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REVIEW OF INFORMATION AND SAMPLING AND ANALYSIS QUALITY PLAN

CAPTAINS FLAT LEAD MANAGEMENT PLAN

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ABBREVIATIONS

Measures	Description
%	per cent
µg/L	Micrograms per Litre
µg/m^3	Micrograms per Cubic Metre
ha	Hectare
km	Kilometres
m	Metre
mAHD	Metres Australian Height Datum
mbgl	Metres below ground level
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre
mg/m^3	Milligrams per Cubic Metre
mm	Millimetre
ppm	Parts Per Million

Contaminant	Description
Al	Aluminium
As	Arsenic
Ba	Barium
Cd	Cadmium
Co	Cobalt
Cr	Chromium (III)
Cu	Copper
Fe	Iron
Hg	Mercury
Pb	Lead
Mn	Manganese
Mo	Molybdenum
Ni	Nickel
Sb	Antimony
Se	Selenium
Ti	Titanium
Zn	Zinc
BTEX	Benzene, toluene, ethylbenzene, xylene
OCP	Organochlorine pesticides
OPP	Organophosphate pesticides
PAH	Polycyclic aromatic hydrocarbons
TRH	Total recoverable hydrocarbons

General	Description
ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
BoM	Bureau of Meteorology
C&R	Contaminants and Risk Team, Environment, Energy and Science Branch of DPIE
CEC	Cation exchange capacity
CLM Act	NSW Contaminated Land Management Act 1997
COC	Chain of Custody
Council	Queanbeyan-Palerang Regional Council
CSM	Conceptual Site Model
DGV	Default guideline value
DO	Dissolved oxygen
DoE	Department of Education (NSW)
DPIE	Department of Planning, Industry and Environment (NSW)
DQI	Data Quality Indicator
DQO	Data Quality Objective
EC	Electrical conductivity
EIL	Ecological Investigation Level
EMP	Environmental Management Plan
Envirolab	Envirolab Services Pty Ltd
EPA	Environment Protection Authority (NSW)
fpXRF	Field portable x-ray fluorescence metals analyser
GIL	Groundwater Investigation Level
GME	Groundwater Monitoring Event
HVAS	High volume air sampler
HIL	Health Investigation Level
LCS	Laboratory Control Sample
LEP	Local Environment Plan
LOR	Limit of Reporting
Mercury	Inorganic mercury unless noted otherwise
MS	Matrix Spike
NATA	National Association of Testing Authorities
ND	Not Detected
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NL	Non-Limiting
n	Number of Samples
OEH	Office of Environment and Heritage
pH	A measure of acidity, hydrogen ion activity
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
QPRC	Queanbeyan-Palerang Regional Council

General	Description
RAP	Remediation Action Plan
Regional NSW	NSW Department of Regional NSW
RFS	Rural Fire Service
RPD	Relative Percent Difference
SAQP	Sampling and Analysis Quality Plan
SES	State Emergency Services
SPR	Source-Pathway-Receptor
SWL	Standing Water Level
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
TfNSW	Transport for NSW
TSP	Total suspended particulates
US EPA	United States Environmental Protection Agency
-	On tables is "not calculated", "no criteria" or "not applicable"

EXECUTIVE SUMMARY

Ramboll was retained by the Department of Regional NSW (Regional NSW) to prepare the Captains Flat Lead Management Plan to address exposure risks from lead within the environment and the community that relates to the legacy Lake George Mine. The NSW Department of Planning, Industry and Environment (DPIE) Contaminants and Risks Team (C&R), Environment, Energy and Science Branch (EES) completed a Literature Review on Nature and extent of contamination in the Captains Flat Region, NSW in April 2021 (C&R 2021). A preliminary conceptual site model (CSM) was developed as a qualitative representation of contaminant sources, migration pathways and potential receptors for potential contaminants from the legacy Lake George Mine.

The objectives of this report are to:

- Refine the existing preliminary CSM (C&R 2021) to provide a suitable platform for detailed data gaps assessment and development of the Captains Flat Lead Management Plan. This will include review of existing sampling and analytical data relevant to contamination within the Captains Flat community
- Define a Sampling and Analysis Quality Plan (SAQP) to address identified data gaps.

The extent of the sampling and analytical program is limited to assessing contaminant exposure risks that may exist for the Captains Flat community and immediate surrounding environment.

The primary data gaps identified in C&R (2021) were information regarding soil contamination impacts in the Captains Flat residential area, groundwater hydrogeological information and groundwater impacts in the region. Data gaps in relation to potential receptors were also identified, for example, use of groundwater, potential agricultural receptors and potential for home grown produce.

Ramboll has undertaken a review of available data and has expanded on the preliminary CSM developed by C&R. The following data gaps were identified to supplement those identified by C&R:

- Systematic assessment of metals concentrations in soils within the community and vertical delineation of elevated lead concentrations in soil within the community. Specific areas requiring assessment and/or vertical delineation are identified
- Bioavailability of metals in soils impacted by dust, ore, mine waste and slag, relevant to assessing human health risks
- Details of surface water and groundwater usage within the Precinct and the alluvial flats some kilometres downstream
- The effect of meteorological variability on the degree and distribution of surface water contamination
- Assessment of dissolved metals concentrations in surface water, relevant to assessing ecological risks
- The distribution of contaminated sediments and exposure risks within the receiving environment
- Potential for sediment to act as an ongoing source of impact to surface water
- Meteorology data in the vicinity of Captains Flat to inform assessment of source to receptor movement of air pollutants in the local airshed
- Assessment of internal dust within public buildings.

An assessment program has been designed to address these data gaps and to characterise the degree and extent of contamination with sufficient detail to confirm the CSM and inform development of the Captains Flat Lead Management Plan.

It is assumed that information relating to surface water and groundwater usage within the Precinct will be made available to Ramboll to inform the preparation of interim water usage guidelines.

Data gaps that will not be resolved under the proposed sampling and analyses include:

- Details of surface water and groundwater usage for the Molonglo River downstream of the Precinct
- Assessment of contaminant impacts to the Molonglo River downstream of the Precinct or interactions with the alluvial aquifer and downstream water users
- Sediment contamination assumed to be present in the water supply dam will not be comprehensively assessed under the proposed sampling and analyses. The Captains Flat Lead Management Plan will be developed under the assumption that contaminant exposure risks exist for benthic and aquatic ecology in the water supply dam. Comprehensive assessment of sediment in the water supply dam should be considered as part of ongoing surface water monitoring
- Effects of meteorological variability on contaminant mobility via airborne, surface water and groundwater migration pathways will remain as a data gap and require ongoing monitoring
- Site specific risk assessment considering bioavailability of metals may be warranted depending on the results of the assessment, the identified risks to human health and ecology and the associated management requirements
- Human health effects from contaminant exposure within Captains Flat and the downstream receiving environment. A systematic assessment of community health effects is recommended as a basis for understanding effects from current exposure scenarios and for validating the Captains Flat Lead Management Plan once implemented.

1. INTRODUCTION

Ramboll Australia Pty Ltd (Ramboll) was retained by the Department of Regional NSW (Regional NSW) to prepare the Captains Flat Lead Management Plan to address exposure risks from lead within the environment and the community that relates to the legacy Lake George Mine. A process diagram for preparation of the Captains Flat Lead Management Plan is presented as Figure 1-1 below.

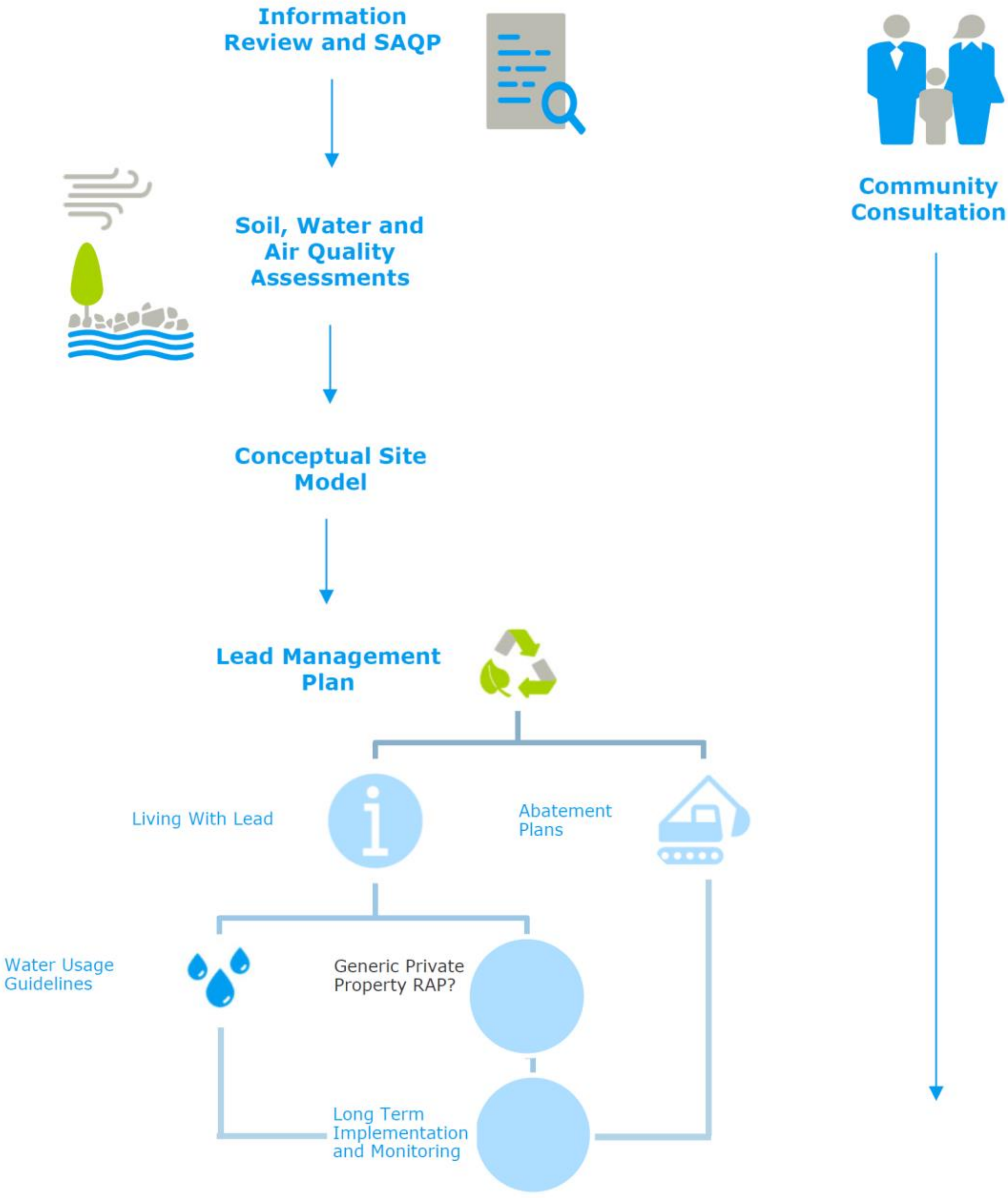

Figure 1-1 Pathway for development of the Captains Flat Lead Management Plan

The NSW Department of Planning, Industry and Environment (DPIE) Contaminants and Risks Team (C&R), Environment, Energy and Science Branch completed the Literature Review – Nature and extent of contamination in the Captains Flat Region, NSW in April 2021. This document includes a preliminary Conceptual Site Model (CSM) as a qualitative representation of contaminant sources, migration pathways and receptors. The CSM is critical element of the legislated framework for management of contaminated land in Australia.

1.1 Objectives

The objectives of this report are to:

- Refine the existing preliminary CSM (C&R 2021) to provide a suitable platform for detailed data gaps assessment and development of the Captains Flat Lead Management Plan. This will include review of existing sampling and analytical data relevant to contamination within the Captains Flat community
- Define a Sampling and Analysis Quality Plan (SAQP) to address identified data gaps.

The extent of the sampling and analytical program is limited to assessing contaminant exposure risks that may exist for the Captains Flat community and immediate surrounding environment.

1.2 Scope of Work

The scope of work performed to meet the objectives comprised review of recent assessments (as cited) and preparation of a SAQP including:

- Identification of the Captains Flat Lead Management Plan Precinct including preliminary identification of geographic boundaries and specific reference to the proposed public space abatement areas and boundaries of the mine and rail corridor, land parcels adjacent the mine and rail corridor and areas where data gaps have been identified
- Review of previous investigations
- Inspection of site condition and surrounding environment
- Review of analytical data and site plans including site boundaries, cadastral boundaries, historic sampling locations, service alignments and service invert depths
- A preliminary Conceptual Site Model (CSM) outlining potential Source-Pathway-Receptor (SPR) linkages including a tabulated summary and detailed discussion
- Data Quality Objectives (DQOs) to define criteria the sampling plan should satisfy
- Criteria for Tier 1 contaminant risk assessment
- Data Quality Indicators to describe how performance against DQOs will be assessed
- A sampling strategy, sampling methods and plans presenting proposed sampling locations
- QA/QC provisions to be completed during the proposed sampling.

2. IDENTIFICATION OF THE CAPTAINS FLAT LEAD MANAGEMENT PLAN PRECINCT

The Captains Flat Lead Management Plan Precinct (the Precinct) encompasses built areas of the Captains Flat community, the legacy Lake George Mine site and the Molonglo River from upstream of the water supply dam to a waterhole approximately 1.5 km downstream of the mine. The Precinct includes roads accessing Captains Flat (to a distance of at least 400 m), the rail corridor (to a distance of 1 km) and bushland areas at the perimeters of the community where these may have been impacted by the mine operations.

Private property assessments are an important aspect of managing lead exposure risks in Captains Flat though to preserve confidentiality the NSW Environment Protection Authority (EPA) is managing private property assessments (except those within the footprint of the former Lake George Mine) and results have not been made available for this report[1]. The Precinct is presented on **Figure 1**, **Appendix 1**. Precinct details are presented in Table 2-1**.**

Table 2-1: Site Identification

Information	Description
Site Area:	Approximately 295 Ha
Local Government Area:	Queanbeyan-Palerang Region
Owners:	Crown Lands (integrating land managed under the Legacy Mines Program), Queanbeyan-Palerang Regional Council (QPRC), Department of Education (DoE), Transport for NSW (TfNSW), Aboriginal Land Councils, numerous private land owners
Current Site Uses:	Land uses within the Precinct include: • Crown Lands (Legacy Mine areas, former preschool, parks, rivers, the water supply dam and bushland)2 • QPRC (public roads, sewerage treatment plant (STP), potable water treatment plant (WTP) and community buildings including the Community Hall, Rural Fire Service (RFS), State Emergency Services (SES) and Men's Shed) • DoE (Captains Flat Public School and the new preschool) • TfNSW (non-operational Captains Flat–Bungendore rail line) • Mogo Local Aboriginal Land Council (areas west of the rail corridor and north of the Northern Tailings Dump) • Numerous discrete private commercial/industrial and residential land parcels.

The site environmental setting information was summarised in C&R (2021) and relevant extracts are included in **Appendix 4**.

[1] Results from assessment of the mine site are included in this report.

[2] Based on review of Crown Lands as presented on the NSW Resources and Geosciences Minview web mapping application (https://minview.geoscience.nsw.gov.au/#/?lon=149.4471&lat=-35.60473&z=17&bm=bm1&l=wa3:y:100,ad6:y:100) accessed 25 May 2021.

3. REGULATORY REQUIREMENTS

This SAQP has been prepared in general accordance with the following guidance documents:

1. NSW EPA, *Contaminated Land Guidelines: Consultants Reporting on Contaminated Land* (NSW EPA 2020)
2. Australia and New Zealand Environment and Conservation Council, *Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000)
3. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018)
4. National Environment Protection Council (NEPC), *National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended 2013* (NEPM, 2013)
5. NSW EPA, *Guidelines for the Site Auditor Scheme (3rd Edition)* (NSW EPA, 2017)

4. PREVIOUS INVESTIGATIONS

The C&R Literature Review (2021) integrated an extensive review of research, guidelines and available geospatial data relevant to contamination associated with the legacy Lake George Mine.

A full list of references from the literature review is presented as **Appendix 3.**

Previous assessments relevant to lead exposure risks within Captains Flat that were provided for review are listed below and discussed in the following sections:

- Lake George Captains Flat Mine Review, Assessment of Remediation Options (GHD 2018)
- Sampling data relating to blue water reported in the Molonglo River (NSW EPA 2019)
- Captains Flat Rail Corridor Detailed Site Investigation (Ramboll 2021)
- Captains Flat Surface Soil Testing Report (NSW EPA 2021)
- Human Health Detailed Site Investigation, Captains Flat Preschool, 27 Foxlow Street, Captains Flat NSW (EnviroScience Solutions 2021a)
- Human Health Detailed Site Investigation, Captains Flat Oval, Foxlow Street, Captains Flat NSW (EnviroScience Solutions 2021b)
- Captains Flat Surface Soil Testing Report (NSW EPA 2021).

Sampling locations from these data sources are presented on **Figures 2 – 4**, **Appendix 1.**

The primary source areas described in the following sections are shown on **Figure 8** extracted from C&R (2021) and included in **Appendix 5.**

4.1 GHD 2018 Lake George Captains Flat Mine Review Assessment of Remediation Options

The objectives of GHD 2018 assessment were to assess the effectiveness of remediation that had occurred at the time to identify ongoing point sources of pollution and quantify their relative contribution to dissolved and suspended pollution loads / contamination flux reporting to the Molonglo River.

The scope of works completed under this assessment targeted pre-identified high-risk source areas including:

- The Main Adit Spring
- Exposed or only partly vegetated contaminated soils in the Rail Loading and Mill areas (Copper Creek catchment) and
- Exposed waste and mineralised rock in the Central and Elliot’s Mine area (Molonglo River and Copper Creek catchment).

Assessment included 149 field portable x-ray fluorescence metals analyser (fpXRF) measurements from 69 locations and collection and analysis of 22 soil/waste rock samples, nine sediment samples and 13 surface water samples.

Key findings were:

- The Main Adit Spring contributes around 80 to 90 % of dry weather, point source dissolved zinc and some 99 % of dissolved lead loads into the Molonglo River
- Metals in sediment (As, Cd, Cu, Ni, Sb, Zn) were observed above adopted assessment criteria. Additionally, Al and Mn were elevated though assessment criteria were not identified
- Bare areas on site and, to a lesser extent, areas colonised by pine trees have significant levels of metal contamination
- The exposed surface areas noted above remain a significant source of lead contaminated dust that could cause windborne contamination within the town of Captains Flat

- Exposed waste rock and soil on the mine site is acid-forming and there is a high risk of ongoing acid, saline and metalliferous drainage unless key contaminant sources are targeted for remediation
- Environmentally significant zinc contamination was observed to extend at least 40 km downstream from Captains Flat.

