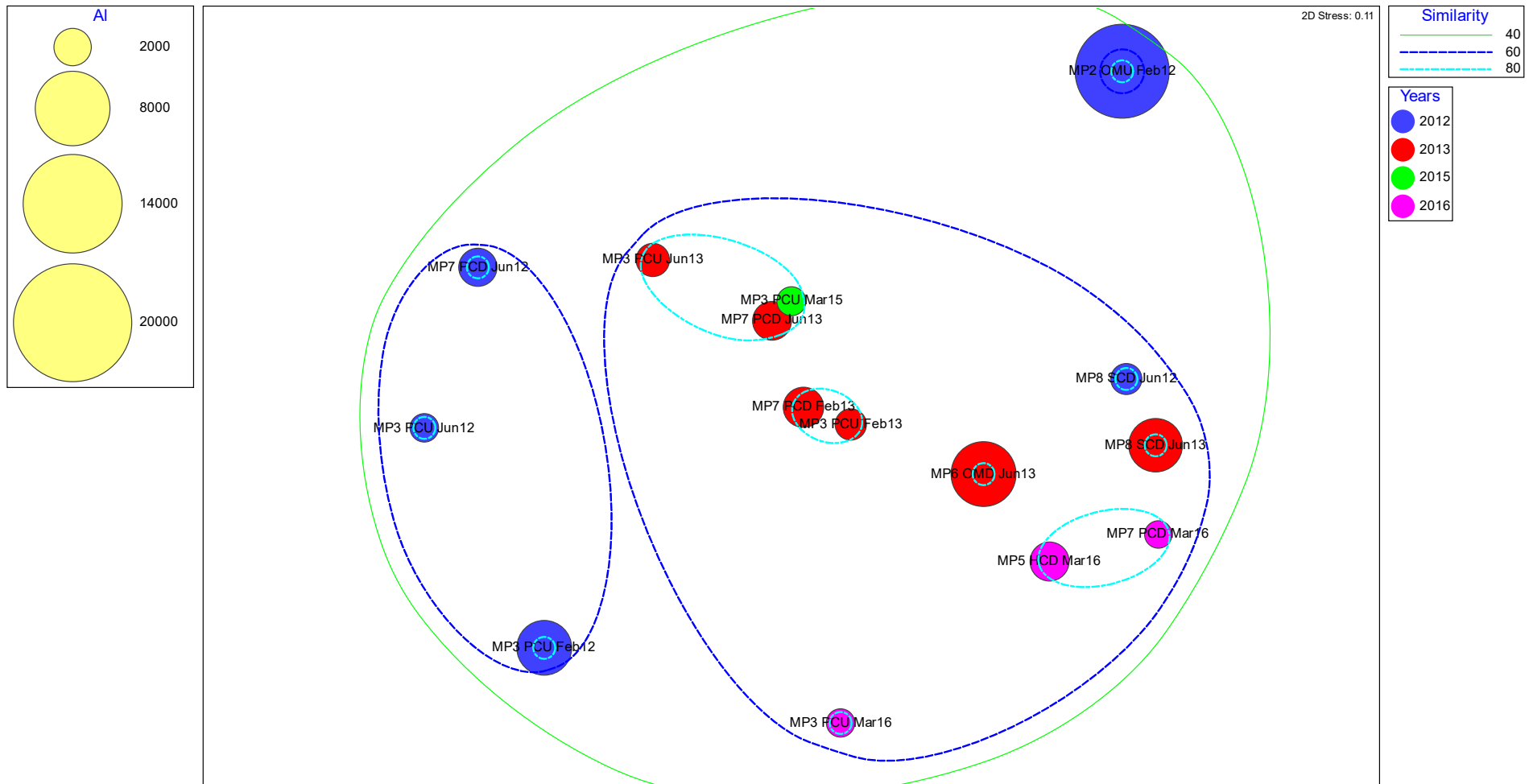
- Total Al and Fe provide the best match with the biotic patterns identified in the MDS

MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Total Aluminium in Sediment (mg/kg)

