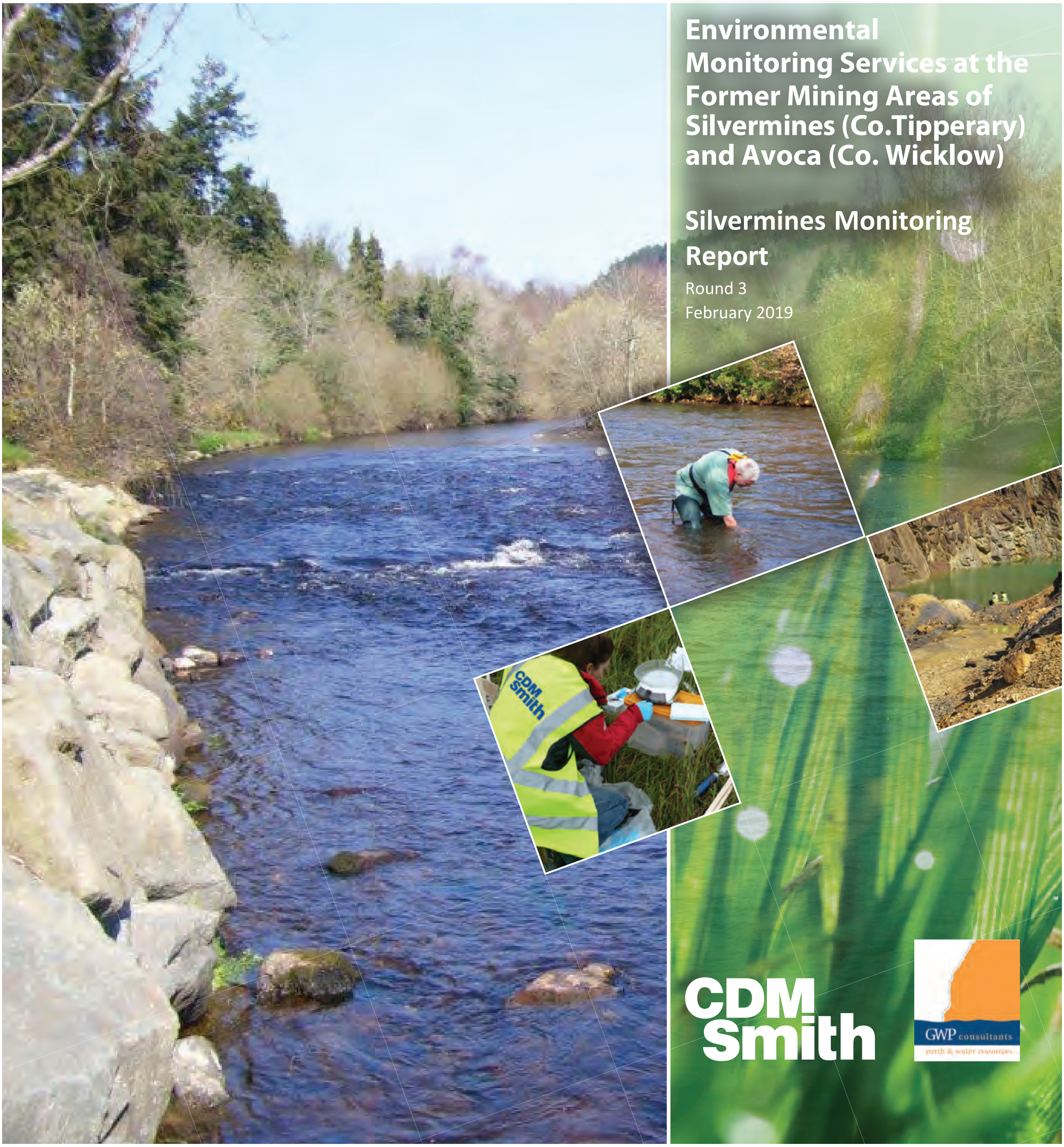
Department of Communications, Climate Action and Environment

# Environmental Monitoring Services at the Former Mining Areas of Silvermines (Co.Tipperary) and Avoca (Co. Wicklow)

## Silvermines Monitoring Report

Round 3

February 2019



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# Section 1

# Introduction

## 1.1 Objectives and Scope

The Department of Communications, Climate Action and Environment (the Department) contracted CDM Smith Ireland Ltd (CDM Smith) to undertake a three-year programme of environmental monitoring at the closed mine sites of Silvermines and Avoca, commencing in 2018.