4.2 NSW EPA 2019 Response to Molonglo River pollution event

In 2019 the NSW EPA responded to a reported pollution event in the Molonglo River. The objective was to determine the cause of blue water and dead fish within the Molonglo River.

The scope of work included sampling of surface water at 13 locations targeting discharge points from the mine and the receiving Molonglo River. Samples were analysed for total and dissolved metals (Al, Co, Cu, Pb, Ni, Zn), pH, alkalinity (as calcium carbonate) and anions.

Key findings were:

- Al, Co, Cu, Pb, Ni, Zn in mine leachate exceeded assessment criteria relevant to the receiving environment
- Zn exceeded assessment criteria to the extent sampled within the downstream receiving environment and was considered likely to be the primary driver of toxicity within the Molonglo River
- The blue water was likely caused by an increased amount of calcium and sulfate coming from the mine in conjunction with low flow, low rainfall and cold weather. It was concluded that this formed a calcium sulfate precipitate that changed the optical properties of the water.

4.3 Ramboll 2021 Captains Flat Rail Corridor Detailed Site Investigation

The Captains Flat Rail Corridor DSI was completed to assess potential soil, dust, sediment and surface water contamination related to historical and current land uses in and around the southern end of the Captains Flat-Bungendore rail corridor and potential effects on surrounding human and ecological receptors.

The scope of work comprised:

- Systematic site inspection for visible asbestos on the site surface
- Assessment of the lateral and vertical extent of metals through fpXRF
- Advancement of test pits and hand augers to facilitate assessment of potential contaminants associated with the general operation of the rail corridor
- Assessment of surface water and sediment upstream and downstream of the site to inform consideration of contaminant migration to and from the site via overland flow
- Assessment of internal dust and paint in buildings on and adjacent the site to inform consideration of risks to sensitive receptors associated with site contamination and potential for lead based paints to contribute risk.

The key findings were:

- Contamination was identified in the rail corridor that is consistent with contamination associated with the adjacent legacy Lake George Mine and with the historic loadout and transport of ore by rail
- The legacy Lake George Mine was identified as the source of site contamination and the rail corridor was identified as a secondary source
- Asbestos was also identified in surface soils within the rail formation including the Copper Creek rail embankment and in surface soils adjacent the rail formation.

4.4 NSW EPA 2021 Captains Flat Surface Soil Testing Report

In 2021, the NSW EPA carried out precautionary testing of surface soils on public and community spaces in the town, including the former preschool, primary school, community hall, parks, roads and road reserves. The testing aimed to:

- Identify if the surface soils were contaminated with lead, arsenic, copper and/or zinc
- Determine if actions were required to protect human health.

The scope of work comprised:

- Screening of lead, arsenic, copper and zinc concentrations using fpXRF
- Laboratory analyses of soil samples collected where elevated metal concentrations were measured in the field. A total of 33 samples were analysed.

The key finding was that 14 of the 33 soil samples that were tested at the laboratory had concentrations of lead above the health investigation level (HIL) for the relevant land use. Areas where elevated metals concentrations were observed included the former Captains Flat Preschool and surrounds, the southern part of Foxlow Street and Foxlow Parklet.

4.5 EnviroScience Solutions 2021a Human Health Detailed Site Investigation Captains Flat Preschool

In 2021, a DSI was completed at the former Captains Flat Preschool. The objective was to assess the suitability of the former preschool for ongoing use.

The scope of works comprised:

- Collection of 18 soil samples from 10 locations to a maximum depth of 0.5 metres below ground level (mbgl). Analyses of all soil samples for metals (As, Cd, Cr, Cu, Pb, Ni, Zn, Hg) and five samples for TRH, BTEX, PAH, metals, OCP, OPP and PCB
- Collection of four dust samples from external areas and the ceiling cavity and analysis for lead
- Air monitoring for lead at four external perimeter locations.

Key findings were:

- 18 of 20 soil samples reported lead above the relevant HIL. All other analytes were reported below adopted assessment criteria
- Dust and air monitoring results were reported below adopted assessment criteria.

4.6 EnviroScience Solutions 2021b Human Health Detailed Site Investigation, Captains Flat Oval

In 2021, a DSI was completed at Colin Winchester Oval off Foxlow Street. The objective was to assess the suitability of the oval for ongoing use.

The scope of works comprised:

- Collection of 40 soil samples from 20 locations to a maximum depth of 0.5 mbgl. Analyses of all soil samples for metals (As, Cd, Cr, Cu, Pb, Ni, Zn, Hg) and six samples for TRH, BTEX, PAH, metals, OCP, OPP and PCB
- Air monitoring for lead at four locations.

Key findings were:

- 3 of 40 soil samples reported lead above the relevant HIL. All other analytes were reported below adopted assessment criteria
- Dust and air monitoring results were reported below adopted assessment criteria.

4.7 Data Summary

4.7.1 Soil

Key findings from soil data include:

- Elevated metal concentrations (As, Cd, Co, Cu, Pb, Mn, Hg, Ni, Zn) have been identified in mine site soils
- Elevated lead concentrations have been identified in shallow soils within the community. Distribution around the former preschool and at the south end of Foxlow Street appears related to application of mine waste as fill, surficial deposition (potential runoff from the eastern embankment of the mine and/or windborne dust deposition). Distribution at Foxlow Parklet appears related to application of fill.

Gaps identified in soil data include:

- The extended period of historic mining infers potential for a wide range of potentially contaminating activities. Systematic assessment of metals concentrations in soils within the community has not occurred and as a result the extent of contamination in soil within the community is not well understood
- Elevated lead concentrations in soil within the community have not been vertically delineated
- Bioavailability of metals in soils impacted by dust, ore, mine waste and slag has not been assessed.

4.7.2 Surface Water

Key findings from surface water data include:

- Al, Co, Cu, Pb, Ni, Zn in mine leachate exceeded assessment criteria relevant to the receiving environment
- Zn exceeded assessment criteria to the extent sampled within the downstream receiving environment and was considered likely to be the primary driver of toxicity within the Molonglo River.

Gaps identified in surface water data include:

- Surface water usage within the Precinct
- The effect of rainfall variability on the degree and distribution of surface water contamination
- Assessment of dissolved metals (relevant to assessing ecological risks) is limited.

4.7.3 Sediment

A slump of tailings from the southern tailings dump is known to have occurred into the water supply dam in the 1940s. Risks to benthic and aquatic ecology in the water supply dam are therefore assumed to exist and this assumption will inform the Captains Flat Lead Management Plan.

The key findings from sediment data include:

- Metals in sediment (As, Cd, Cu, Ni, Sb, Zn) were observed above adopted assessment criteria. Additionally, Al and Mn were elevated though assessment criteria were not identified

Gaps identified in sediment data include:

- The current distribution of contaminated sediments within the Precinct
- Potential for sediment to act as an ongoing source of impact to surface water.

4.7.4 Air Quality

No known ambient air quality data was available for review in the vicinity of Captains Flat. GHD 2018 provided a high-level commentary of historic meteorological conditions which is of relevance to air quality in the region, where meteorology is a primary driver of atmospheric dispersion.

The GHD hydrology and climate review describes rainfall data collected in Captains Flat (Foxlow Street) from 1898 to 2017. Average monthly rainfall collected for the period did not show an annual seasonal trend. Average monthly rainfall varied from approximately 50 mm average in July to just over 70 mm average in November for the period reviewed.

Data from the Tuggeranong Bureau of Meteorology (BoM) station was reviewed by GHD, a station located approximately 36 km to the northwest of Captains Flat. The GHD report presents the BoM-produced 3 pm average wind rose, which indicates a prevailing north-westerly at 10 – 30 km/h. The data collected at Tuggeranong is unlikely to be representative of Captains Flat given the differences in terrain, where Tuggeranong is a relatively flat urban environment compared to Captains Flat which has distinctive valley terrain orientated roughly from north to south. The terrain is likely to steer winds through the valley and influence dispersion of particulate matter. It is also noted that the 3 pm average wind conditions at Tuggeranong only consider an hourly average, where dispersion conditions are likely to change throughout a diurnal period.

The nearest BoM station to Captains Flat is located in Braidwood, approximately 34.5 km to the northeast of Captains Flat, a considerable distance to be considered representative. Braidwood may be more representative of the conditions at Captains Flat than Tuggeranong, but again the terrain differs. The absence of known meteorology data in the vicinity of Captains Flat presents a data gap for the air quality monitoring program, where these conditions will influence source to receptor movement of air pollutants in the local airshed.

4.7.5 Internal Dust

Limited assessment of internal dust within public buildings has occurred. Data from the Captains Flat SES (assessed by Ramboll 2021) indicates lead loadings exceeded the adopted assessment criteria however an exposure assessment integrating limited use of the building supported the conclusion that risks were acceptable.

It is understood that assessment of internal dust has occurred at the former preschool and the RFS building however this data has not been provided for review to date.

4.7.6 Groundwater

There has been no assessment of groundwater or groundwater usage within the Precinct.

5. PRELIMINARY CONCEPTUAL SITE MODEL

Contaminants of potential concern (CoPC) identified by C&R in the literature review include As, Cd, Cu, Pb, Hg, Mn, Ni, and Zn. The review found that the mine site's unvegetated areas could be a source of significant contaminant transport to surrounding areas due to increased chance of erosion, dissolved and solid run-off, and contamination via wind-borne dust. Contamination from the mine site has been recorded in sediments of the Molonglo River extending up to 63 km downstream to Lake Burleigh Griffin in the north (C&R 2021). Along with metalliferous contamination, other contributing factors to environmental degradation in off-site surface waters include suspended particulates and the formation of thick iron oxide precipitates in the Molonglo River from mine seeps, and the ongoing issues of acid mine drainage/ seepage from on-site sources.

C&R developed a preliminary CSM as a qualitative representation of contaminant sources, migration pathways and potential receptors for CoPC from the legacy Lake George Mine. C&R developed cross-section figures representative of potential SPR linkages which are included in **Appendix 5**.

C&R identified the following knowledge/information gaps when undertaking the literature review. Answering the data gaps will better define SPR relationships in the CSM. The data gaps identified by C&R were as follows:

- Soil contamination impacts in the Captains Flat residential area: there was no literature/ investigations identified which provide information on the extent of soil contamination in the Captains Flat residential area. C&R is aware that the EPA has recently undertaken soil survey/sampling for lead in the area. However, these data were not available at the time of preparing this literature review. The soil survey and sampling results may be useful to address this gap.
- Groundwater hydrogeological information: groundwater flow is inferred towards the east/north-east, in line with Copper Creek flowing into the Molonglo River. However, no supporting groundwater surveys are available to confirm this information.
- Groundwater impacts in the region: there was no literature/ investigations identified during the review which address groundwater impacts in the area.
- Groundwater use in the area: there is no information on the use of groundwater within the Captains Flat residential area. C&R's bore search identified the closest groundwater bore is within 5 km of the area for domestic purposes. However, it is not clear whether this is representative of the Captains Flat region.
- Agricultural receptors in the area: it is not clear in the literature/ reports collected by C&R as to whether agricultural or horticultural activities are undertaken in the area.
- Home grown produce in the area: it is not clear whether residents in the Captains Flat area grow home-grown vegetables/ produce.

A tabulated summary of the preliminary CSM is presented as **Appendix 2** which integrates the literature review (C&R 2021) with Ramboll's review of data as described in **Section 4**. Ramboll has identified the following additional data gaps to supplement those identified by C&R:

- Systematic assessment of metals concentrations in soils within the community and vertical delineation of elevated lead concentrations in soil within the community. Specific areas requiring assessment and/or vertical delineation are identified in Table 7-2
- Bioavailability of metals in soils impacted by dust, ore, mine waste and slag, relevant to assessing human health risks
- Details of surface water and groundwater usage within the Precinct and the alluvial flats some kilometres downstream

- The effect of meteorological variability on the degree and distribution of surface water contamination
- Assessment of dissolved metals concentrations in surface water, relevant to assessing ecological risks
- The current distribution of contaminated sediments and exposure risks within the receiving environment
- Potential for sediment to act as an ongoing source of impact to surface water
- Meteorology data in the vicinity of Captains Flat to inform assessment of source to receptor movement of air pollutants in the local airshed
- Assessment of internal dust within public buildings.

An assessment program has been designed to address these data gaps and confirm the CSM. This in turn will inform preparation of the Captains Flat Lead Management Plan, as outlined in Figure 1-1**.**

It is assumed that information relating to surface water and groundwater usage within the Precinct will be made available to Ramboll to inform the preparation of interim water usage guidelines.

Data gaps that will not be resolved under the proposed sampling and analyses include:

- Details of surface water and groundwater usage for the Molonglo River downstream of the Precinct
- Assessment of contaminant impacts to the Molonglo River downstream of the Precinct or interactions with the alluvial aquifer and downstream water users
- Sediment contamination assumed to be present in the water supply dam will not be comprehensively assessed under the proposed sampling and analyses. The Captains Flat Lead Management Plan will be developed under the assumption that contaminant exposure risks exist for benthic and aquatic ecology in the water supply dam. Comprehensive assessment of sediment in the water supply dam should be considered as part of ongoing surface water monitoring
- Effects of meteorological variability in contaminant mobility via airborne, surface water and groundwater migration pathways will remain as a data gap and require ongoing monitoring
- Site specific risk assessment considering bioavailability of metals may be warranted depending on the results of the assessment, the identified risks to human health and ecology and the associated management requirements
- Human health effects from contaminant exposure within Captains Flat and the downstream receiving environment. A systematic assessment of community health effects is recommended as a basis for understanding effects from current exposure scenarios and for validating the Captains Flat Lead Management Plan once implemented.

6. ASSESSMENT CRITERIA

Tier 1 assessment criteria relevant to each environmental media are presented in sub sections below.

6.1 Soil

The NEPM (2013) provides health-based soil investigation levels (HILs) and ecological investigation levels (EILs) for various land uses. The assessment criteria to be adopted will depend on the local land use, as follows:

- HIL A – HIL for residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), also includes childcare centres, preschools and primary schools
- HIL C – HIL for public open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths
- HIL D – HIL for commercial / industrial such as shops, offices, factories and industrial sites.
- The HILs are applicable for assessing human health risk via all relevant pathways of exposure. The HILs are generic to all soil types and apply generally to a depth of 3 mbgl.
- If the above exposure assumptions are not applicable (e.g. poultry), site specific risk assessment may be required.
- EILs for Urban Residential and Public Open Space or Commercial/Industrial land use. EILs depend on specific soil physio-chemical properties such as pH, clay content, cation exchange capacity (CEC) and background concentrations. The published range of the added contaminant limits are listed in Table 6-1 as an initial screen. To define site-specific EILs, pH, clay content, CEC and background contaminant concentrations will be measured during the proposed sampling and the EILs presented in Table 6-1 will be modified accordingly.

The soil assessment criteria for metals are summarised in Table 6-1.

Table 6-1: Soil Assessment Criteria (mg/kg)

Contaminant	HIL A	HIL C	HIL D	EIL (Urban residential/ public open space)	EIL (Commercial/ Industrial)
Arsenic	100	300	3,000	100	160
Barium	-	-	-	-	-
Cadmium	20	90	900	-	-
Chromium	100[a]	300[a]	3,600[a]	130	320
Cobalt	100	300	4,000	-	-
Copper	6,000	17,000	240,000	95	140
Iron	-	-	-	-	-
Mercury	40	80	730	-	
Lead	300	600	1,500	1,100	1,800
Manganese	3,800	19,000	60,000	-	-
Molybdenum	-	-	-	-	-
Nickel	400	1,200	6,000	30	55
Selenium	-	-	-	-	-
Titanium	-	-	-	-	-
Zinc	7,400	30,000	400,000	70	110

- Indicates no criteria available

[a]HIL for chromium (VI)

6.2 Surface Water and Groundwater

The site receptors that can be exposed to mine discharges, seepages, surface runoff and waters within Copper Creek and Molonglo River may potentially include humans, ecology (aquatic and terrestrial), livestock and plants (via irrigation and direct absorption from surface water and groundwater).

The tier 1 assessment criteria adopted for different receptor groups are shown in Table 6-2. Note that:

- Australian Drinking Water Guidelines (ADWG) Section 6.3.1 (2011) states that guideline values refer to the total amount of the substance present, regardless of its form (e.g. in solution or attached to suspended matter) and so analytical results from unfiltered samples should be assessed against human health criteria. Similar reasoning is also applicable to irrigation and livestock guideline values. Total concentration analyses are proposed for surface water however groundwater samples will be field filtered, in accordance with Australian Standards
- ANZG (2018) guidelines for metals in freshwater states that the major toxic effect of metals comes from the dissolved fraction, so it is valid to filter samples (e.g. to 0.45 μm) and compare the filtered concentration against the respective guideline values
- Water hardness is identified as a physical parameter for which quantifiable effects correction factors are defined in the ANZG (2018) guidelines to address the effect of water hardness on the bioavailability of cadmium, chromium, lead, nickel and zinc to ecology. To define appropriate hardness correction factors, water hardness will be measured during the proposed sampling and the ecological screening criteria presented in Table 6-2 will be modified accordingly.

Table 6-2: Surface Water and Groundwater Assessment Criteria (mg/L)

Contaminant	**Drinking Water (NHMRC 2011) mg/L *(or US EPA RSL (for Tap Water))***	**Human Health - Recreation Screening***	**95% Fresh water (ANZG 2018)**	**Irrigation – Screening (ANZG 2018)**	**Stock Water – Screening (ANZG 2018)**
Criteria Applied to	Total concentration**	Total concentration**	Filtered (dissolved) concentration	Total concentration**	Total concentration**
Aluminium	*(20)*	200	0.055 (pH>6.5) & 0.0008 (pH<6.5)[a]	20	5
Arsenic	0.01[b]	0.1[b]	0.024 (III) 0.013 (V)	2[b]	0.5-5[b]
Cadmium	0.002	0.02	0.0002	0.05	0.01
Chromium	0.05	0.5	0.001	1	1
Cobalt	*(0.006)*	0.06	0.0014	0.1	1
Copper	2	20	0.0014	5	0.4-5
Iron	*(14)*	140	-	10	not sufficiently toxic
Lead	0.01	0.1	0.0034	5	0.1
Manganese	0.5	5	1.9	10	not sufficiently toxic
Mercury	0.001	0.01	0.00006[d, e]	0.002	0.002
Nickel	0.02	0.2	0.011	2	1
Zinc	*(6)*	60	0.008	5	20

blank cell denoted with – indicates no criterion available.

** Values based on site-specific exposures will be used in final assessment*

*** For surface water samples. Groundwater samples will be field filtered, in accordance with Australian Standards*
[a] Aluminium guidelines for pH > 6.5and pH <6.5 based on variable (acidic-neutral-alkaline) pH measured previously in various surface waters, seeps and runoffs.

[b] Guideline value for total arsenic.

[c] Guideline value for chromium (VI).

[d] Guideline value for inorganic mercury.