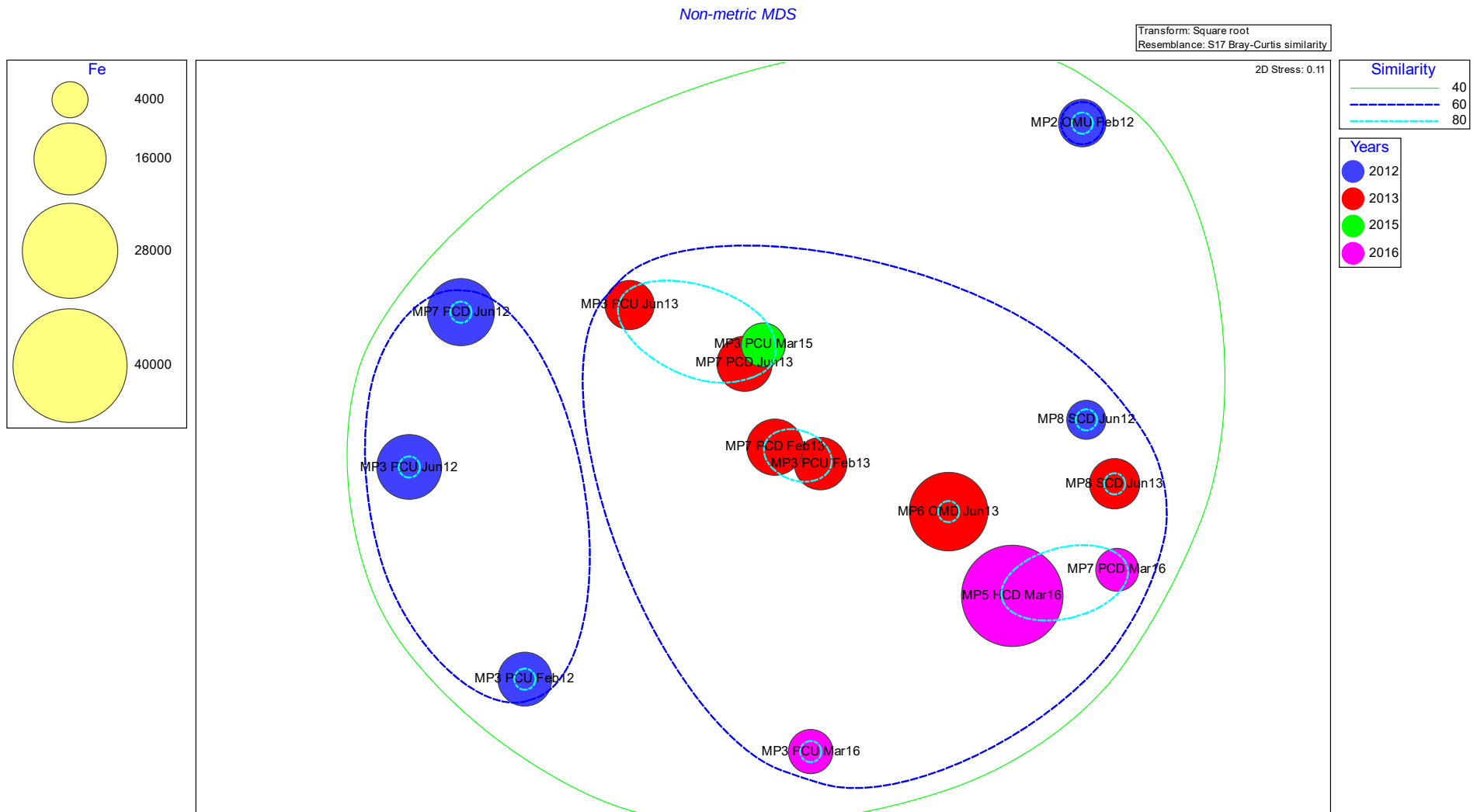
Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity

2D Stress: 0.11



MDS Plot of Macroinvertebrate Community Composition (2012-2016) with Bubble Overlay of Total Iron in Sediment (mg/kg)



BEST Results of Macroinvertebrate Community Composition and Sediment, Water, Particle Size Distribution and Habitat Scores (2015-2016)

BEST

Biota and/or Environment matching

Resemblance worksheet

Name: Resem1

Data type: Similarity

Selection: All

Data worksheet

Name: Data4

Data type: Environmental

Sample selection: All

Variable selection: All

Parameters

Correlation method: Spearman rank

Method: BIOENV

Maximum number of variables: 5

Analyse between: Samples

Resemblance measure: D1 Euclidean distance

Best result for each number of variables

No. Vars	Corr.	Selections
1	0.679	Si
2	1.000	Te, Dis Mn
3	1.000	+15, +6, Dis Mn
4	1.000	+7, Gr, Te, HC
5	1.000	+7, +15, +6, +11, DO