The scope of the monitoring programme is defined in the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan*, (Document Ref: 118174/40/DG/01, dated February 2018) and sampling activities were performed in accordance with the programme and procedures set out therein.

The Monitoring Report for the Silvermines Mining Area presents an evaluation of the results of the field investigations carried out in February 2019. This report should be read alongside the Silvermines Data Report (Document Ref: 118174/40/DG/12, dated April 2019) which contains all field observations and laboratory analytical results collected during the monitoring programme.

## 1.2 Background of Silvermines Mining Area

The Silvermines mining area is located in the northern foothills of the Silvermine Mountains in Co. Tipperary. The area has been mined intermittently for over one thousand years for a range of commodities including lead, zinc, copper, silver, barite and sulphur. The mining sites include Ballygown (BG), Garryard (GA), Gorteenadiha (GTD), Magcobar (MA) and Shallee South (ShS) /East (ShE) and cover an area of approximately 2,300 ha as shown on Map 1 in **Appendix A**. The last working mine, a barite operation at Magcobar, closed in 1993. Just over a decade previously, the final base metal mine shut down, following the cessation of underground operations by Mogul Mines Ltd. (Mogul) at Garryard. The latter operation resulted in the generation of significant volumes of fine to coarse grained sand-sized particles referred to as tailings. Approximately 8 Mt of such tailings were deposited in a specially constructed, 60 ha tailings management facility (TMF) at Gortmore (GM). Rehabilitation works have been completed at various localities including Gortmore TMF, with the site work administered by North Tipperary County Council on behalf of the Department. To date this rehabilitation work has included:

- Capping poorly and non-vegetated areas of the TMF surface, covering approximately 24 ha, with a range of materials (Geogrid/geotextile, crushed calcareous rock and blinding layers and a seeded growth medium);
- Establishing a vigorous grass sward on the capped areas of the TMF to minimise the risk of future dust blow events;
- Various engineering works on the TMF (e.g. improvements to the surface water drainage system, construction of rockfill buttresses to lessen the slopes of the TMF sidewalls, etc.);
- Remedial works to the TMF's retention ponds and wetlands, so as to improve the quality of waters discharging into adjoining watercourses;

- Fencing and/or capping of old mine shafts and adits at Ballygown, Garryard and Shallee;
- Drainage improvement works at Ballygown, Gorteenadiha and Shallee; and
- Filling an open pit at Ballygown and re-vegetating the pit area.

## 1.3 Catchment Description

The area is located in the northern foothills of the Silvermine Mountain, Co. Tipperary as shown on Map 1 in Appendix A. The Kilmastulla River is the main river which rises in the Silvermine Mountain just south of Silvermines Village (called the Silvermines Stream) and flows north through the Ballygown mining area. The river then flows west towards the Gortmore TMF which is located to the north of the river. The river is located northwest of the other main areas of previous mining activity including Shallee, Garryard and Magcobar. Streams from Shallee and Garryard drain into the Yellow Bridge River which discharges to the Kilmastulla River at the south-eastern corner of Gortmore TMF.

**Ballygown** has been extensively worked both on the surface and underground. Most of the many shafts sunk in the area are collapsed or backfilled but a drainage adit that links them continues to discharge mine water into the Silvermines Stream north of the village of Silvermines.

**Magcobar** mine was the last active mine in the district. Open-pit mining was followed by limited underground mining developed from the base of the pit. Streams draining Silvermines Mountain have been diverted around the open pit using drainage channels which are still operational. SW6-MAG is the sampling point on Foilborrig Stream which has been diverted around the pit.