[e] 99% species protection level DGV has been adopted to account for the bioaccumulating nature of this contaminant.

The water quality criteria protective of human health adopted for assessment is primarily adopted from Australian Drinking Water guidelines; however, US EPA RSL for tap water is adopted for analytes where no Australian guideline (ADWG) was available. It is considered likely that primary human health exposures will occur via recreational activities. The National Health and Medical Research Council (NHMRC) (2008) suggests that 10-times the ADWG values may provide a conservative estimate of acceptable recreational exposure guidelines values. This approach is based on the assumption that recreational activities contribute to 10% of drinking water consumption, which is equivalent to a daily lifetime consumption of about 0.2 L of water. NHMRC (2019) suggests that this approach may not provide realistic site-specific recreational exposure estimate as:

- The method makes no allowance for other exposure routes, such as inhalation and dermal absorption, which may be significant for some chemicals. In the case of heavy metals at the site these exposure routes may be considered to be negligible.
- The method does not apply explicit assumptions for rates of accidental water ingestion during recreational water use.
- The method does not provide explicit assumptions regarding patterns of recreational water use. Therefore, it is not possible for communities to assess whether the assumptions apply to realistic patterns of recreational activity at specific sites, which may vary according to location, availability of alternative recreational facilities, and cultural practices.

NHMRC (2019) provides an approach for estimating recreational exposure guidelines values based on water intake from estimated frequency of exposure. The NHMRC (2019) approach will be used to calculate recreational exposure guideline values based on estimated exposure frequencies or events for the final assessment and development of water use guidelines. The site-specific exposure frequencies will be determined from a review of water use practices within the Precinct. The recreational guideline values (based on 10-fold adjusted drinking water values) shown in Table 6-2 will be replaced by the exposure adjusted recreational guideline values for assessment. Currently, no health-based sediment guideline values are available. Background sediment concentrations will be used in the assessment, although any exceedances may not indicate risks to human health, as background values are not based on health effects.

6.3 Sediment

The criteria proposed for the assessment of sediment contamination are sourced from the default guideline values (DGVs) for sediment quality in ANZG (2018). The adopted assessment criteria for sediment are summarised in Table 6-3.

Table 6-3: Sediment Assessment Criteria (mg/kg)

Contaminant	Sediment DGV	GV-High
Aluminium	-	-
Arsenic	20	70
Barium	-	-
Beryllium	-	-
Cadmium	1.5	10
Chromium	80	370
Cobalt	-	-

Contaminant	Sediment DGV	GV-High
Copper	65	270
Iron	-	-
Lead	50	220
Manganese	-	-
Mercury	0.15	1.0
Nickel	21	52
Zinc	200	410

The DGV was derived using a ranking of both observed field and laboratory ecotoxicity-effects and represents the 10th percentiles of that data distribution.

GV-high represents the median of that data distribution to provide an upper guideline value. Effects on sediment biota are rarely seen for concentrations below the DGV, while effects are more frequently evident above the GV-high value.

6.4 Air Quality

Relevant ambient air quality criteria for NSW are defined in Table 6-4 from the following sources:

- NEPC (1998). Ambient Air – National Environment Protection Measure for Ambient Air Quality, National Environment Protection Council, Canberra
- NHMRC (1996). Ambient Air Quality Goals Recommended by the National Health and Medical Research Council, National Health and Medical Research Council, Canberra.

Table 6-4: Air Quality Assessment Criteria

Pollutant	Averaging period	Criteria	Source
Lead	Annual	0.5 µg/m³	NEPC (1998)
Total suspended particulates (TSP)	Annual	90 µg/m³	NHMRC (1996)

6.5 Internal Dust

The preliminary screening criteria proposed for the assessment of dust contamination are sourced from the following references:

- USEPA (2020) Protect your family from lead in your home. US Environmental Protection Agency – January 2020.
- AS 4361.2-1998 Guide to lead paint management - Residential and commercial buildings.

The dust results are to be presented as lead loadings (µg lead/m^2). Where dust samples are collected by vacuum, the lead loading is calculated using the following equation:

$$\textit{Lead loading } (\mu g/m^2) = \frac{\textit{lead concentration } (mg/kg) \times \textit{dust sample mass } (g)}{\textit{sample area } (m^2)}$$

Where samples are collected by swab, the lead loading is calculated using the following equation:

$$\textit{Lead loading } (\mu g/m^2) = \frac{\textit{total lead } (\mu g)}{\textit{sample area } (m^2)}$$

Assessment criteria adopted for lead dust contamination within public buildings are summarised in Table 6-5.

Table 6-5: Lead Dust Assessment Criteria (µg/m^2)

	Assessment Criteria - Commercial Property (µg/m^2)
Dust interior – hard floors	1,000
Dust interior – windowsills and shelves	5,000

7. DATA QUALITY OBJECTIVES

To refine the preliminary CSM to appropriately represent lead exposure risks within Captains Flat, both the field and laboratory programs must result in data that is representative of the conditions at the site. Data Quality Objectives (DQOs) have been developed for the tasks to be completed to address data gaps identified in the preliminary CSM. The DQO process is a systematic, seven-step process that defines the criteria that the sampling should satisfy in accordance with the *Guidelines for the NSW Site Auditor Scheme (3rd Edition)* (NSW EPA 2017).

The seven step DQOs process comprises:

1. Step 1: State the problem
2. Step 2: Identify the decisions/ goal of the study
3. Step 3: Identify the information inputs
4. Step 4: Define the boundaries of the study
5. Step 5: Develop the decision rules or analytical approach
6. Step 6: Specify the performance or acceptance criteria
7. Step 7: Develop the plan for obtaining data.

7.1 Step 1: State the problem

Historic metalliferous mining has contaminated Captains Flat. Previous assessments define some of the impacts however further assessment is required to characterise the degree and extent of contamination with sufficient detail to inform development of the Captains Flat Lead Management Plan.

7.2 Step 2: Identify the decisions/ goal of the study

Goals of the study are:

1. To determine the lateral and vertical extent of lead contamination in soil in the Precinct with sufficient detail to inform a refined CSM and development of the Captains Flat Lead Management Plan
2. To identify whether other metal contamination exists within the Precinct soils
3. To determine the degree and extent of metals contamination in surface water and groundwater
4. To determine the current distribution of contaminated sediments within the Precinct
5. To determine the degree and extent of lead contamination in ambient air and indoor dust in public buildings
6. To complete a Tier 1 risk assessment for human health and ecology within the area of assessment.

7.3 Step 3: Identify the information inputs

Inputs to the decisions will be sourced from:

1. Historical soil and surface water data from previous investigations completed within the Precinct
2. Additional analyses of soils by fpXRF and laboratory analysis of soils for lead for correlation to fpXRF samples
3. Laboratory analysis for CoPC in sediment, surface water and groundwater
4. Analysis for lead in internal dust in public buildings and for lead and TSP in ambient air
5. Site-specific meteorological data

6. Information regarding surface water and groundwater usage within the Precinct (it is assumed this will be made available to Ramboll)
7. Surveyed groundwater levels from installed groundwater monitoring wells.

7.4 Step 4: Definition of the Study Boundary

The boundaries for the assessment are the Precinct boundaries as defined in **Figure 1**, **Appendix 1**.

The assessment will be limited vertically to an indicative depth of 1.5 mbgl in soil to assess potential risks to maintenance workers with groundwater well installation proposed to a maximum depth of 10 mbgl targeting shallowest serviceable aquifer or shallowest groundwater observed.

The temporal boundaries of the assessment will cover one mobilisation and sampling event for soil, sediment, surface water, groundwater and internal dust approximately within June 2021. Air quality will be monitored for an initial two-month period, to be repeated in two further monitoring periods covering an overall monitoring period of 6 months.

7.5 Step 5: Develop the decision rules or analytical approach

1. Do contaminant concentrations exceed Tier 1 assessment criteria?
2. Is the extent of contamination defined?
3. Does the degree and extent of exceedances warrant further assessment or remediation/management?
4. Have all identified data gaps been addressed?
5. If not, what further assessment is required to assess data gaps and determine remediation/management requirements?

7.6 Step 6: Specify the performance or acceptance criteria

Performance criteria are defined to assess potential for a false positive or false negative in data. Data quality indicators (DQIs) and performance criteria for fpXRF measurements of lead in soil, and sampling for laboratory analyses of sediment, internal dust, groundwater, surface water and airborne dust are presented in Table 7-1 following. Further details of the proposed sampling and QA/QC procedures are provided in the subsequent sections.

Decision Error Protocol

If the data received is not in accordance with the defined acceptable limits outlined in Steps 5 and 6, it may be considered to be an estimate or be rejected. Determination of whether this data may be used or if re-sampling is required will be based on the following considerations:

- Closeness of the result to the guideline concentrations
- Specific contaminant of concern (e.g. response to carcinogens may be more conservative)
- The area of site and the potential lateral and vertical extent of questionable information
- Whether the uncertainty can be effectively incorporated into site management controls.

Table 7-1: Performance Criteria

Data quality indicator	Performance Criteria			
	Soil	**Sediment, Groundwater, Surface Water**	**Internal Dust**	**Air Quality**
Field Quality Control Samples	Intra- and inter-laboratory duplicate sampling density of 5% (1 in 20 samples) 1 rinsate sample per day	Intra- and inter-laboratory duplicate sampling density of 5% (1 in 20 samples) 1 rinsate sample per day	Intra- and inter-laboratory duplicate sampling density of 5% (1 in 20 samples) 1 rinsate sample (cleaned barrel swab) per day for vacuum sampling	-
Field Quality Control Results	Relative Percentage Differences (RPDs) should be below 30% for inorganic analytes. No detections in rinsate samples The correlation coefficient (R) should be above 0.7.	RPDs below 30% for inorganic analytes. No detections in rinsate samples	RPDs below 30% for inorganic analytes. No detections in rinsate samples	-
NATA Registered Laboratory and NATA Endorsed Methods	Laboratories used should be NATA accredited and laboratory certificates should be NATA stamped.			
Analytical Methods	As stated in US EPA Method 6200 (2007), to increase accuracy of the results, complete digestion of soil and sediment samples is valuable to ensure accurate correlation. Ideally, Method 3052 should be adopted for analysis of soil and sediment, however, this method is not available at the NATA accredited laboratories considered for this project and Method 3050 will be used. To reduce dilution errors in reported results, the laboratory will be advised a likely metals concentration range based on fpXRF readings for each sample sent for laboratory analysis.			
Holding Times	Holding times for all analytes should be met.			
Practical Quantitation Limit (PQL)	PQLs should be below the adopted assessment criteria.			
Laboratory Quality Control Samples	Laboratory quality assurance testing should be undertaken at appropriate frequencies.			
Laboratory Quality Control Results	Laboratory Quality Control Results should meet laboratory acceptance limits.			

7.7 Step 7: Develop the Plan for Obtaining Data

7.7.1 Soil Sampling

The proposed soil sampling is summarised in Table 7-2 with reference to SAQP item numbers from the preliminary CSM tabulated summary in **Appendix 2**. A systematic sampling approach is proposed within each Area of Concern. Primary soil measurements will be collected using fpXRF. 5% of soil fpXRF samples will be laboratory analysed to establish a correlation, targeted based on field observed concentrations to provide coverage of the total concentration distribution range.

Proposed sampling locations are shown on **Figure 6a – 6b**, **Appendix 1**.

Table 7-2: Proposed Soil Sampling Program

Area of Concern	SAQP Item	CoPC	Proposed Soil Sampling
Above Ground Tailings and Mine Waste	2	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	8 surface XRF measurements along ephemeral drainage line from tailings dumps.
Southern Smelter	5	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	10 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Northern Ridge	6	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	5 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Sewage Treatment Area	7	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	10 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Mogo Land adjacent (west of) the Rail Loader	8	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	8 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Foxlow Parklet	9	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	5 push tubes to 1.0 m depth with XRF measurements at surface, 0.1, 0.25, 0.5, 0.75 and 1 m depth.
Foxlow Street	10	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	6 shallow push tubes to 1.5 m depth with XRF measurements at surface, 0.1, 0.25, 0.5, 0.75, 1, 1.25 and 1.5 m depth.
Areas behind the former preschool	11	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	10 shallow push tubes to 1.0 m depth with XRF measurements at surface, 0.1, 0.25, 0.5, 0.75 and 1 m depth.
Western embankment at southern end of town	13	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	5 shallow push tubes to 1.0 m depth with XRF measurements at surface, 0.1, 0.25, 0.5, 0.75 and 1 m depth. 10 shallow hand augers to minimum 0.3 m depth (maximum 1 m depth) with XRF measurements at surface, 0.1 and 0.25 m depth
Foxlow Street public amenity areas (playing fields swimming pool etc)	14	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	25 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Subdivisions east and west of north end of town	15	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	10 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth

Area of Concern	SAQP Item	CoPC	Proposed Soil Sampling
Land northeast of the water supply dam	16	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	5 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Crown land	18	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	18 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Community Gardens	19	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	5 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Miners Road	20	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	14 shallow hand augers to 0.3 m depth with XRF measurements at surface, 0.1 and 0.25 m depth
Public roads to assess community exposure	106	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)	Surface soil fpXRF measurements in public road reserves on 50 lineal metre increments where buildings are present south of the river (approx. 1 km - 20 locations), 100 lineal metre increments where buildings are north of the river (approx. 7 km - 70 locations) and on 250 lineal metre increments in other areas (approx. 4 km - 16 locations).

To facilitate bioavailability analyses, three bulk samples (approx. 2 kg) will be collected from three areas of contamination within the community (the southern smelter slag stockpile, the eastern embankment of the mine site and the rail corridor). That is, a total of nine samples will be collected. Sampling locations will be informed based on review of fpXRF measured lead to represent a range of concentrations from each location.

7.7.2 Surface Water Sampling

Surface water sampling will occur at a total of 15 locations targeted to assess contaminant concentrations in the background environment (upstream of the water supply dam), discharge points and the downstream receiving environment.

Proposed sampling locations target historic sampling locations as described in Table 7-3 and on **Figure 2**, **Appendix 1**.

Table 7-3: Proposed Surface Water Sampling Locations

Previous Sample ID	Reference	Location
Sample Site 3: Upstream of reservoir	EPA 2019	Upstream of water supply dam (will be moved further upstream)
CF001-W	GHD 2018	Water supply dam
SW07	GHD 2018	Southern Tailings Dump seepage (east side)
Second Seepage Point	EPA 2019	Southern Tailings Dump seepage (north end)
Upstream Forsters Creek Confluence	GHD 2018	Upstream Forsters Creek confluence
Forsters Creek Confluence	GHD 2018	Forsters Creek Confluence

Previous Sample ID	Reference	Location
SW02	EPA 2019	Main Adit Spring
SW01	Ramboll 2021	Drainage line downstream of mine site sediment dams. Upstream of rail corridor.
SW02	Ramboll 2021	Drainage line downstream of mine site sediment dams and rail corridor.
SW04	Ramboll 2021	Copper Creek upstream of rail corridor.
SW05	Ramboll 2021	Copper Creek downstream of rail corridor.
SW04	GHD 2018	Copper Creek confluence with Molonglo River
SW06	GHD 2018	Captains Flat Road bridge
Molonglo River Bridge	EPA 2019	Molonglo River downstream of Copper Creek
Swimming Hole	EPA 2019	Swimming hole at northern end of precinct

All surface water samples will be analysed for total and dissolved metals (Al, As, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Zn). To facilitate dissolved metals analyses surface water samples will be filtered in the field using 0.45 µm filters. pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), redox and total dissolved solids (TDS) will be measured using a water quality meter in the field at the time of sampling at each location.

7.7.3 Sediment Sampling

Sediment samples will be co-located with surface water sampling locations described in Table 7-3: Proposed Surface Water Sampling Locations

. Sediment samples will target the upper 5 cm of sediment in the drainage channel/ creek/ dam.

Sediment samples will be analysed for total metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn).

7.7.4 Air Quality Monitoring

Five locations in Captains Flat are proposed for monitoring heavy metals in airborne particulate matter. The five proposed monitoring locations are summarised in Table 7-4. The air quality criteria are relevant at sensitive receptors, so it is preferable to monitor in community locations such as residences and schools rather than industrial locations such as the sewage treatment plant or SES. Should measurement of meteorological conditions be further considered for this location, it is recommended that equipment be located at AQM4 given the elevated terrain in this location which would be representative of prevailing regional conditions.

Proposed Air quality monitoring locations are presented on **Figure 3**, **Appendix 1**.

Table 7-4: Air Quality Monitoring Locations

ID	Location	Reason for selection	Monitoring Technique	Parameters measured
AQM1	Residence, 2 Copper Creek Road	Identified as the nearest sensitive receptor to identified mining areas to the north-west	High-volume air sampler (HVAS) with total suspended particulate (TSP) size selective inlet, measuring for 24-hours every 1 day in 6	Heavy metals in TSP (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)
AQM2	Captains Flat former Preschool, 27 Foxlow Street	Identified as a sensitive receptor of interest and representative of potential impacts to the south-east	HVAS with TSP inlet, measuring for 24-hours every 1 day in 6	Heavy metals in TSP (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)

AQM3	Captains Flat Public School, Montgomery Street	Representative of potentials impacts of the largest community to the north-east	HVAS with TSP inlet, measuring for 24-hours every 1 day in 6	Heavy metals in TSP (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)
AQM4	Residence, Old Mine Road	Representative of potential impacts to the south-west. Elevated terrain may provide a less localised, regional measure of lead in particulate compared to other locations	HVAS with TSP inlet, measuring for 24-hours every 1 day in 6	Heavy metals in TSP (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)
AQM5	Adjacent Residential property south-east of the mine	Representative impacts to residents down-wind of the mine	HVAS with TSP inlet, measuring for 24-hours every 1 day in 6	Heavy metals in TSP (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn)

The initial monitoring program will be maintained for six months, after which the scope may be reviewed (e.g. metals analysed). It is noted that the ambient air quality criteria for lead is based on an annual average and that air quality can exhibit distinct annual patterns contributed to by seasonal changes in meteorology. An annual monitoring period would be considered representative and could be compared to the air quality criteria. Data reporting will be completed on a two-monthly basis, as requested in the tender.