Best results

No. Vars	Corr.	Selections
2	1.000	Te, Dis Mn
2	1.000	Te, Tot Mn
3	1.000	+15, +6, Dis Mn
3	1.000	+15, +6, Tot Mn
3	1.000	+15, St, Dis Mn
3	1.000	+15, St, Tot Mn
3	1.000	+3, +6, Dis Mn
3	1.000	+3, St, Dis Mn
3	1.000	+3, St, Tot Mn
3	1.000	+4, +6, Dis Mn

VARIABLES

+7	+75µm
+15	+150µm
+3	+300µm
+4	+425µm
+6	+600µm
+11	+1180µm
Clay	Clay (<2 µm)
Si	Silt (2-60 µm)
Sa	Sand (0.06-2.00 mm)
Gr	Gravel (>2mm)
Bottom su	Bottom substrate available cover
Em	Embeddedness
Bottom sc	Bottom scouring and deposition
Po	Pool riffle run bend ratio
Bank s	Bank stability
Bank v	Bank vegetative stability
St	Stream side cover
Al	Al
Cr	Cr
Co	Co
Cu	Cu
Fe	Fe
Mn	Mn
Ni	Ni
V	V
Zn	Zn
pH	pH
EC	EC
DO	DO
OR	ORP
Tu	Turb
Te	Temp
SS	SS
C03	C03 Alk
HC	HC03 Alk

Tot Alk	Tot Alk
S0	S04
Cl	Cl
Ca	Ca
Mg	Mg
Na	Na
K	K
Dis A	Dis Al
Dis B	Dis B
Dis C	Dis Cu
Dis F	Dis Fe
Dis Mn	Dis Mn
Dis Mo	Dis Mo
Dis N	Dis Ni
Dis U	Dis U
Tot Al	Tot Al
Tot As	Tot As
Tot B	Tot B
Tot Cr	Tot Cr
Tot Co	Tot Co
Tot Cu	Tot Cu
Tot F	Tot Fe
Tot Pb	Tot Pb
Tot Mn	Tot Mn
Tot Mo	Tot Mo
Tot Ni	Tot Ni
Tot U	Tot U
Fl	Fl
NH	NH4-N
N02-N	N02-N
N03	N03-N
N02-N	N02-N + N03-N
TK	TKN
Tot N-	Tot N-N
Tot P-	Tot P-P
DOC	DOC

- Temperature, dissolved Mn, Total Mn, particle sizes (+300, +425, +600, +150 µm) and stream side cover provide the best match of the biotic patterns identified in the MDS from 2015-2016 data.

MACROINVERTEBRATE COMMUNITY COMPOSITION

2012-2016

- Macroinvertebrate community composition was analysed using Bray Curtis Similarity and visualised using Multi-Dimensional Scaling (MDS). No significant difference in macroinvertebrate composition was found between locations (ANOSIM: $R = 0.136$, $P = 9.7\%$); no significant difference between early and late sampling run (ANOSIM: $R = -0.009$, $P = 45.8\%$); and no significant difference was found between years (ANOSIM: $R = 0.239$, $P = 3.4\%$)
- BEST analysis comparing water quality with macroinvertebrate composition suggested that CO_3^{2-} alkalinity, dissolved Fe, dissolved Zn, total Co and total P were likely to be the main parameters linked to the separation of sites in the MDS. However, since there is no statistical difference (72.7 % corr.) between sites in composition their influence is likely to be low.
- BEST analysis comparing sediments with macroinvertebrate composition suggested that total Al, Cd and Mn in sediments provided the best matching of the biotic patterns identified in the MDS.
- SIMPER analysis showed an average 35.55 % dissimilarity between early and late sampling times.
- SIMPER analysis showed an average 36.34 % dissimilarity between upstream and downstream sites.
- SIMPER analysis showed an average 38.46 % dissimilarity between 2012 and 2013, average dissimilarity between 2012-2015 of 36.84 %, 2012-2016 of 43.54 %, 2013-2015 of 22.47 %, 2013-2016 of 32.23 % and 36.0 % of 2015-2016.
- Diptera, Ephemeroptera and Microcrustacea were the most abundant taxa over the years.

Saraji Mine

**Power Point/Graphs
& Reporting:**

Alison Craig

QA/QC:

Geeta Gautam Kafle
Leigh Stitz
Wayne Houston
Larelle Fabbro

Review:

Sue Vink (UQ)
Larelle Fabbro (CQU)