**Garryard** is located on both sides of the main road R499. To the south of the road is the old ore stockpile area, whilst north of the road, the site is split by a railway. Knight Shaft was the main mine access and is now covered by a concrete cap. An overflow pipe in the cap discharges mine water, typically after heavy rainfall, which flows north under the railway to the tailings lagoon. The tailings lagoon also receives run-off from the yard. Both the water and the tailings in this lagoon contain high concentrations of mine-related metals such as Lead, Zinc, Arsenic and Cadmium. The two settlement ponds south of the railway receive surface runoff from the Garryard plant area, which can also have high metal concentrations. Ponds and the tailings lagoon ultimately drain into the Yellow Bridge River, 1km downstream of the site. Surface water run-off from the stockpile area south of the main road enters a drain that runs westwards, parallel to the road, before crossing under the road to enter farmland.

**Shallee** has been extensively worked both on the surface and underground. A cut-off drain is located upslope of the surface working and drum dump which collects and diverts runoff from Silvermine Mountain; however, the mine does act as a drain for rain water and the open pit and underground workings are partially flooded. Near the southernmost tailings dump, a spring is present in an old streambed that is thought to be fed by water from the underground workings. This then passes under the main R499 road via a culvert and flows along the western boundary of the north tailings impoundment to join the Yellow Bridge River.

**Gortmore TMF** is some 60 ha in area with surface elevations ranging from approximately 54.0 m to 56.5 m. The tailings were pumped as a slurry through a pipe from Garryard and deposited in lagoons on the surface of the impoundment. When production at the Garryard plant ceased, the tailings impoundment was closed, and the pipeline removed. Various works have been carried out to rehabilitate the impoundment, and most of the surface is now vegetated with grass and moss. Some areas have exposed tailings, with some ponded water. Typical existing ground elevations outside the perimeter of the dam range from approximately 48 to 50 m.  Excess water drains via a cascade to ponds which overflow into the Kilmastulla River. A number of constructed wetlands are also present at various locations near the toe of the dam.

## 1.4 Geology and Hydrogeology

### 1.4.1 Geology

The geology of the Silvermines district comprises Silurian and Devonian sedimentary rocks (greywackes, pebble conglomerates, sandstones and siltstones) which are overlain by Lower Carboniferous transgressive siliciclastics and carbonates. The local geology of the area is dominated by a complex structure known collectively as the Silvermines Fault. The fault zone trends broadly east-northeast but includes west-northwest-striking components. The fault has downthrown the younger Carboniferous strata against the older Silurian and Devonian clastic sequences. Mineralization occurs in fracture zones and as stratabound zones within brecciated and dolomitized Waulsortian reef limestone.

### 1.4.2 Hydrogeology

The bedrock is overlain by subsoils derived from Devonian Sandstone Till (DSTs). Subsoils are thin (<2 metres) or absent on hilltops and thicker (>2 metres) along valley floors. Alluvial sediments are deposited along the course of the Kilmastulla River valley. Similarly, the groundwater vulnerability ranges from Extreme in the upland areas to Moderate in low-lying areas.

In terms of groundwater yield, the Geological Survey (GS) classifies the bedrock in the Silvermines area as poorly productive: Ll (Locally Important Bedrock Aquifer, Moderately Productive only in Local Zones) and Lm (Locally Important Bedrock Aquifer, Generally Moderately Productive). A locally important (Lg) gravel aquifer overlies the bedrock aquifers in the valley north of the Silvermine Mountain where gravels have accumulated.

Ll is the predominant aquifer type: a relatively poorly connected network of fractures, fissures and joints exists, giving a low fissure permeability which tends to decrease further with depth. A shallow zone of higher permeability is likely to exist within the top few metres of more fractured/weathered rock, and higher permeability may also occur along fault zones. In general, the lack of connection between the limited fissures results in relatively poor aquifer storage and flow paths that may only extend a few hundred metres. Artesian and upward vertical flows are present in the Garryard area and the Gortmore TMF area as indicated by recorded groundwater levels.