The air quality monitoring program will be completed in the following steps:

- Selection of five suitable monitoring locations in Captains Flat with consideration of potential source locations, prevailing meteorology, accessible power source, appropriate security, and the recommendations of *AS/NZS 3580.1.1 – Methods for sampling and analysis of ambient air – Part 1.1: Guide to siting air monitoring equipment*.
- Commissioning of five high-volume air samplers with size selective inlets for total suspended particulate (TSP) in Captains Flat. The instruments will be calibrated and maintained consistent with *AS/NZS 3580.9.3 – Method 9.3 – Determination of suspended particulate matter – Total suspended particulate matter (TSP) – High volume sampler gravimetric method.* Sampling will be configured for a 24-hour period every 1 day in 6.
- Mobilisation of experienced field staff to replace filters, complete instrument checks and clean the equipment every 1 day in 6. Calibration will be completed on a 2-monthly basis consistent with *AS/NZS 3580.9.3*.
- Submission of samples to a NATA accredited laboratory and analysed for 15 metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) in accordance with *AS/NZS 3580.9.15 – Method 9.15: Determination of suspended particulate matter – Particulate metals high or low volume sampler gravimetric collection – Inductively coupled plasma (ICP) spectrometric method*. TSP concentration will be calculated through filter weighing before and after sampling and flow volume.
- A report will be prepared on a 2-monthly basis outlining the methodology and summarising the sampling results with comparison to publicly available meteorology data and relevant air quality criteria. All reports will be peer reviewed by a senior air quality specialist prior to submission.

7.7.5 Internal Dust Sampling

Internal dust sampling will be undertaken at four public buildings (locations TBC). A total of 16 samples will be collected comprising four samples per building (vacuum and swab at each location).Internal dust sampling locations remain to be confirmed though will target public buildings adjacent the rail loading area, eastern embankment of the mine and areas north of the Molonglo River.

Swab sampling of internal dust sampling will be completed in general accordance with US EPA 2009 Lead Dust Sampling Technician Field Guide (US EPA 2009) as well as the following:

- Sample areas will be marked out using masking tape. Sampling areas of 0.09 m^2 will be targeted where feasible
- Dust sampling will be completed wearing single use disposable nitrile gloves and using single use sanitary wipes. Dust will be collected by making S-shaped motions through the sampling area, folding the wipe in half and repeating the process at least three times and until all visible dust is removed.
- The swab will be collected and analysed for total lead.

Vacuum samples will be collected in general accordance with the Guidance for the sampling and analysis of lead in indoor residential dust for use in the integrated exposure uptake biokinetic (IEUBK) model (US EPA 2008) and will include:

- Marking out of 2 m^2 sampling areas using masking tape
- subdividing sample areas into 0.5 m^2 sub-sample areas
- A high-flow cyclonic vacuum will be run in strips to cover each sub-sample area four times back and forth
- Dust from the vacuum will be collected and analysed for total dust and total lead.

7.7.6 Groundwater Sampling

For the purpose of assessing groundwater contamination, 10 monitoring wells will be installed to a maximum depth of 10 m targeting the upper aquifer.

Monitoring well locations have been proposed to assess:

- The presence/absence and flow direction of a shallow alluvial aquifer assumed to exist and contaminant impacts via seepage from identified contaminant sources
- Interaction between the assumed alluvial aquifer and surface water in the Molonglo River with specific regard for contaminant distribution and effects on potential receptors
- Potential groundwater contamination from the rail loading area as measured along an anticipated flow path north to Copper Creek
- Potential groundwater contamination from the northern tailing dump as measured along an anticipated flow path north to the Molonglo River.

Wells will be constructed using a licensed drilling contractor and will be constructed as per the Minimum Construction Requirements for Water Bores in Australia, Fourth Edition, 2020 and will comprise the following:

- 50 mm PVC class 18 factory slotted (0.5mm) well screen (no filter socks will be used to assess the presence of LNAPL/DNAPL)
- 50 mm PVC class 18 blank casing
- A push-on end cap at the base of each well
- A top cap suitable for suspension of groundwater level data loggers
- A graded 2 mm gravel pack installed from the base, generally to 0.5 m above the top of the well screen in the annulus between the well screen/casing and the borehole wall
- An annular seal consisting of at least 1 m of 3/8” bentonite chips installed on top of the gravel pack
- A cementitious grout slurry installed on top of the bentonite annular seal to near surface
- Wells will be completed on the surface with a surface bentonite seal and a concrete plinth in which a flush mount well cover will be set and the well capped with a lockable steel cap that is finished flush with the surrounding surface level.

Wells will be installed ensuring screens are located within the aquifer of concern (shallow) and are not screened across the two distinct aquifers causing cross contamination.

Following installation, the wells will be developed/purged to remove disturbed fines and to try to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction, around the immediate vicinity of each well. The wells will be left for up to one week to equilibrate prior to collection of groundwater samples. Completed monitoring wells will be surveyed by an accredited land surveyor, recording easting, northing, ground elevation and top of casing elevation for all wells. Coordinates will be collected in GDA2020 Zone 56 datum.

Purge water and liquid waste generated during well installation will be stored in 205 L drums onsite and clearly marked with the appropriate liquid waste category. These materials will be removed by a waste contractor to an appropriately licensed waste receival facility.

Groundwater sampling will utilise low-flow sampling techniques and be carried out as follows:

- Mobilisation of two field staff experienced in sampling of contaminated groundwater
- Chemical and physical parameters, including temperature, pH, EC, DO, redox potential and TDS will be measured in the field. A filtered sample for metals analysis will be collected from each location.
- To facilitate dissolved metals analyses groundwater samples will be filtered in the field using 0.45 μm filters.
- Groundwater samples will be collected when parameters are stabilised.
- Each sample bottle will be clearly labelled with a unique sample name, date and location

Samples will be analysed for dissolved metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn).

7.7.7 Proposed Methodology and Quality Assurance/Quality Control Procedures

Table 7-5: Methodology and QA/QC

Category	**Performance Criteria**					
	fpXRF Measurements	**Sediment**	**Internal Dust**	**Groundwater**	**Surface Water**	**Air Quality**
Accuracy: Accuracy in the collection of field data will be controlled by:	Appropriate sampling methodologies will be utilised and complied with. Works to be completed in accordance with US EPA 2007, *Method 6200, Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment*. These will include: • Daily system checks and internal calibration as recommended by the instrument manual. • Measurement of blank reference material (silicon dioxide, SiO_2) – this will be done at the start of the day and repeated every 10 samples. This will mitigate potential inaccuracies associated with cross-contamination of samples. The analyser window will also be cleaned regularly to prevent cross-contamination. • Certified reference materials will be measured to check instrument response and calibration. This will be conducted every 20 samples. • Adopting a dwell time appropriate for measurement of CoPC. A dwell of 60 seconds is considered to provide sufficient precision for the sampling program.	Sediment sampling will be completed in general accordance with the Handbook for Sediment Quality Assessment (Simpson et al, 2005). Sediment samples will be collected using plastic tubing (bailers) cut down to act as disposable sediment core samplers targeting the upper 5 cm of sediment in the drainage channel/creek/dam.	Swab sampling of internal dust sampling will be completed in general accordance with US EPA 2009 Lead Dust Sampling Technician Field Guide (US EPA 2009) as well as the following: • Sample areas will be marked out using masking tape. Sampling areas of 0.09 m2 will be targeted where feasible • Dust sampling will be completed wearing single use disposable nitrile gloves and using single use sanitary wipes. Dust will be collected by making S-shaped motions through the sampling area, folding the wipe in half and repeating the process at least three times and until all visible dust is removed.	• Calibrated measurement equipment used. The water quality meter will be calibrated by the technical rental company prior to use. • Appropriate sampling methodologies utilised and complied with. Works to be completed with regard for *AS/NZS 5667.11:1998 Water quality - Sampling - Guidance on sampling of groundwaters.*	• Calibrated measurement equipment used. The water quality meter will be calibrated by the technical rental company prior to use. • Appropriate sampling methodologies utilised and complied with. Works to be completed with regard for *AS NZS 5667.6-1998 Water quality - Sampling - Guidance on sampling of rivers and streams*.	Airborne lead in particulate matter will be measured in accordance with *AS/NZS 3580.9.3 Determination of suspended particulate matter – Total suspended particulate matter (TSP) High volume sampler gravimetric method*. All samples will be analysed by a NATA accredited laboratory in accordance with *AS/NZS 3580.9.15 Determination of suspended particulate matter – Particulate metals high or low volume sampler gravimetric collection – Inductively coupled plasma (ICP) spectrometric method.* Air quality monitoring instruments will be sited, as far as practicable, with the recommendations of *AS/NZS 3580.1.1 Guide to siting air monitoring equipment*. The instruments will be maintained in accordance with the manufacturer's guidance.

Precision: The degree to which data generated from replicate or repetitive measurements differ from one another due to random errors. Precision of field data will be maintained by:	• XRF readings will be collected by an experienced scientist holding a NSW EPA license required for field based XRF testing
	• XRF readings will be collected from soil in-situ and measurements will be taken by placing the XRF directly on the ground surface.
	• The soil surface to be measured will be cleared of debris and grass prior to taking the measurement to ensure that there is no obstruction, that the analyser window is protected and that contact with the sample surface is maintained during measurements.
	• As moisture is known to affect measured concentrations, visually dry surfaces will be chosen for measurement.
	• Soil sampling for confirmatory laboratory analyses will occur at a frequency of 5% covering the observed distribution of concentrations in general accordance with AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil - Non-volatile and semi-volatile compounds. This will include:
	  o Collection of samples by a suitably experienced environmental scientist
	  o Use of disposable nitrile rubber gloves between locations
	  o Soil samples will be placed immediately into laboratory supplied and appropriately preserved sampling vessels.
	  o Sample numbers, preservation and analytical requirements are to be recorded on chain of custody documents.
		In the field, precision will be maintained by:
		• Using standard operating procedures for the collection of sediment samples.
		• Collection of sediment samples by suitably experienced environmental scientists.
		• Use of disposable nitrile rubber gloves between sampling locations.
		• Placement of samples directly into designated single use sampling containers.
		• Collection of intra-laboratory and inter-laboratory duplicate samples at a rate of 1 in 20 primary samples.
		• Collection of one rinsate sample on reusable sampling equipment at the end of each day.
		• Recording of sample identification and analytical requirements on chain of custody documents.
		• Samples transported to the laboratory under chain of custody conditions to a laboratory with NATA accreditation for the analytical methods prescribed.
			In the field, precision will be maintained by:
			• Using standard operating procedures for the collection of dust samples.
			• Collection of dust samples by suitably experienced environmental scientists.
			• Use of disposable nitrile rubber gloves between sampling locations.
			• Placement of samples directly into designated single use sampling containers.
			• Collection of intra-laboratory and inter-laboratory duplicate samples at a rate of 1 in 20 primary samples.
			• Recording of sample identification and analytical requirements on chain of custody documents.
			• Samples transported to the laboratory under chain of custody conditions to a laboratory with NATA accreditation for the analytical methods prescribed.
				• Groundwater sampling will be completed by experienced scientists
				• A new pair of disposable nitrile gloves to handle each sample.
				• Samples will be placed immediately into laboratory supplied and appropriately preserved sampling vessels
				• Samples will be stored in chilled, insulated containers with ice for transportation to the laboratory
				• Sample numbers, preservation and analytical requirements will be recorded on chain of custody documents.
				• Samples will be transported to the laboratory under chain of custody conditions.
				• Collection of intra-laboratory and inter-laboratory duplicate samples at a rate of 1 in 20 primary samples.
				• Collection of one rinsate sample on reusable sampling equipment at the end of each day.
					• Surface water sampling will be completed by experienced scientists
					• A new pair of disposable nitrile gloves to handle each sample.
					• Samples will be placed immediately into laboratory supplied and appropriately preserved sampling vessels
					• Samples will be stored in chilled, insulated containers with ice for transportation to the laboratory
					• Sample numbers, preservation and analytical requirements will be recorded on chain of custody documents.
					• Samples will be transported to the laboratory under chain of custody conditions.
					• Collection of intra-laboratory and inter-laboratory duplicate samples at a rate of 1 in 20 primary samples.
					• Collection of one rinsate sample on reusable sampling equipment at the end of each day.
						In the field, precision will be maintained by:
						• Using standard operating procedures for air quality monitoring.
						• Completion of air quality monitoring by suitably experienced environmental scientists.
						• Recording of sample identification and analytical requirements on chain of custody documents.
						• Samples transported to the laboratory under chain of custody conditions to a laboratory with NATA accreditation for the analytical methods prescribed.

Category	Performance Criteria					
	fpXRF Measurements	**Sediment**	**Internal Dust**	**Groundwater**	**Surface Water**	**Air Quality**
Completeness: The completeness of the data set shall be judged by:	• All locations sampled as outlined in Section 7.7.1. • Sampling completed by experienced personnel • Field documentation completed correctly	• All locations sampled as outlined in Section 7.7.3. • Sampling completed by experienced personnel • Field documentation completed correctly	• All locations sampled as outlined in Section 7.7.5 • Sampling completed by experienced personnel • Field documentation completed correctly	• All locations sampled as outlined in Section 7.7.6 • Sampling completed by experienced personnel • Field documentation completed correctly	• All locations sampled as outlined in Section 7.7.2 • Sampling completed by experienced personnel • Field documentation completed correctly	• All locations sampled as outlined in Section 7.7.4. • Sampling completed by experienced personnel • Field documentation completed correctly
Representativeness: The representativeness of the field data will be judged by:	• Non-disposable sampling equipment, such as the hand auger, will be thoroughly decontaminated between locations using Decon 90 solution and deionised rinsate water. • At each location, a pair of disposable nitrile gloves will be worn while sampling and handling the sample; gloves will be replaced between each successive sample. • Soil analytical samples will be collected directly into the sampling vessels.	• Non-disposable sampling equipment, such as the hand auger/trowel/sediment sampler will be thoroughly decontaminated between locations using Decon®90 solution and deionised rinsate water. • At each location, a pair of disposable nitrile gloves will be worn while sampling and handling the sample; gloves will be replaced between each successive sample. • Sediment analytical samples will be transferred directly from the sediment corer to the sample container. • Each sample jar will be clearly labelled with a unique sample name, date and location.	• All dust sampling will be undertaken wearing disposable nitrile rubber gloves. Samples will be in single use zip lock bags labelled with unique identifiers which will be cross-referenced with site plans and submitted to the laboratory under chain of custody. • Sampling areas will be measured and marked out, the actual area sampled will be recorded in the field notes.	• Non-disposable sampling equipment, such as the water quality meter, will be thoroughly decontaminated between locations using Decon 90 solution and deionised rinsate water. • At each location, a pair of disposable nitrile gloves will be worn while sampling and handling the sample; gloves will be replaced between each successive sample. • Groundwater analytical samples will be collected directly into the sampling vessels from the sample tubing via 0.45 µm disposable filters. • Filtered samples will be collected for analysis of heavy metals which will be representative of dissolved concentrations.	• Non-disposable sampling equipment, such as the grab sampler and water quality meter, will be thoroughly decontaminated between locations using Decon 90 solution and deionised rinsate water. • At each location, a pair of disposable nitrile gloves will be worn while sampling and handling the sample; gloves will be replaced between each successive sample. • Surface water analytical samples will be collected directly into the sampling vessels using an extendable pole sampler where appropriate via 0.45 µm disposable filters. • Both filtered and non-filtered samples will be collected for analysis of heavy metals which will be representative of both dissolved and total metal concentrations.	• At each location, a pair of disposable nitrile gloves will be worn while sampling and handling the sample; gloves will be replaced between each successive sample • Dust HV filters will be transported in disposable zip-lock bags
Comparability: Comparability to existing field data will be maintained by:	• Use of the same appropriate sampling methodologies • Same sampling depths will be used (i.e.: 0-0.05 mbgl) • Analytical samples will be collected for submission to the laboratory to establish a correlation between fpXRF and laboratory results • Photographs will be taken of sampling location conditions at the time of sampling.	• Use of the same appropriate sampling methodologies • Same sampling depths will be used (where practical) • Analytical samples will be collected for submission to the laboratory • Photographs will be taken of sampling location conditions at the time of sampling.	• Use of the same appropriate sampling methodologies • Same sampling areas (or justification where a different area was used) • Analytical samples will be collected for submission to the laboratory • Photographs will be taken of sampling location conditions at the time of sampling.	• Use of the same appropriate sampling methodologies • Same sampling depths (i.e. middle of the screen) for groundwater (where practical) • Consistent field staff undertaking the groundwater and consistent methodologies used to measure water quality parameters and take samples. • Visual and olfactory observations will also be recorded on the field sheet. • Photographs will be taken of sampling location conditions at the time of sampling.	• Use of the same appropriate sampling methodologies • Same sampling depths for surface water (where practical) • Visual and olfactory observations will also be recorded on the field sheet. • Photographs will be taken of sampling location conditions at the time of sampling.	• Use of the same appropriate sampling methodologies • Same sampling locations will be used • Analytical samples will be collected for submission to the laboratory • Photographs will be taken of sampling location conditions at the time of sampling.

7.7.8 Proposed Analytical Schedule

Table 7-6: Analytical Schedule

Sampling Method	Media	Number of Sampling Points	Analysis - number of analyses
Borehole	Soil	8	Heavy metals by fpXRF (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) - 80*
Hand Auger		102	Heavy metals by fpXRF (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) - 306* pH, clay content, CEC - 10
Push Tubes		26	Heavy metals by fpXRF (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) - 147*
Surface XRF		106	Heavy metals by fpXRF (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) – 106*
	Total soil	***242***	***639***
Grab Sample	Sediment	15	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) – 14
Grab Sample	Surface Water	15	Dissolved and total Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) – 15 Hardness - 15
Low-Flow Sampling	Groundwater	10	Dissolved Heavy metals (As III and As V, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) – 10 Hardness - 10
Vacuum	Internal Dust	16	Lead – 16
Swab		16	Lead - 16
High Volume Air Sampler	Air Quality	4	Heavy metals (As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, Ni, Se, Ti, Zn) and TSP 36 (over two month period)

* 5% of soil fpXRF samples will be laboratory analysed to establish a correlation, targeted based on field observed concentrations to provide coverage of the total concentration distribution range

**Sediment samples will be co-located with each surface water sample.

8. CONCLUSIONS AND RECOMMENDATIONS

Historic metalliferous mining has contaminated Captains Flat. C&R (2021) developed a preliminary CSM as a qualitative representation of contaminant sources, migration pathways and potential receptors for potential contaminants from the legacy Lake George Mine. The primary data gaps identified were information regarding soil contamination impacts in the Captains Flat residential area, groundwater hydrogeological information and groundwater impacts in the region. Data gaps in relation to potential receptors were also identified, for example, use of groundwater, potential agricultural receptors and potential for home grown produce.

Ramboll has undertaken a review of available data and has expanded on the preliminary CSM developed by C&R. The following data gaps were identified to supplement those identified by C&R:

- Systematic assessment of metals concentrations in soils within the community and vertical delineation of elevated lead concentrations in soil within the community. Specific areas requiring assessment and/or vertical delineation are identified
- Bioavailability of metals in soils impacted by dust, ore, mine waste and slag, relevant to assessing human health risks
- Details of surface water and groundwater usage within the Precinct and the alluvial flats some kilometres downstream
- The effect of meteorological variability on the degree and distribution of surface water contamination
- Assessment of dissolved metals concentrations in surface water, relevant to assessing ecological risks
- The current distribution of contaminated sediments and exposure risks within the receiving environment
- Potential for sediment to act as an ongoing source of impact to surface water
- Meteorology data in the vicinity of Captains Flat to inform assessment of source to receptor movement of air pollutants in the local airshed
- Assessment of internal dust within public buildings.

An assessment program has been designed to address these data gaps and to characterise the degree and extent of contamination with sufficient detail to confirm the CSM and inform development of the Captains Flat Lead Management Plan.

The extent of the sampling and analytical program is limited to assessing contaminant exposure risks that may exist for the Captains Flat community and immediate surrounding environment.

It is assumed that information relating to surface water and groundwater usage within the Precinct will be made available to Ramboll to inform the preparation of interim water usage guidelines.

Data gaps that will not be resolved under the proposed sampling and analyses include:

- Details of surface water and groundwater usage for the Molonglo River downstream of the Precinct
- Assessment of contaminant impacts to the Molonglo River downstream of the Precinct or interactions with the alluvial aquifer and downstream water users
- Sediment contamination assumed to be present in the water supply dam will not be comprehensively assessed under the proposed sampling and analyses. The Captains Flat Lead Management Plan will be developed under the assumption that contaminant exposure risks exist for benthic and aquatic ecology in the water supply dam. Comprehensive

assessment of sediment in the water supply dam should be considered as part of ongoing surface water monitoring

- Effects of meteorological variability on contaminant mobility via airborne, surface water and groundwater migration pathways will remain as a data gap and require ongoing monitoring
- Site specific risk assessment considering bioavailability of metals may be warranted depending on the results of the assessment, the identified risks to human health and ecology and the associated management requirements
- Human health effects from contaminant exposure within Captains Flat and the downstream receiving environment. A systematic assessment of community health effects is recommended as a basis for understanding effects from current exposure scenarios and for validating the Captains Flat Lead Management Plan once implemented.

9. REFERENCES

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Ramboll 2021. Captains Flat Rail Corridor Detailed Site Investigation.

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10. LIMITATIONS

Ramboll Australia Pty Ltd prepared this report in accordance with the scope of work as outlined in our proposal to Regional NSW and in accordance with our understanding and interpretation of current regulatory standards.

A representative program of sampling and laboratory analyses is proposed as part of this investigation, based on past and present known uses of the Precinct. While every care has been taken, concentrations of contaminants measured may not be representative of conditions between the locations sampled and investigated. We cannot therefore preclude the presence of materials that may be hazardous.

Site conditions may change over time. This report is based on conditions encountered at the Site at the time of the report and Ramboll disclaims responsibility for any changes that may have occurred after this time.

The conclusions presented in this report represent Ramboll's professional judgment based on information made available during the course of this assignment and are true and correct to the best of Ramboll's knowledge as at the date of the assessment.

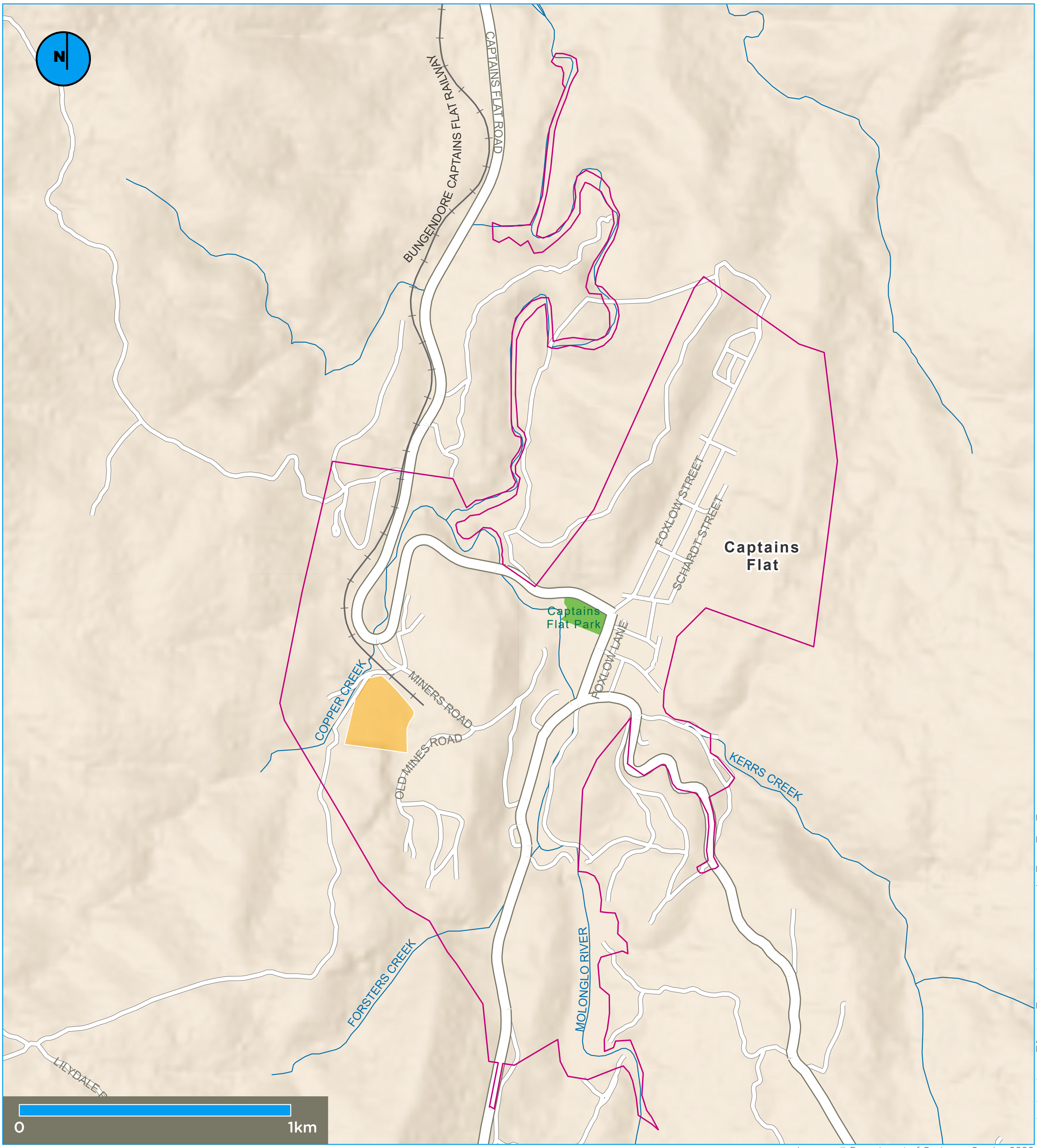
Ramboll did not independently verify all of the written or oral information provided to Ramboll during the course of this investigation. While Ramboll has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

10.1 User Reliance

This report has been prepared exclusively for Regional NSW and may not be relied upon by any other person or entity without Ramboll's express written permission.

APPENDIX 1
FIGURES



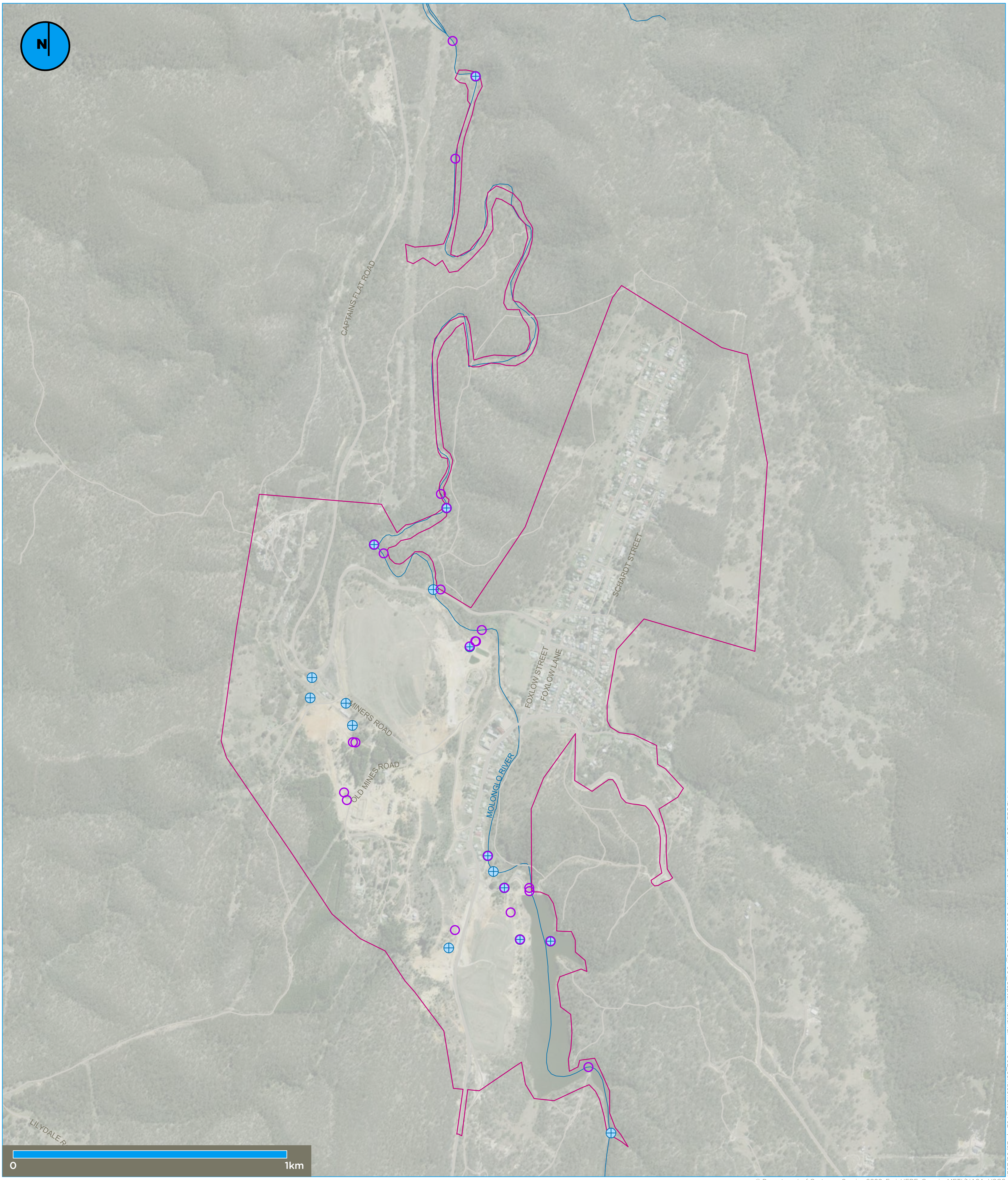
Imagery © Department of Customer Service 2020

A4
1:20,000

Legend

- Precinct boundary
- Railway
- Former Processing Area Lake George Mine

Figure 1 : Site locality plan



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RAMBOLL AUSTRALIA - GIS MAP file : 318001193_GIS_P001_CaptainsFlatSAQP | F002_Surfacewater_V02 | 26/05/2021

Legend

- Precinct boundary
- Previous surface water location
- Proposed surface water location
- Creek

A3
1:13,000

Figure 2 : Surface water and sediment sampling locations

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RAMBOLL AUSTRALIA - GIS MAP file: 318001193_GIS_P001_CaptainsFlatsAQP | F003_Airquality_V02 | 1/06/2021

Legend

Precinct boundary

Proposed air quality monitoring location

Creek

A3
1:4,000

Figure 3 : Air quality monitoring locations

RAMBOLL

RAMBOLL AUSTRALIA - GIS MAP file : 318001193_GIS_P001_CaptainsFlatSAQP | F004_Groundwater_V02 | 1/06/2021