# Section 2

# Methodology

## 2.1 Field Sampling Methods

### 2.1.1 Groundwater Sampling

Two groundwater monitoring wells were sampled on 20 February 2019 as listed in Table 1 and shown on Map 2 in Appendix A. Water levels were measured at an additional seven monitoring wells (Table 1), located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder. Groundwater level data are contained in Appendix A of the Data Report and discussed in Section 6.

**Table 1 Location of Groundwater Monitoring Points**

| Borehole Identifier | Easting | Northing | Water Level | Field Parameters & Chemical Analysis | Depth (m bgl) | Screen Interval (m bgl) |
|---|---|---|---|---|---|---|
| TMF1(D)/SRK/01 (TMF1) | 179826 | 173165 | Yes | Yes | 23 | 22-23 |
| TMF2(D)/SRK/01 (TMF2) | 179445 | 172307 | Yes | Yes | 18 | none |
| BH1A-GORT-06 | 180181 | 172490 | Yes | No | 8.8 | 5.5 - 8.8 |
| BH2A-GORT-06 | 180216 | 172855 | Yes | No | 10 | 7 - 10 |
| BH3A-GORT-06 | 179835 | 173126 | Yes | No | 10 | 7 - 10 |
| BH4A-GORT-06 | 179570 | 172826 | Yes | No | 10 | 7 - 10 |
| BH5A-GORT-06 | 179537 | 172312 | Yes | No | 10 | 7 - 10 |
| BH6A-GORT-06 | 179868 | 172212 | Yes | No | 10 | 7 - 10 |
| BH6B-GORT-06 | 179867 | 172225 | Yes | No | 5 | 3 - 5 |

TMF1(D)/SRK/01 (TMF1) is upgradient of the TMF and TMF2(D)/SRK/01 (TMF2) is downgradient (Golder Technical Memo 4 April 2007). TMF1 and TMF2 have a double well installation: the deep installation is sealed in the bedrock and the shallow well is sealed within the overlying soil overburden. Samples were obtained from the deep well installations outside the TMF perimeter.

Groundwater samples are collected using the procedure consistent with the Low Flow Groundwater Sampling Procedure (SOP 1-12) detailed in the Monitoring Plan. Groundwater is collected using a portable submersible low-flow pump (Grundfos MP1 pump). The static water level is measured prior to pumping and is also measured throughout the purging process to monitor drawdown.

Water quality indicator parameters are monitored in the field during low-flow purging using a flow-through cell to minimise oxidation by the atmosphere. Water quality indicator parameters include temperature, pH, oxidation-reduction potential (ORP), conductivity and dissolved oxygen (DO).  Purging continues until the field parameters have stabilised. The results are recorded approximately every five minutes during the purging process and the data were recorded digitally in a tablet.  Data collected on-site were exported from the tablet to an Excel spreadsheet and are summarised in Appendix A of the Data Report.

After the well was purged and the parameters have stabilised, the flow was reduced for low-flow sample collection. Samples for trace metal analyses were filtered in the field using a 0.45 micron membrane syringe filter before preservation. New bottles supplied by the laboratories were used for sample collection.

During the February 2019 sampling event, as previously, TMF1 borehole is an exception to the low flow sampling procedure. The borehole has been damaged approximately 1m from the surface. A major obstruction exists within the well and the pump cannot be lowered into the well. The borehole was sampled by hand pumping the well using designated tubing with a foot valve. The sample was collected after three volumes of the well (calculated as $\pi r^2 h$; r is the inner casing radius and h is the height of the water column) had been purged and the field parameters had stabilised.

### 2.1.2 Surface Water Sampling

Table 2 lists thirty five locations, of which one was not sampled (dry and no flow) SW1-Gar. Thirty four surface water locations were sampled for chemical analyses between 18 and 20 February 2019, as listed in Table 2 and shown on Maps 2 to 5 in **Appendix A**.

Surface water sampling was conducted in accordance with the Surface Water Sampling Procedure (SOP 1-1) as detailed in the Monitoring Plan (*Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan*, (Document Ref: 118174/40/DG/01, dated February 2018)). The predetermined surface water sampling locations were located in the field using a GPS. Photographs were taken of the surface water sampling locations (Appendix B of the Data Report). Samples were grab samples collected from a well-mixed portion of the water stream where possible. The sample location was approached from downstream so that the underlying sediments were not disturbed.

Samples were placed into new laboratory provided bottles with the correct preservatives. The sample bottles that required no filtering (and contained no preservatives) were filled directly in the stream. A container was filled at the same time and transported to the shore for filtering using a 0.45 micron membrane syringe filter before preservation for the trace metal analysis.

Water quality indicator parameters were monitored during sampling by collecting them directly from the stream or discharge when possible using a multi-parameter meter. The final stabilised results were recorded on the Trimble field tablet and are summarised in Appendix A of the Data Report.

#### Flow Measurements

The locations at which flow is required to be measured are contained in Table 14 of the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan*, (Document Ref: 118174/40/DG/01, dated February 2018). Flow was measured at 25 locations using various methods depending upon the quantity of flow to be measured and any safety concerns as detailed in the standard operating procedures in the Monitoring Plan (see Table 2). Where flow measurement is not required because of high flow and no access to cross the Kilmastulla River or no access to certain sampling locations, this is noted in this report in Table 2. Flow cannot be measured at SW5-GAR due to a grate covering it. SW1-Gar was dry and there was no sample collected or flow measured.

**Table 2 Location of Surface Water and Discharge Monitoring Points in Silvermines**

| Site Name | Area | Easting | Northing | Sample Site Notes | Field Parameters | Chemical Analysis | Flow Method |
|---|---|---|---|---|---|---|---|
| SW18-Gort | GM | 179770 | 172652 | Site of discharge from the main pond on the TMF. | Yes | Yes | N/A [1] |
| SW19-Gort | GM | 180081 | 172971 | Discharge to TMF wetlands. DS of decant. | Yes | Yes | Flume Method |
| SW17-Gort | GM | 180538 | 173059 | Site located on Kilmastulla River, upstream of TMF | Yes | Yes | N/A [1] |
| SW10-Gort-US | GM | 180212 | 172410 | Immediately upstream of the outfall on the Kilmastulla River | Yes | Yes | N/A [1] |
| SW10-Gort-Discharge | GM | 180206 | 172395 | Wetland discharge prior to outfall | Yes | Yes | Bucket Stop Watch |
| SW10-Gort-DS | GM | 180191 | 172368 | 20m downstream of the outfall, on the Kilmastulla River | Yes | Yes | N/A [1] |
| Gort-TMF-Seep | GM | 179818 | 172172 | Seeps at the southern edge of TMF, discharging to wetlands | Yes | Yes | Flow not possible to measure [2] |
| SW12-Gort-Discharge | GM | 179551 | 172193 | Sample of wetland discharge prior to outfall | Yes | Yes | Bucket Stop Watch |
| SW12-Gort-DS | GM | 179535 | 172140 | 20m downstream of the outfall, on the Kilmastulla River | Yes | Yes | N/A [1] |
| SW14-Gort | GM | 179343 | 172167 | Site located on Kilmastulla River, downstream of TMF | Yes | Yes | N/A [1] |
| DS-Gort | GM | 178499 | 171868 | Site located on Kilmastulla River, downstream of TMF | Yes | Yes | Float Method |
| SW6-Mag | MG | 182776 | 171402 | Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road. | Yes | Yes | N/A [1] |
| US-Shal | ShS | 180715 | 171798 | Yellow River upstream of ShS | Yes | Yes | Flow Meter |
| SW4-Shal | ShS | 180328 | 171088 | Water-course west of ‘Drum Dump’ and Shallee South workings. | Yes | Yes | Bucket Stop Watch |
| SW5-Shal | ShS | 180571 | 171299 | Water course west of fenced off area enclosing King’s House and core sheds. Further west, this same feature runs along the toe of the drum dump. | Yes | Yes | Flume Method |
| SW6-Shal | ShS | 180589 | 171345 | Stream emanating from flooded Field Shaft | Yes | Yes | Bucket Stop Watch |
| SW15-Shal | ShS | 180611 | 171344 | Stream downgradient of the drum dump and SW5-Shal in the Shallee mining area. | Yes | Yes | Bucket Stop Watch |
| SW9-Shal | ShS | 180526 | 171500 | Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road. | Yes | Yes | Flow Meter |
| SW12-Shal | ShS | 180674 | 171174 | Stone lined drainage channel SSW of reservoir | No | Yes | Bucket Stop Watch |
| SW13-Shal | ShS | 180706 | 171777 | Stream draining the eastern section of the tailings impoundment (adjacent to SW1-Shal in northern most corner) | Yes | Yes | Flow Meter |