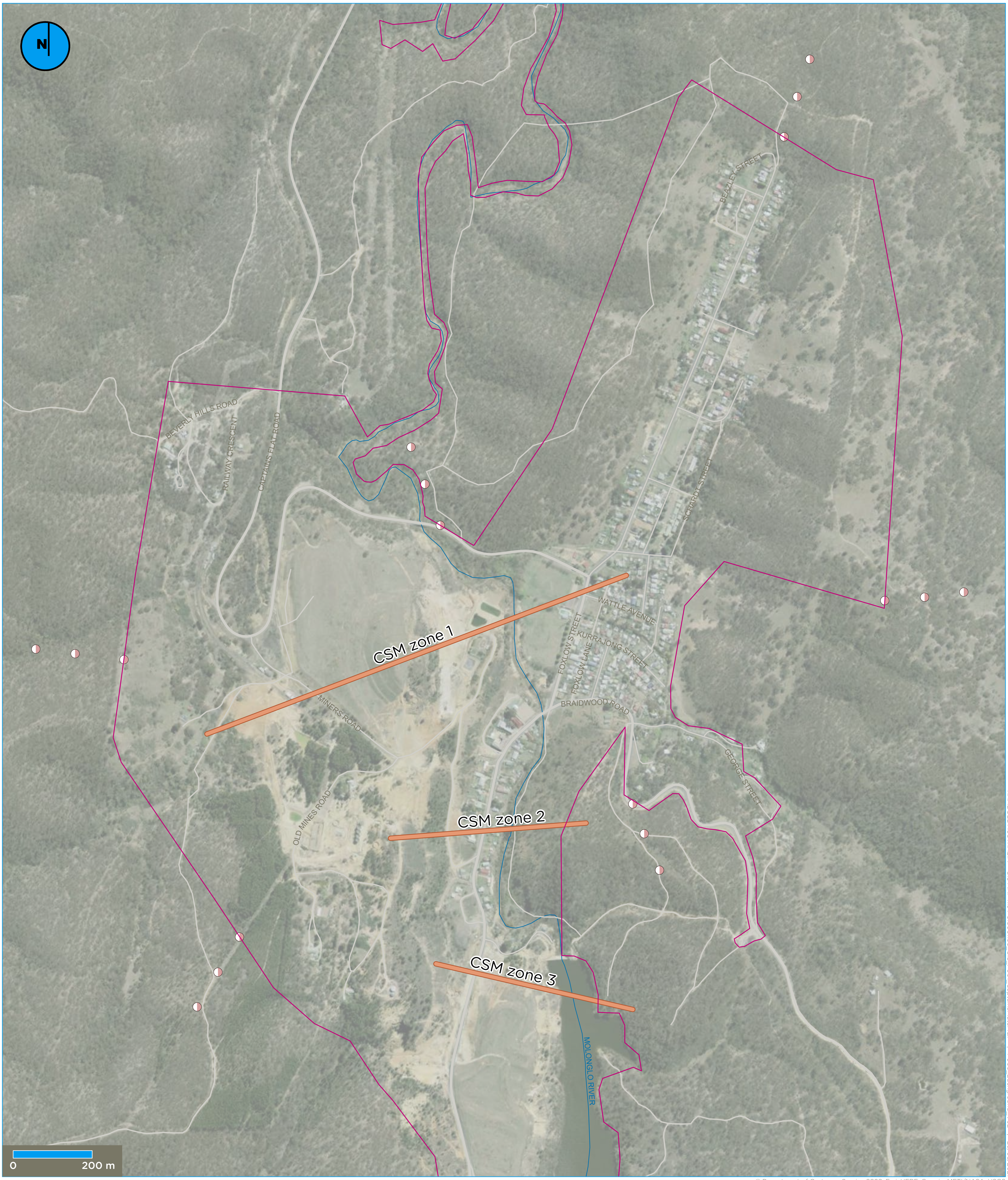
A3
1:4,500

Legend

Precinct boundary
Proposed groundwater location
Creek

Figure 4 : Groundwater monitoring locations

RAMBOLL



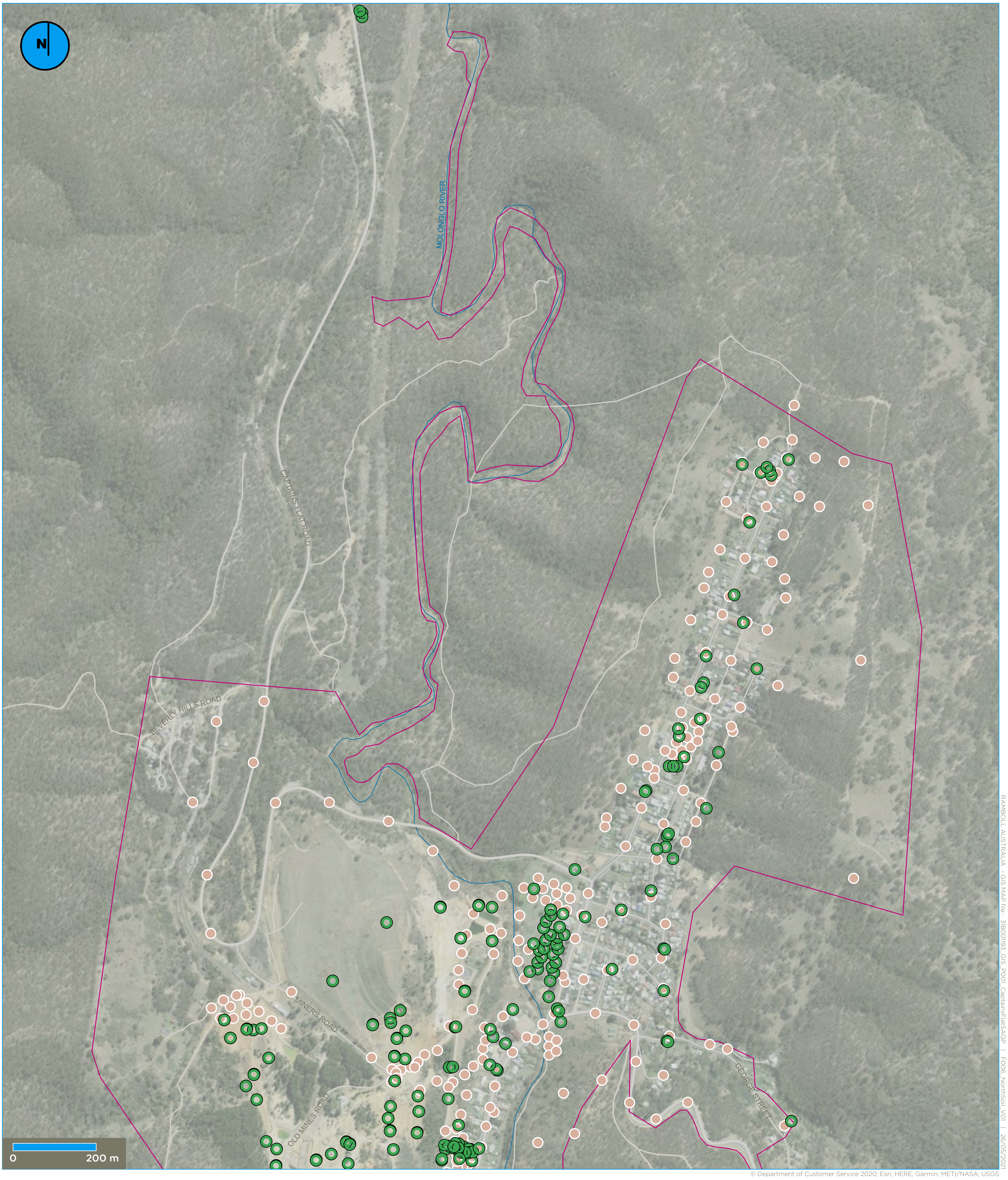
Legend

- Precinct boundary
- Proposed soil sample location
- Creek
- CSM zone

A3
1:9,000

Figure 5 : Background soil assessment locations and CSM zones

RAMBOLL



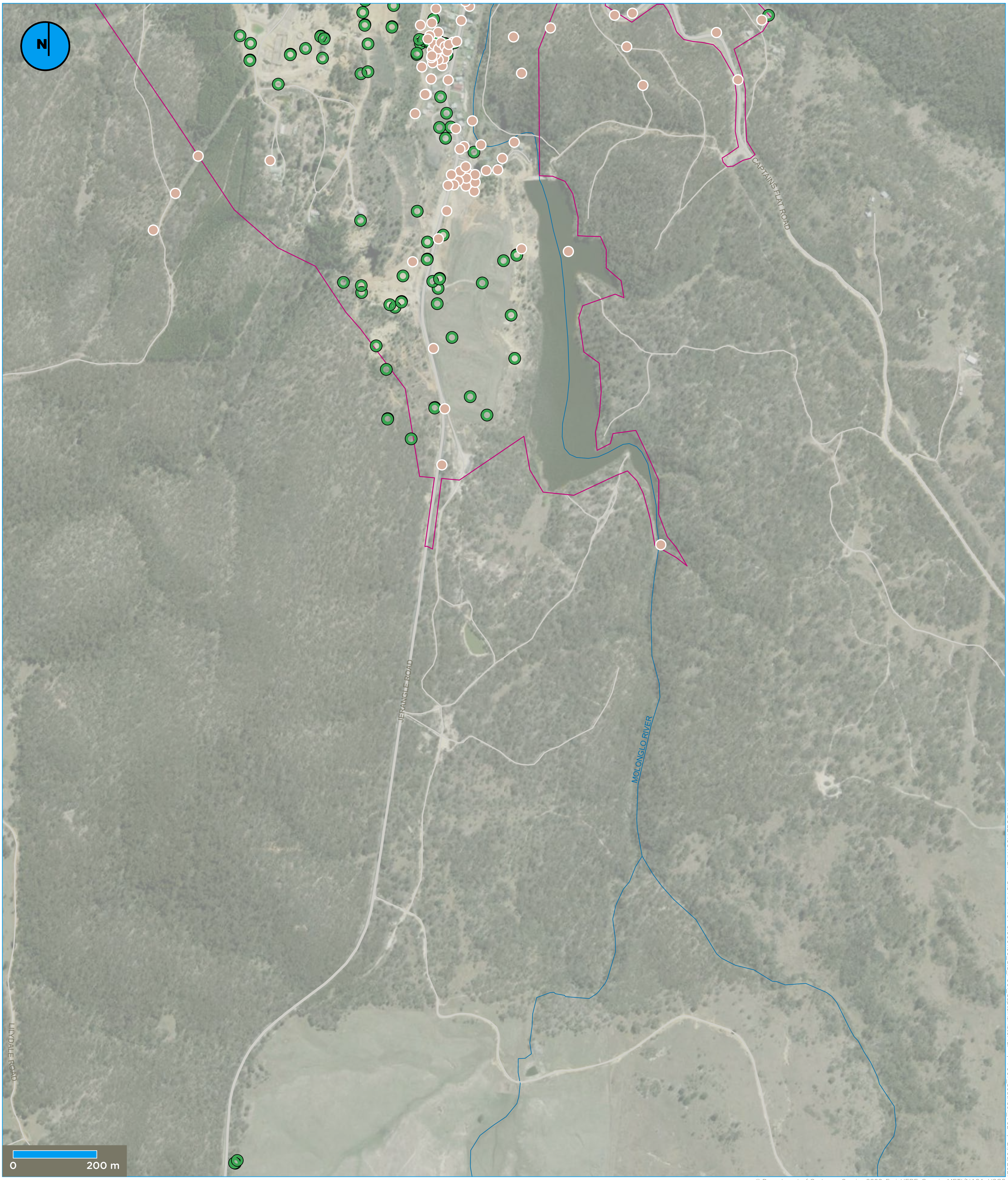
Legend

- Precinct boundary
- Previous soil sample location
- Proposed soil sample location
- Creek

A3
1:8,500

Figure 6a : Soil sampling locations

RAMBOLL



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RAMBOLL AUSTRALIA - GIS MAP file : 318001193_GIS_P001_CaptainsFlatSAQP | F007_SouthSoil_V02 | 27/05/2021

Legend

- Precinct boundary
- Previous soil sample location
- Proposed soil sample location
- Creek

A3
1:8,500

Figure 6b : Soil sampling locations

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APPENDIX 2
PRELIMINARY CONCEPTUAL SITE MODEL TABULATED SUMMARY

Client: Regional NSW
Job No: 318001193
Project Name: Captains Flat Lead Management Plan
02-06-21

Table 1 - Captains Flat Conceptual Site Model

Source	Source Area of Concern	Migration Pathways	Receptors and Exposure Pathways	Existing Data	Data Gaps	SAQP Item
Underground mine workings	Central Mine Area North Mine Mine Adit Spring Keatings mine Open cut areas Magazine / Explosives Adit Spring and nearby fracture seeps	Acid mine drainage and seeps	Public: Incidental ingestion and dermal contact during access to the mine site or recreational use of the Molonglo River	GHD (2018) Targeted assessment of high risk areas on the mine with lesser assessment in the surrounding environment. Assessment included: 149 fpXRF measurements from 69 locations targeting 22 soil/waste rock samples 9 sediment samples 13 surface water samples (totals only) NSW EPA (2019) - total and dissolved phase data from Molonglo River and mine leachate.	Onsite public access frequencies Nature and frequency of onsite workers current and future Surface water and groundwater usage Groundwater contaminant impacts Contaminants in airborne dust Dissolved concentration data for metals in seepage and runoffs Effect of meteorological variability on surface water and groundwater contamination	1
			Mine site workers: incidental ingestion and dermal contact with soil and seepage/runoff/groundwater; inhalation of dusts (wind blown and excavation generated) Uptake by aquatic and/or terrestrial ecology at the Molonglo River	NSW EPA 2019 Assessment of surface water targeting mine discharge points and the downstream environment. Assessment included 13 locations and samples were analysed for total and dissolved metals (Al, Co, Cu, Pb, Ni, Zn), pH, alkalinity (as calcium carbonate) and anions		
		Leaching into groundwater and migration downgradient to Molonglo River (unknown)	Uptake by aquatic and/or terrestrial ecology at the Molonglo River	GHD (2018) NSW EPA (2019)		See 17 below
			Extraction for beneficial use			
			Incidental ingestion by people during recreational use of the Molonglo River	NSW EPA (2019)		
		Public access to the mine site	Direct contact/inhalation and incidental ingestion of contaminated soils	GHD (2018) NSW EPA (2019)	Bioavailability of metals remains unclear and would support development of site specific trigger levels (SSTLs).	
		Private ownership of areas of the mine site	Direct contact/inhalation and incidental ingestion of contaminated soils under current and future approved uses of the land.	Confidential	Unknown	
Above ground tailings and mine waste	Northern and southern tailings dumps Mill areas Old mill areas Exposed slag, smelter and ores processing areas Keatings collapse	Seepage and overland runoff	Uptake by aquatic and/or terrestrial ecology at the Molonglo River Members of the public - direct contact / incidental ingestion of soils along ephemeral drainage lines. Incidental ingestion by people during recreational use of the Molonglo River	GHD (2018) NSW EPA (2019)	Contaminant concentrations in overland flow paths from the tailings and mine through the community	2
		Windborne dust (deposition)	Uptake by terrestrial ecology,	GHD 2018, NSW EPA 2021, Ramboll 2021, EnviroScience Solutions 2021. Cumulatively these data sources include approximately 500 surficial soil samples targeting the mine, rail corridor and community public spaces.	Contaminant concentrations in surficial soils (deposited dust) throughout the community	3
		Direct exposure to contaminated soil				
		Windborne dust (inhalation)	Human health - (on-site) visitors (adults and children) accessing the site. Human health - (off-site) rural residents and Captains Flat residents.	None	Contaminant concentrations in airborne dust	4
Contaminant point Sources within the Community	Southern Smelter		Members of the public (direct contact, incidental ingestion) and uptake by terrestrial ecology	GHD 2018	Minimal historic soil assessment	5
	Northern Ridge				Minimal historic soil assessment adjacent Miners Road	6
	Sewerage treatment area		STP workers (direct contact, incidental ingestion) and uptake by terrestrial ecology		Minimal historic soil assessment along western bank of the mine	7
	Mogo Land adjacent Rail Corridor				Minimal historic soil assessment	8

Table 1 - Captains Flat Conceptual Site Model

Source	Source Area of Concern	Migration Pathways	Receptors and Exposure Pathways	Existing Data	Data Gaps	SAQP Item
Identifed abatement areas	Foxlow Parklet	Windborne dust, surface water, seepage to groundwater	Members of the public (direct contact, incidental ingestion) and uptake by terrestrial ecology	NSW EPA 2021	Vertical delineation	9
	Foxlow Street			NSW EPA 2021	Delineation of contamination in soil horizontally and vertically	10
	Areas behind childcare centre			NSW EPA 2021, EnviroScience Solutions 2021	Vertical delineation not known and limited data assessing degree in shallow soils	11
Additional Risk Area	Childcare Centre		Uptake by terrestrial ecology (now closed to the community)	NSW EPA 2021, EnviroScience Solutions 2021	Vertical delineation	12
	Western embankment at southern end of town			GHD 2018	Delineation of contamination in soil horizontally and vertically	13
Sensitive receptors	Foxlow Street public amenity areas (playing fields swimming pool etc)	Windborne dust, surface water, seepage to groundwater	Members of the public (direct contact, incidental ingestion) and uptake by terrestrial ecology	NSW EPA 2021	Delineation of contamination in soil horizontally and vertically. Groundwater contamination impacts	14
	School	Windborne dust		NSW EPA 2021	Delineation of contamination in soil horizontally and vertically	
	Community Gardens			None		19
Future development areas	Subdivisions east and west of north end of town			None		15
	Miners Road			NSW EPA 2021		20
	Land north-east of the water supply dam			None		16
Rail Loading area	Rail Loading area	Overland runoff	Ecological - Molonglo River and Copper Creek aquatic receptors. Human health - recreational users of Molonglo River.	Ramboll (2021) Detailed site investigation including: 346 fpXRF measurements of metals in soil to depths of up to 2m and extending from the southern rail corridor terminus approximately 1.7 km north. 6 co-located surface water and sediment samples targeting Copper Creek and mine site sediment dam overflow upstream and downstream of the rail corridor. Internal dust sampling at the SES lease area (9 swabs and 3 vacuum samples) 3 external paint samples.	Bioavailability of metals remains unclear and would support development of SSTLs.	
		Windborne dust	Ecological - terrestrial organisms exposed to soil.			
		Direct exposure to contaminated soil				
Sediment dams	Lower and upper sediment dam	Existing water and sediment contamination in dam	Public: Incidental ingestion and dermal contact of waters and sediments in the dam/surface runoff/groundwater	GHD 2018	No total concentration data. Single round of measurement only.	
			Onsite ecology - Ecology within he dam is expected to be limited however terrestrial ecology likely drinks from the dam. It has been shown previously that species richness is reduced with only metal tolerant species remaining.			
		Seepage and overland run-off and leaching into groundwater with offsite transport	Public: Incidental ingestion during recreational use of the Molonglo River (see below); any groundwater users for watering and irrigation in the vicinity			
			Uptake by aquatic and/or terrestrial ecology			
Secondary Sources						
Water supply dam	Waters and sediments acting as a secondary source of contaminants.	Contamination existing in water column (particulate and dissolved phase) and sediments	Public: Incidental ingestion during recreational use of the water supply dam Public: Potable use after treatment Uptake by aquatic and/or terrestrial ecology	GHD 2018, NSW EPA 2019	Effect of water level and meteorological (temperature and rainfall) on contaminant distribution and bioavailability. Metal accumulation in biota that can be consumed	
Molonglo River and Copper Creek	Waters and sediments acting as a secondary source of contaminants.	Migration of particulates and dissolved phase in water	Human Health: Ingestion, dermal contact, domestic consumption of aquatic biota	NSW EPA - Total and dissolved metal conc (various locations); Ramboll data for Copper Creek; GHD sediment data, dissolved metals	Only single round of total metal data biota data	

Table 1 - Captains Flat Conceptual Site Model

RAMBOLL

Source	Source Area of Concern	Migration Pathways	Receptors and Exposure Pathways	Existing Data	Data Gaps	SAQP Item
			Ecological - Aquatic receptors.			
Groundwater	Captains Flat	Interface with Molonglo River	Ecological - Molonglo River and Copper Creek aquatic receptors. Human health - recreational users of Molonglo River. (Possible) Human health - groundwater use.	None	Groundwater use and groundwater contamination	17
Background Assessment including Crown land transitioning to aboriginal ownership				None	Delineation of contamination in soil horizontally and vertically	18

APPENDIX 3
LITERATURE REVIEW REFERENCE LIST

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APPENDIX 4
LITERATURE REVIEW EXTRACT – ENVIRONMENTAL SETTING

2. Environmental setting

The Captains Flat region sits on the Lachlan Fold Belt, a volcanic-hosted massive pyritic ore body derived from Silurian shale and volcanics. This geology comprises a heterogeneous mixture of shale, siltstone, dacite, tuff, minor basalt, limestone and conglomerate. The dominant ore mineral within the deposit is pyrite (FeS_2), followed by arsenopyrite (AsFeS), chalcopyrite (CuFeS), galena (PbS), sphalerite (ZnS), tennantite ($Cu_{12}As_4S_{13}$), and minor veins of silver (Ag) and gold (Au) (Chapter 3 Hyperspectral case study 2. Captains Flat (NSW) – Acid Mine Drainage pollution; Jacobson and Sparksman, 1988).

Mining operations in the area operated from 1882 to1962 starting as two separate ventures, Koh-i-noor to the north and El Capitan to the south, before merging into a single venture, the Lake George Mine (Stinton et al., 2020; Mindat.org, 2021). The locations of the various mines and related infrastructure are shown in Figure 1 and Figure 2. Mining originally targeted alluvial gold using mercury-based amalgamation processes. It expanded to include smelting of the pyritic ores (galena, sphalerite, chalcopyrite and pyrite) to extract lead (Pb), zinc (Zn), copper (Cu) and iron (Fe) (Stinton et al. 2020; Bierwirth and Pfitzner, 2001).

Mining operations are reported to have consisted of underground mining works, surface ore processing (Ag, Au, Cu, Fe, Pb, Zn), smelting and waste storage facilities. It is reported that milling, smelting and storage of waste materials were performed near the Molonglo River (Wadige et al. 2016; GHD, 2018). A summary of the mineralogy encountered at the mines and tailings dumps in Captains Flat is provided in Table 2.

Table 2: Mineralogy of mines and tailings in the Captains Flat region. Information sourced from Mindat.org

Location	Characteristics and metal mineralogy
Lake George mine and adits Dominant metals: Al, As, Cu, Fe, K, Mg, Pb, Sb, Sn, Zn.	A pyritic copper-zinc-lead deposit. Arsenopyrite, biotite, cerussite, chalcopyrite, chlorite group minerals, feldspar group minerals, galena, gold iron oxide, muscovite, sericite, pyrite, pyromorphite, pyrrhotite, quartz, sphalerite, stannite, tetrahedrite.
Mine workings and tailings Metals: Al, As, Au, Ba, Bi, Ca, Cu, Fe, K, Mg, Pb, Sb, Si, Sn, Te and Zn	Heterogenous mixture of waste rock and minerals including anglesite, arsenopyrite, azurite, baryte, biotite, bournonite, calcite, cerussite, chalcopyrite, covellite, chlorite group minerals, dolomite, feldspar group minerals, galena, gold, iron oxides, K-feldspar, limonite, malachite, montanite, muscovite, pyrite, pyromorphite, pyrrhotite, quartz, sphalerite, stannite, tellurobismuthite, tennantite, tetradymite, tetrahedrite.

During mine operations, direct and indirect releases of metal-contaminated wastes into the Molonglo River occurred. The literature has attributed major sources of contamination to the failure of tailings dumps at the southern and northern ends of the mine and ongoing acid mine drainage and seepage from the mines and adits[1] (Dames and Moore, 1993; Hogg, 1990). The two main tailings dumps are the Northern Tailings Dumps, to the north of the central mine area, and the Southern Tailings Dumps, to the south of the central mine area on

[1] An adit is a horizontal or near-horizontal passage into a mine, constructed for the purpose of working, ventilation or removal of waters from the mine.

the western side of the town water supply. The location of tailings dumps, dams and areas of historical contaminant breaches are shown in Figure 3 (sourced from Bierwirth and Pfitzner, 2001).

Rehabilitations works (in excess of $3M) involving the reshaping and capping of tailings dumps with clay, shale and soil and the planting of grasses and legumes is reported to have been undertaken in the 1970s (Craze, 1980; Bierwirth and Pfitzner, 2001). Rehabilitation also included the diversion of surface waters from the underground mine to minimise the release of mine waste into the river but did not involve the remediation of tailings associated with sediments and surrounding floodplains (Singh, 2012; Wadige et al., 2016).

Figure 1: Location of Captains Flat (red dot)

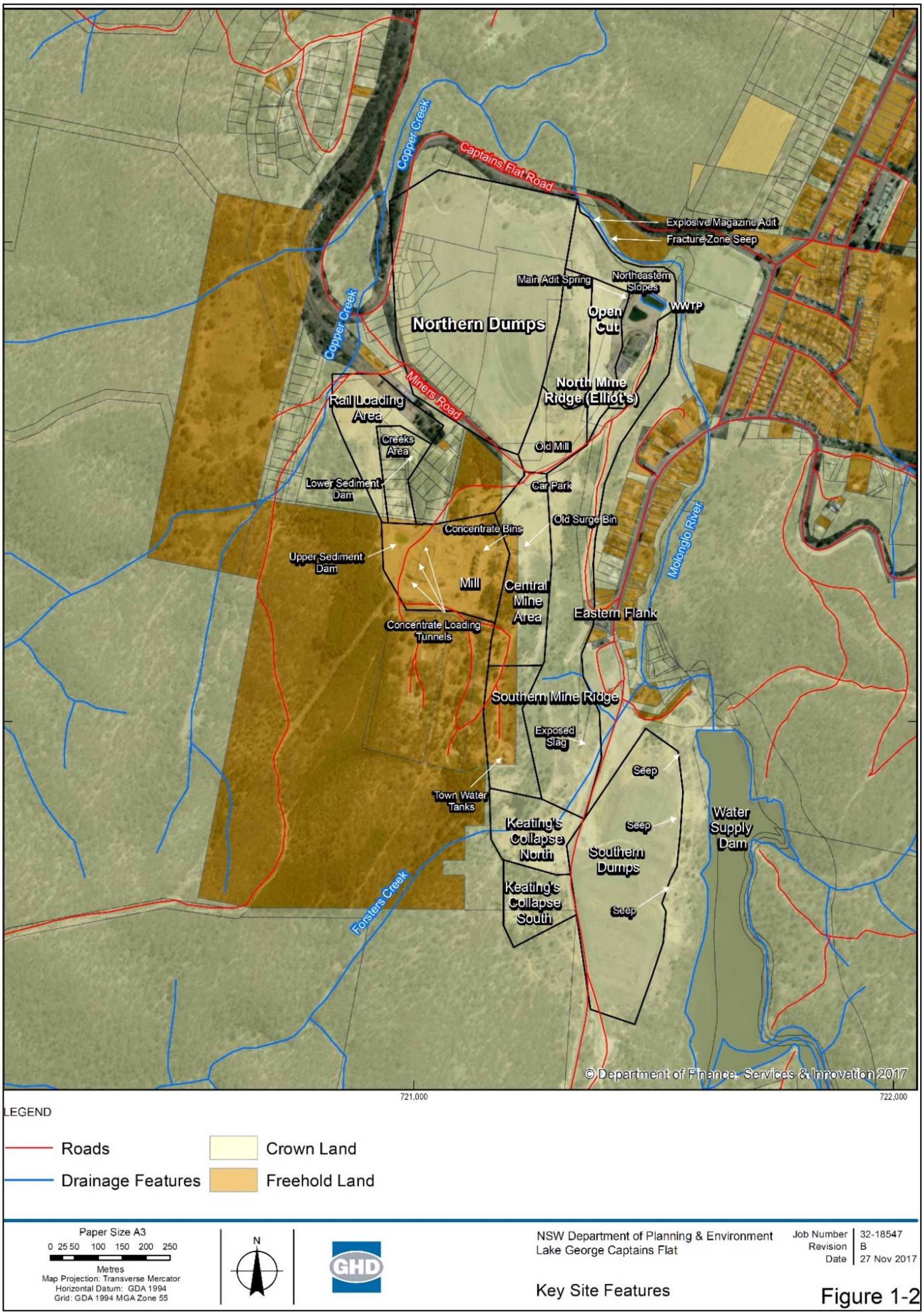

Figure 2: Layout of the mining infrastructure in Captains Flat. Image source: GHD (2018)

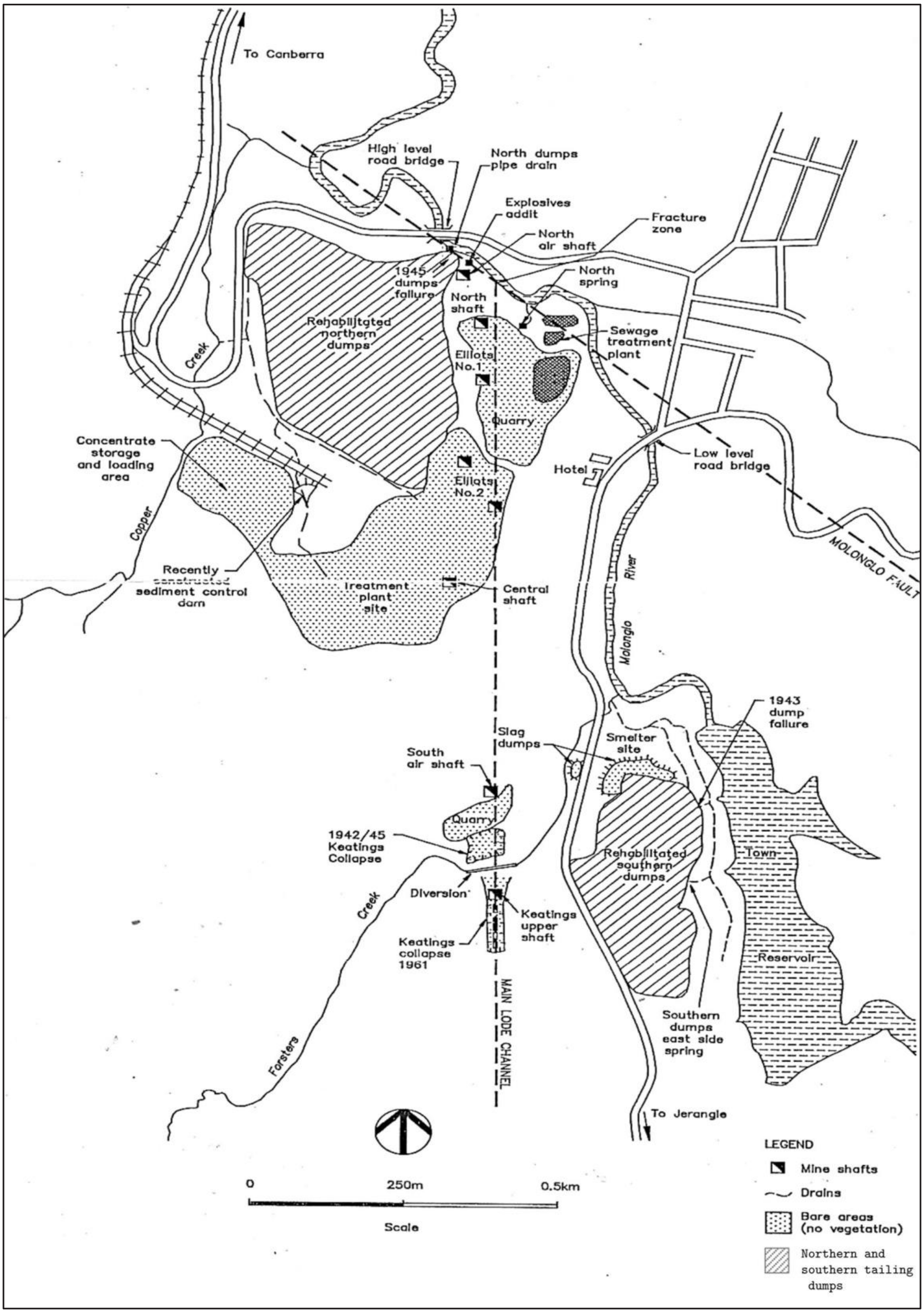

Figure 3: Locations of mine utilities, tailings dumps and dams. Published in Dames and Moore (1993)

2.1 Climate

Similar to the nearby city of Queanbeyan (approximately 35 km to the north-west), Captains Flat is classified as subtropical highland climate with warm to hot summers and cold winters. Based on data from the Captains Flat weather station (Foxlow Street), average annual rainfall for the area, from January 1898 to February 2021, is approximately 737 mm. Rainfall appears quite consistent throughout the year with some increase in rainfall over late spring, summer and early autumn (Figure 4). Average monthly temperatures range from ~ 12 °C in winter (June - July) to ~ 29 °C in summer (January - February).

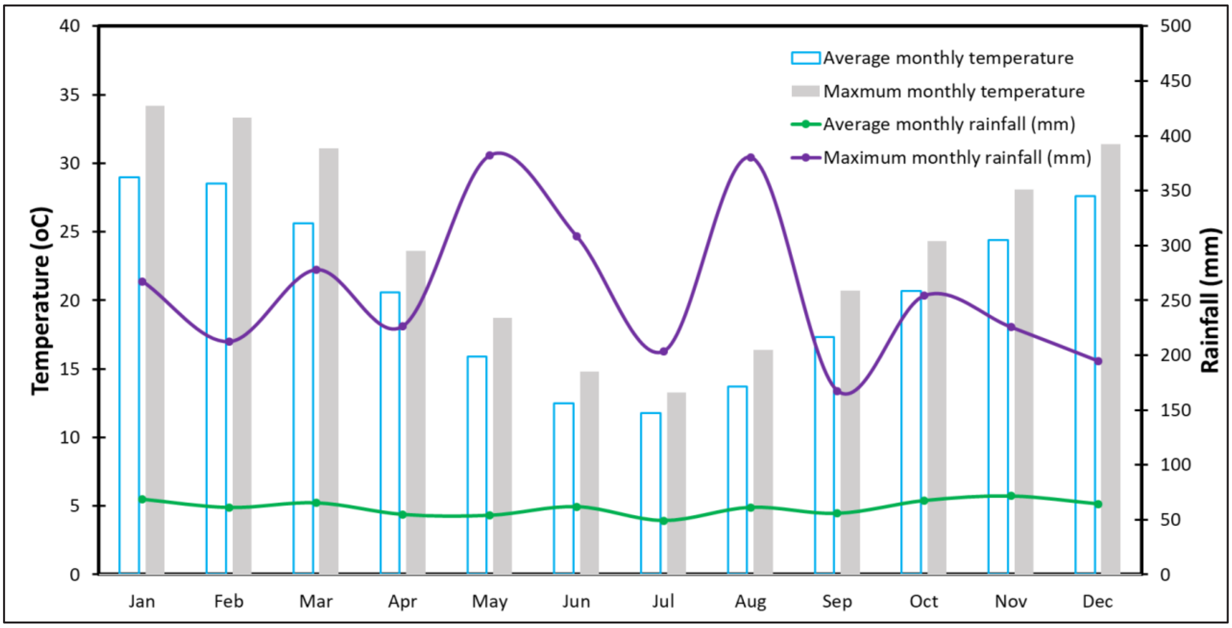

Figure 4: Average and maximum monthly temperature (columns) and rainfall (lines) for the region. Data for the temperature recorded at the Queanbeyan Bowling Club (data from January 1909 to February 2021) and rainfall data recorded at Captains Flat Foxlow Street (data from January 1898 to February 2021). Source: Australian Bureau of Meteorology (data search on 3 March 2021)

2.2 Topography and hydrology

The Captains Flat area is part of the Southern Highlands of New South Wales and located on the western slopes of the Great Dividing Range. Overall, the area is of rugged relief and is characterised by a prominent north-south trending ridge bisected by a saddle and alluvial flats in the northern part of the Molonglo River. The main headworks and processing facilities of the mine are located along the ridge line with several adits and collapsed areas along the Eastern Flank. The extent of height variations across the site range from 840 m Australian Height Datum (AHD) at the Molonglo River to 940 m AHD at the top of the mine ridge (GHD, 2018).

The area is situated within the Molonglo River catchment. The river runs towards the north and has a confluence with its major tributary, the Queanbeyan River (55 km downstream). The river then continues to Lake Burley Griffin and subsequently towards the Murrumbidgee River (BOM, 2019). GHD (2018) identified local drainage features to include:

- Cooper Creek - receives drainage from the Mill, Rail Loading, western slopes of the Central Mine, and Northern Tailings Dumps.

- Forsters Creek - receives drainage from Keating's Collapse diversion channels, Southern tailings dumps on the western side, areas of slag associated with the former smelter, and the Central Mine.
- Molonglo River - receives drainage from the Cooper Creek (confluence is ~ 100 m north of the Northern Tailings Dumps), Forsters Creek (confluence is ~ 100 m north of the Southern Tailings Dumps), Southern Tailings Dumps, Eastern Flank of the Central and Elliot's mines, Open Cut, Main Adit and Explosive/Magazine Adit Springs, seepage through Molonglo Fault fractures, Northern Dumps at the northeast corner, and Southern Dumps on the eastern side

2.3 Geology

The Captains Flat mining site is a volcanic hosted massive sulfide (VHMS) zinc-lead-copper deposit hosted by Late Silurian volcanic and associated siliciclastic (meta-) sedimentary rocks (Davis, 1990). These rocks are found within the eastern Lachlan Fold Belt, a >1000 km-wide orogenic system developed along the Pacific margin of Australia.

The geological structure in the Captains Flat area is characterised by a well-defined north-south trending graben[2] (2 to 8 km wide), bounded by two horsts[3] at its southern and northern ends. The horsts comprise tightly folded Middle to Upper Silurian felsic pyroclastics, volcanogenic sediments and shales (GHD, 2018; Downes and Seccombe, 2004).

The sequence, from the base, is the following (Davis, 1990):

- Copper Creek Shale - 60 to 150 m thick of sediments with subordinate tuffs.
- Kohinoor Volcanics - 50 to 850 m thick of coarsely porphyritic andesitic to dacitic to rhyolitic lavas, tuffs, volcanic breccias, tuffaceous shales and volcanic cherts. This unit hosts the orebodies.
- Captains Flat Formation - 850 to 1200 m thick of predominantly shales and siltstones with minor volcanic flows and tuffs.

An extensional geodynamic environment is critical to the development of VHMS mineralisation. Extensional geological structures (e.g. horsts, grabens) are common in the Captains Flat area. Faults at the boundaries of these structures have the potential to be preferential pathways for groundwater (e.g. Molonglo Fault) (Frenda, 1965; GHD, 2018).

2.4 Soils

Information on soil types in the Captains Flat area is limited. Ramboll (2020b) reported information from a previous site assessment undertaken by URS in 2004 where soils were described in the former load-out area approximately 50-100 m south of the rail loading area. The soil profile described in Table 3.

[2] A graben is defined as a valley caused by the downward displacement of a section of the earths crust. These are produced by parallel faults.

[3] A horst is a raised block of land bounded by parallel normal faults. Horsts are bits of land which have either been lifted or has remained stationary while the land on either side (graben) have fallen.

Table 3: Soil profile as described by Ramboll (2020b) in the former load-out area

Depth (mbgl)	Soil Description
0.0 - 0.3 (up to 1.0)	FILL: Sandy clay fill of yellow/orange colour, moist, loose, containing oxidised rock fragments, increasing clay content with depth
0.3 - 1.2	NATURAL: clay of yellow/white colour with moderate to high plasticity, moist becoming extremely weathered bedrock included rock fragments of orange-red colour
1.2 - bedrock depth	Weathered shale of orange-red colour

Soil descriptions from the NSW DPIE eSPADE v2.1 database appear to be overall consistent with the soil profile showing that on-site soils are composed of sandy clay fill material with abundant gravel fragments (top 0.5-0.7 mbgl) grading towards natural light brown/yellow clay with coarse gravel and pebbles until 1.3-1.5 mbgl (OEH, 2021a-d).

The eSPADE database reports natural red/yellow Podzolic soils (Great Soil Group classification) approximately 1.5-2 km to the north (OEH, 2021e-g), 1-1.5 km to the south (OEH, 2021h), and 1-1.5 km to the south-west (OEH, 2021i). Podzolic soils are typical of eucalypt forests and heathlands in southern Australia.

Alluvial soils (clayey and sandy loam) appear to be present approximately 2 km south (OEH, 2021j), and 1-1.5 km to the north-west (OEH, 2021k).

2.5 Hydrogeology

GHD (2018) stated that there are potentially three main natural aquifers based on the general geology of the site, which comprises:

- a thin narrow zone of alluvial sediment along the Molonglo River
- regionally fractured rock
- fault-associated aquifers, such as the ~10 m wide Molonglo Fault, which runs north-north-west (NNW) along the eastern edge of the deposit, adjacent to the Molonglo River.

Local groundwater within alluvial deposits is expected to flow towards the east/north-east, in line with the Copper Creek flowing into the Molonglo River (Ramboll, 2020b). Regional groundwater within the fractured rock is expected to flow towards the north direction (Ramboll, 2020b).

A search of the online groundwater database (on 08 March 2021) from the Bureau of Meteorology Australian Groundwater Explorer indicated eight registered groundwater bores within 5 km of Captains Flat (Figure 5, Table 4) and none on-site. The nearest registered bore (GW414772) is across the Molonglo River, approximately 1 km east of the southern tailings' storage facility. The remaining registered bores are located to the south-west, south-east, east and north-east, within 2-4 km from the Captains Flat site.

Table 4: Registered groundwater bores within a 5 km radius of the Captains Flat site

Bore ID	Bore Depth (m)	Drilled Date	Purpose	Status
GW414798.1.1	36	01/08/2008	Water Supply	Functioning
GW402606.1.1	20	15/06/1998	Water Supply	Unknown
GW402396.1.1	49	19/04/2003	Water Supply	Unknown
GW402934.1.1	84	07/02/2005	Monitoring	Unknown
GW414772.1.1	70	30/05/2000	Water Supply	Functioning
GW416013.1.1	66	01/01/1985	Water Supply	Functioning
GW402331.1.1	65	06/02/2003	Water Supply	Unknown
GW402995.1.1	36	02/02/2005	Water Supply	Unknown

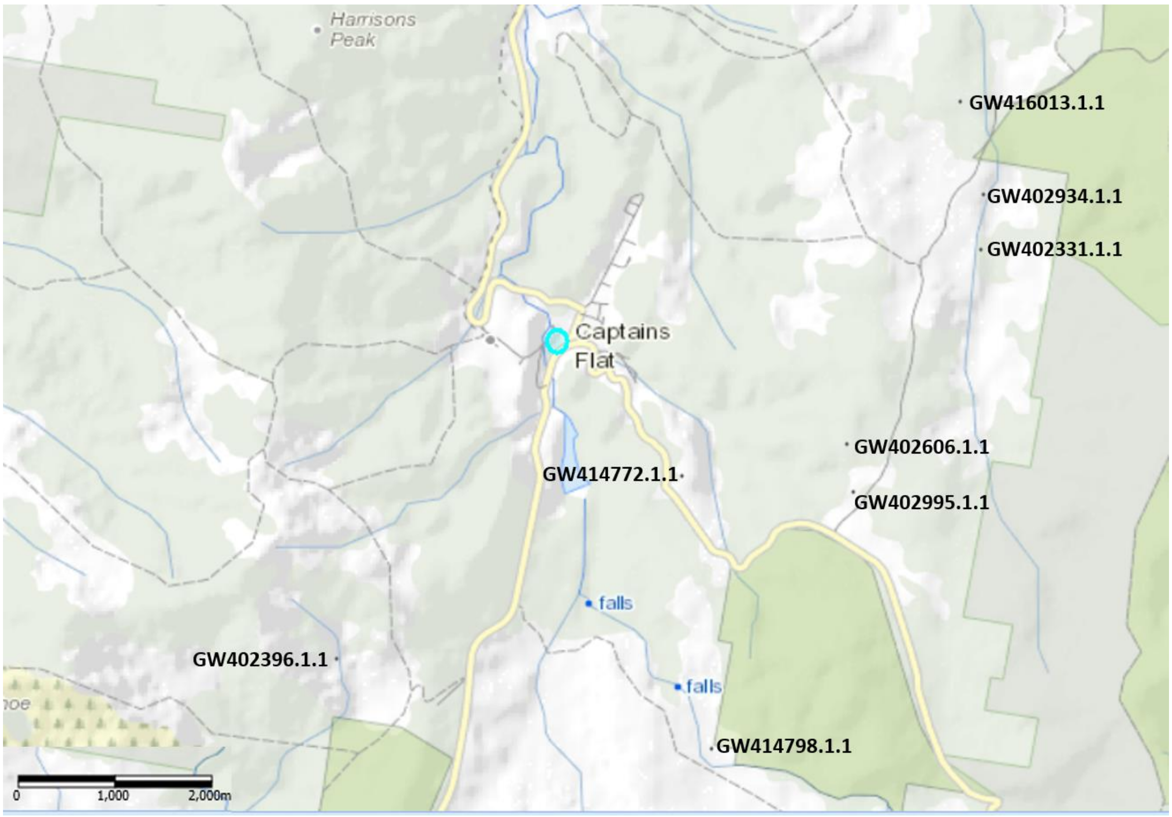

Figure 5: Locations of registered groundwater bores within a 5 km radius of Captains Flat from a search on 08 March 2021 on the Australian Groundwater Explorer

2.6 Land use in the area

The NSW Government ePlanning Spatial Viewer (ePlanning, 2021) indicates that the predominant land use in the area is split into six types including rural villages (RU5), primary production zones (RU1), public and private recreational areas (RE1 and RE2), environmental conservation areas (E2) and special purpose infrastructure zones (SP2). This land zonation is shown in Figure 6.