| Site Name | Area | Easting | Northing | Sample Site Notes | Field Parameters | Chemical Analysis | Flow Method |
|---|---|---|---|---|---|---|---|
| SW1-Shal | ShS | 180703 | 171778 | Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment. | Yes | Yes | Flow Meter |
| DS-Shal | ShS | 178644 | 172952 | Yellow River downstream of ShS and BG | Yes | Yes | Flow Meter |
| DS-Gorteenadiha | GTD | 180685 | 171797 | Stream downgradient of Gorteenadiha | Yes | Yes | Flow Meter |
| SW1-Gar | GA | 182124 | 171315 | Stream south of R499 road (south of old Mogul Yard). | No | No | Dry [2] |
| SW5-Gar | GA | 181932 | 171422 | Discharge from Knight Shaft | Yes | Yes | Inaccessible, covered by grate [1] |
| SW12-Gar | GA | 181779 | 171577 | Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon. | Yes | Yes | Flume Method |
| SW10-Gar | GA | 181612 | 171734 | Discharge from Garryard tailings lagoon | Yes | Yes | Flow Meter |
| SW7-Gar | GA | 181521 | 171492 | Discharge from smaller settlement pond | Yes | Yes | Bucket Stop Watch |
| SW3-Gar | GA | 181310 | 171661 | Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard. | Yes | Yes | Flume Method |
| SW1-SM | BG | 184066 | 170707 | Site on Silvermines Stream (upstream of Ballygown mine workings). | Yes | Yes | Flow Meter |
| SW3-SM | BG | 184245 | 171445 | Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit) | Yes | Yes | Flow Meter |
| SW2-SM-South | BG | 184255 | 171582 | Discharge from 'Southern' adit. | Yes | Yes | Bucket Stop Watch |
| SW5-SM | BG | 184296 | 171708 | Site on Silvermines Stream (downstream of main Ballygown workings and of North adit) | Yes | Yes | Flow Meter |
| SW6-SM | BG | 184117 | 172064 | Site on Silvermines Stream (downstream of main Ballygown workings and of North adit) | Yes | Yes | Flow Meter |
| SW4-SM-GA | BG | 183951 | 172485 | Site on Silvermines Stream (downstream of all mine workings) | Yes | Yes | Flow Meter |

Abbreviations: GM- Gortmore; MG- Magcobar; ShS- Shallee South; GTD – Gorteenadiha; GA- Garryard; BG- Ballygown; Notes: [1] The locations at which flow is required to be measured are contained in Table 14 of the Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan, (Document Ref: 118174/40/DG/01, dated February 2018); where flow measurement is not required because of high flow and no access to cross the Kilmastulla River or no access to certain sampling locations, this is noted in this report in Table 2. Flow could not be measured at the discharge from one shaft (SW5-GAR) due to the grate covering it.

[2] Discharges at Gort-TMF-Seep could not be measured for flow. SW1-Gar was dry.

Surface water flow results are discussed in Section 5.1 and the data and measurement methodologies are contained in Appendix A of the Data Report. A portable flume was used for small discharges and streams while for very small discrete discharges, a stop watch and calibrated volume container was used. On this sampling event, at locations with greater flow, trial use was made of flow measurement using a HACH digital flow meter; a Marsh McBirney meter was also used along-side to measure flow velocities and depths at regular intervals across stream sections at certain locations. Both the HACH meter and the Marsh McBirney meter operate on the same flow measurement principle, however, the HACH meter digitally performs streamflow calculations and records readings. It is proposed that locations and flow conditions which currently allow for flow monitoring using the Marsh McBirney meter will have the flow measurement taken with the HACH digital flow meter, for ease of flow measurement. The use of the HACH digital flow meter from the trial flow testing is being reviewed to confirm the methodology for future use.

The float method was used when the river was unsafe to wade. It is the least accurate method but provides a reasonable estimate. This method requires the measurement and calculation of the cross-sectional area of the channel as well as the time it takes an object to “float” a designated distance. The water depth was measured (approximately 8 locations) and the float was released into the channel upstream of the beginning of the section and the amount of time it takes the “float” to travel the marked section was recorded. This was repeated at least three times and the average time calculated.

### 2.1.3 Field QA/QC Samples

In accordance with the QA/QC Protocols set out in the Monitoring Plan, the following field QA/QC samples were collected:

**Groundwater and Surface water**

- Groundwater:
  - One duplicate groundwater sample was collected; and
  - One decontamination blank was collected by pumping deionised (DI) water through the groundwater pump after decontamination.
- Surface Water:
  - Three duplicate surface water samples; and
  - One decontamination blank was collected by pouring DI water over the surface water sampling equipment after decontamination.
- Two certified standard reference material samples containing known concentrations of the 18 metals were shipped blind to ALS laboratory (the SRM certificate is contained in Appendix E of the Data Report).
- One water blank was collected of the DI water during the sampling event. An additional filtration blank was collected to quantify any contamination caused by the filtration procedure.

Sample IDs for the field QA/QC samples are listed in Table 3. The duplicate samples are an independent check on sampling procedure and laboratory precision. The standard reference materials are an independent check on laboratory accuracy. The decontamination blanks are a check on the decontamination procedures used in the field. These checks are very important and are independent from the QA/QC samples performed by the laboratories (see discussion in Section 3).

**Table 3 Field QA/ QC Sample IDs and Descriptions**

| Sample ID | QA/QC Sample Type | Description |
|---|---|---|
| ***Groundwater and Surface water*** | | |
| SM GD01.12 | GW Duplicate | Duplicate of TMF2(D) |
| SM DB01.12 | GW Decontamination blank | DI water VWR chemicals (Ref No.) 18L134-120 pumped through groundwater pump after final decon at site TMF2 |
| SM SD01.12 | SW Duplicate | Duplicate of SW12-Shal |
| SM SD02.12 | SW Duplicate | Duplicate of SW7-Gar |
| SM SD03.12 | SW Duplicate | Duplicate of SW12-Gort-D/S |
| SM DB02.12 | SW Decontamination blank | DI water (VWR chemicals 18L134120) poured over SW composite sample bottle after final decontamination at DS-Gorteenadiha. |
| SM SR01.12 | Standard Reference Material | Water ERA “Trace Metals” Lot P282-740A |
| SM SR02.12 | Standard Reference Material | Water ERA “Trace Metals” Lot P282-740A |
| WB 01.12 | Filtration blank | Deionised water filtered onsite VWR chemicals (Lot Ref 18L134120) |
| WB 02.12 | Water blank | Deionised water VWR chemicals (Lot Ref 18L134120) |

## 2.2 Sample Handling

One waterproof label for each sample container collected was completed with an indelible, waterproof, marking pen. The label contained the location, Sample ID code and date and time of sample collection. Samples were stored appropriately so they remained representative of the time of sampling. Sufficient ice packs and ice was added to cool the samples.