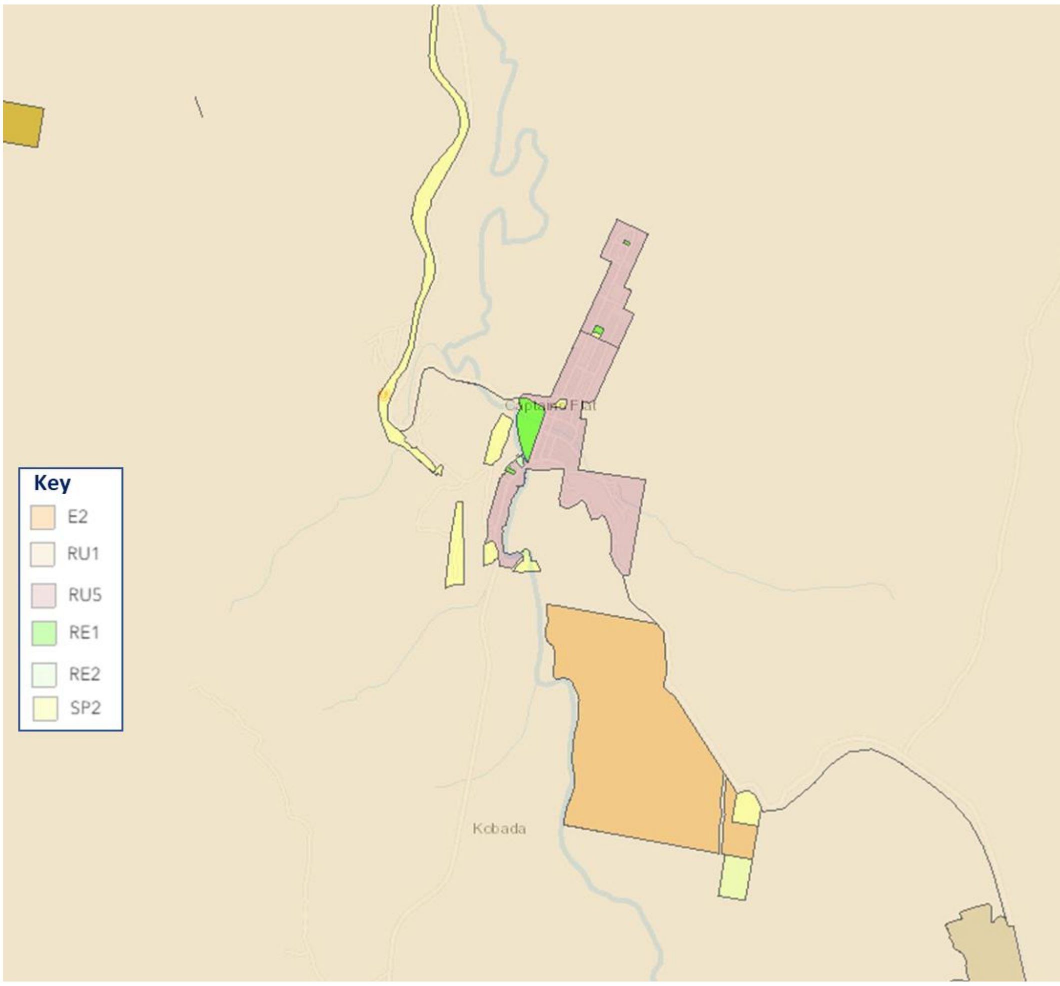

Figure 6: Land use zonation of the Captains Flat area and surround. Data sourced from the NSW Government ePlanning Spatial Viewer (2021)

3. Contamination

The literature and investigation reports for the Captains Flat area indicate that the main contaminants of potential concern (CoPC) are arsenic, copper, mercury, lead and zinc (Bierwirth and Pfitzner, 2001; Chapter 3 Hyperspectral case study 2. Captains Flat (NSW); GHD, 2018). Additional stressors include acid mine drainage and the deposition of hydrous iron oxide precipitates in receiving waters (Wadige et al., 2014; Reich et al., 2019). Mercury contamination has been reported off-site (Stinton et al., 2020), which was initially sourced from the extraction of gold from alluvial sediments through amalgamation. However, it was also an impurity in pyrites and was extracted during smelting operations. This section provides a review of the state of contamination in the Captains Flat area and surrounds.

APPENDIX 5
LITERATURE REVIEW EXTRACT – CSM FIGURES

4.3 Cross-sectional CSMs

Based on the literature review, C&R constructed a cross-sectional CSM, separating the area into three zones of interest (shown in Figure 8). These zones are:

- **CSM Zone 1** (Figure 9), which includes Copper Creek, Rail Loading Area, Northern Tailings Dumps, Molonglo River and Captains Flat Township.
- **CSM Zone 2** (Figure 10), which includes Central Mine area, Eastern Flank, Residential Area and Molonglo River.
- **CSM Zone 3** (Figure 11), which includes Exposed Slag area, Southern Tailings Dump, Water Supply Dam and Captains Flat Township.

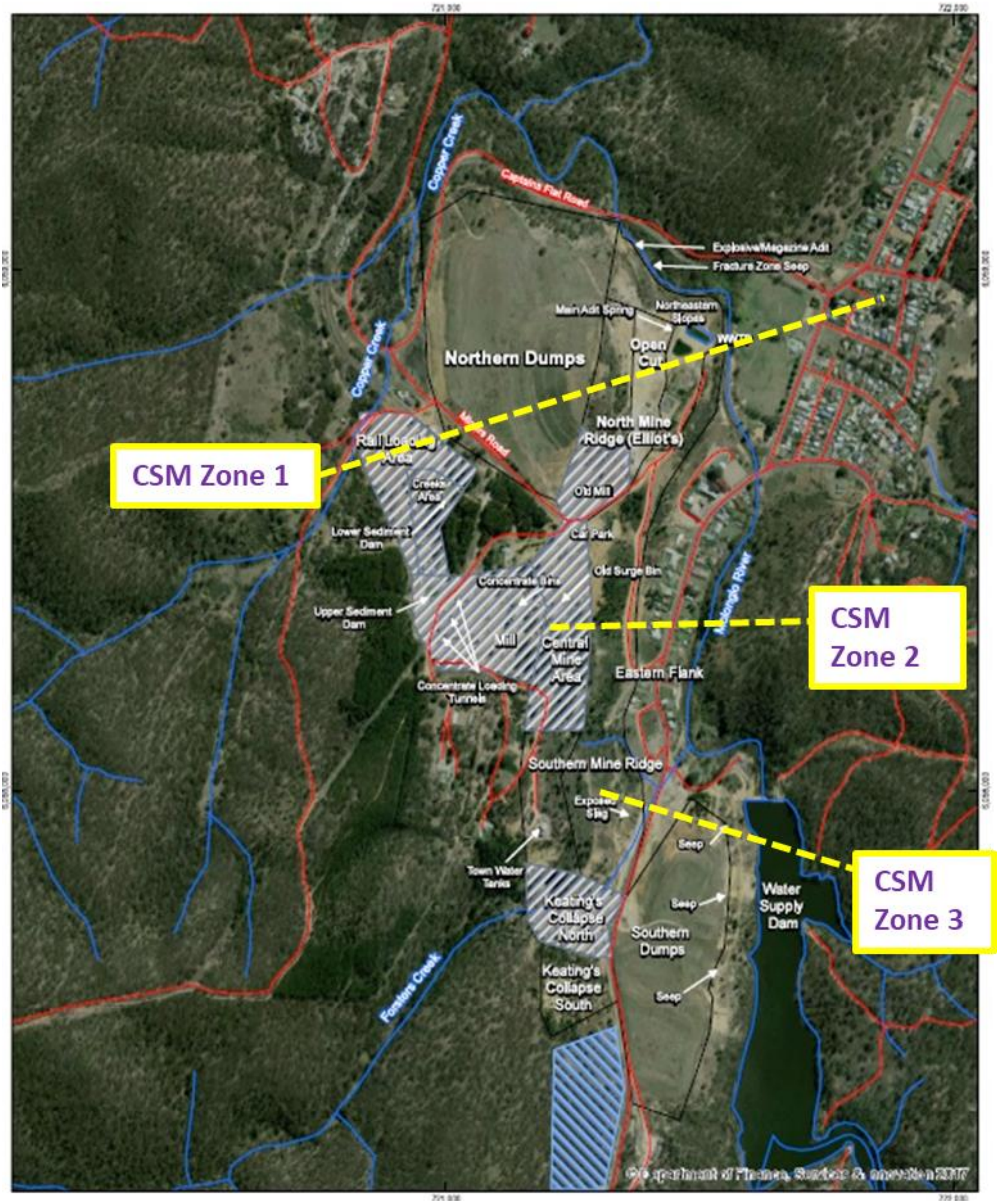

Figure 8: Zones represented by cross-sectional CSMs

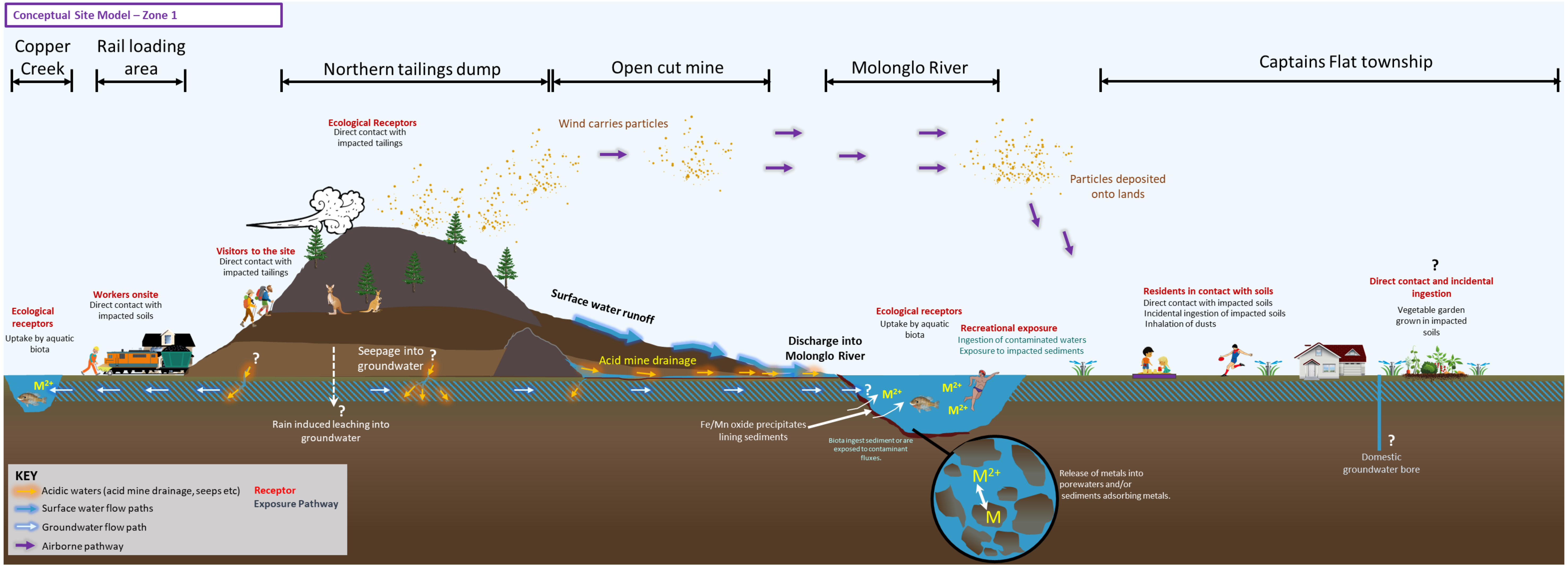

Figure 9: Preliminary cross-sectional CSM for Zone 1.

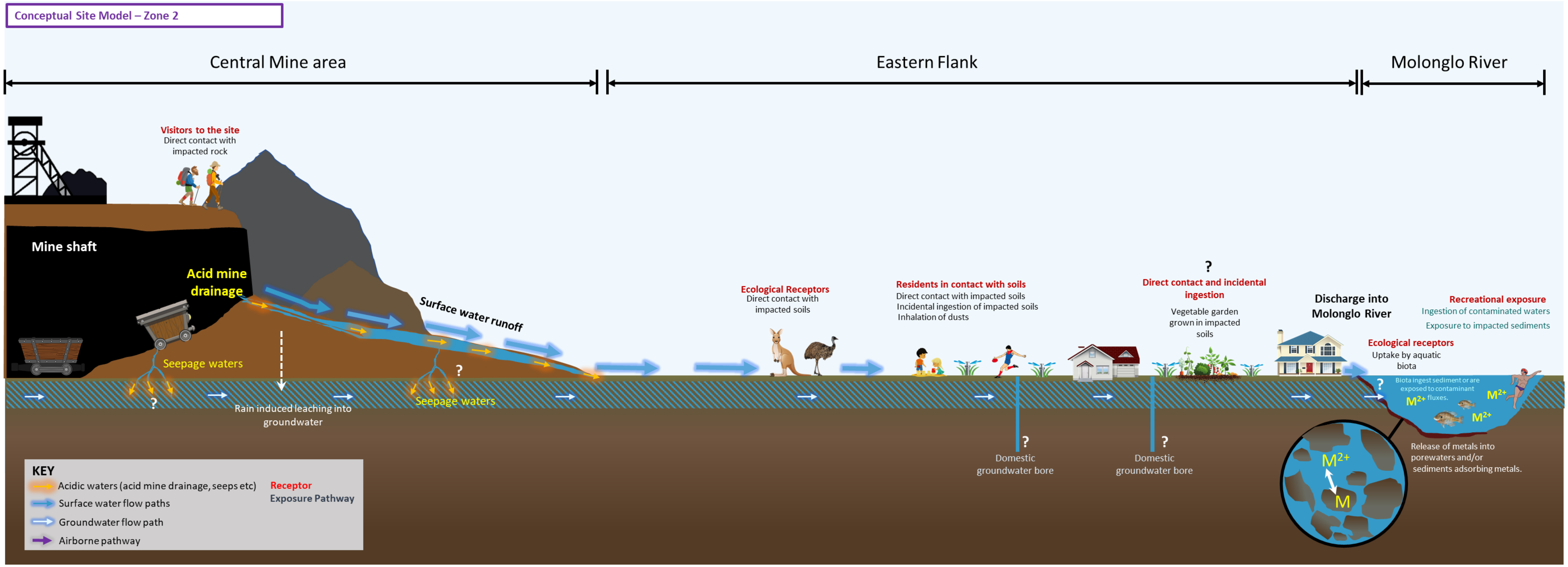

Figure 10: Preliminary cross-sectional CSM for Zone 2.

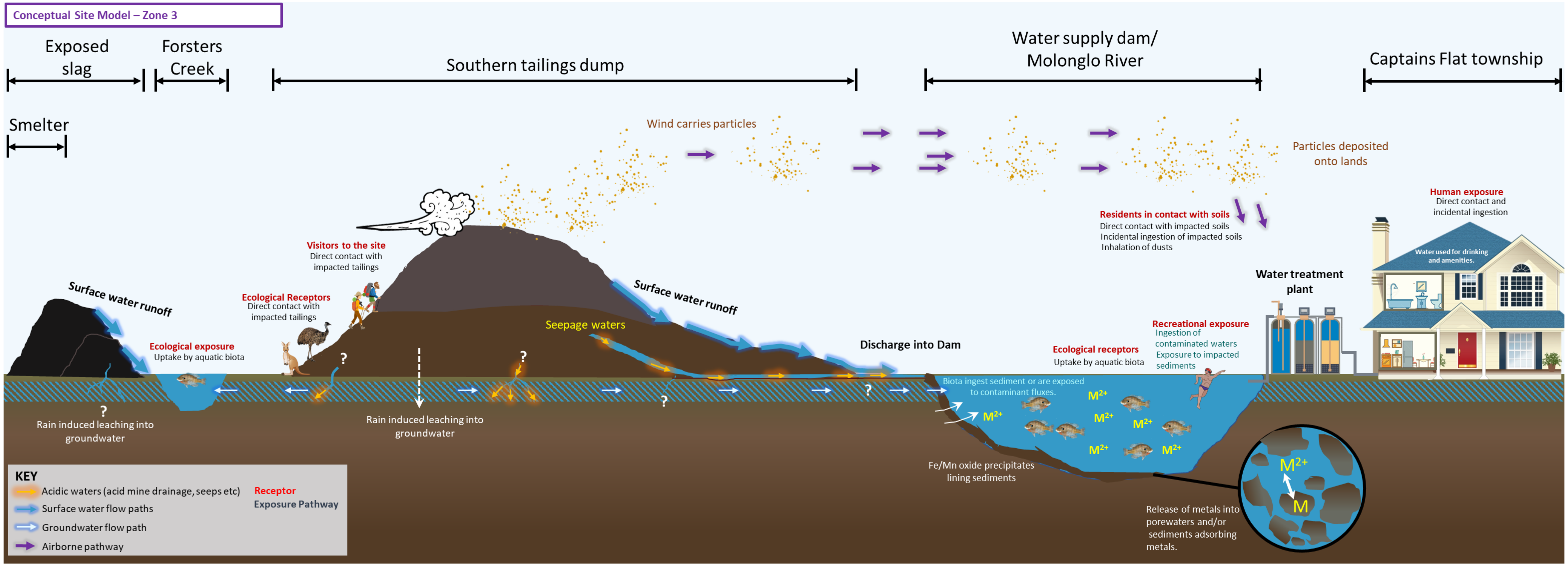

Figure 11: Preliminary cross-sectional CSM for Zone 3.