A Chain-of-Custody (COC) form was filled out for each sample type at each sampling location. The field staff double-checked that the information recorded on the sample label was consistent with the information recorded on the COC record. The COC record was placed in a re-sealable plastic bag and placed inside of all shipping and transport containers. All samples were shipped by courier to the laboratory. Samples were packed so that no breakage would occur. Signed COCs are provided in Appendix C of the Data Report.

## 2.3 Sample Analysis

### 2.3.1 ALS Laboratory North Wales (Water Samples)

Analysis of water samples was undertaken by ALS (formerly ALcontrol). Water (both surface water and groundwater) samples were dispatched from its distribution centre in Dublin and analysed at its facility in North Wales. ALS is accredited by the United Kingdom Accreditation Service (UKAS) in accordance with ISO/IEC 17025:2005 and has also obtained a Certification of Approval by Lloyd’s Register Quality Assurance for Environmental Management System Standard ISO 14001:2004.

For groundwater and surface water, analyses were performed for the following parameters: pH, ammoniacal nitrogen as N, sulphate and dissolved metals including Al, Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, V and Zn. In addition, Total Organic Carbon (TOC) and Calcium (Ca) were analysed on river and stream samples to assess bioavailable concentrations of several metals (further discussed in Section 4.4). The Monitoring Plan provides details on the analytical methods, holding times and reporting limits.  Most metals were analysed by ICP-MS to achieve the lowest possible detection limits.

All the laboratory reports and analytical data are contained in Appendix D of the Data Report and discussed in Section 4 of this report.

# Section 3

# Data Quality and Usability Evaluation

## 3.1 Introduction

Laboratory data quality and usability were assessed using data quality indicators (DQIs). Data "usability" means that the data are considered acceptable to use for their intended purpose and associated evaluations. The DQIs for assessing data are expressed in terms of precision and accuracy. These DQIs provide a mechanism to evaluate and measure laboratory data quality throughout the project. The definitions and methods of measurement of precision and accuracy are discussed below. In addition, use of blank samples as a DQI is also discussed.

### 3.1.1 Accuracy

Accuracy is defined as the degree of agreement of a measurement with an accepted reference or true value. The accepted reference is typically a standard reference material (SRM) provided by an established institute or company. The "true" value has been determined by performing multiple analyses by various methods and laboratories. Accuracy is a measure of the bias in a system (i.e. the laboratory procedures). Each measurement performed on a sample is subject to random and systematic error. Accuracy is related to the systematic error. Attempts to assess systematic error are always complicated by the inherent random error of the measurement. Accuracy is quantitative and usually expressed as percent recovery (%R) of a sample result compared to the SRM.

%R is calculated as follows:

$$\%R = \frac{A}{T} \text{ x } 100$$

where: %R = Percent recovery
A = Measured value of analyte (metal) as reported by the laboratory
T = True value of the analyte in the SRM as reported by the certified institute

Acceptable QC limits are typically between 80 to 120 %R for inorganic methods (i.e. metals in this report). However, the exact acceptable limits depend upon the actual SRM used (see Section 3.2.3). The SRMs used for this project are discussed below.

### 3.1.2 Precision

Precision is the measurement of the ability to obtain the same value on re-analysis of a sample (i.e. the reproducibility of the data). The closer the results of the measurements are together, the greater is the precision. Precision is not related to accuracy or the true values in the sample. Instead precision is focused upon the random errors inherent in the analysis that result from the measurement process and are compounded by the sample vagaries. Precision is measured by analysing two portions of the sample (sample and duplicate) and then comparing the results. This comparison can be expressed in terms of relative percent difference (RPD). RPD is calculated as the difference between the two measurements divided by the average of the two measurements.

RPD is calculated as follows:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2) \times 0.5} \times 100$$

where: RPD = Relative percent difference
$D_1$ = First sample value
$D_2$ = Second sample value (duplicate)

Acceptable RPD values for duplicates generated in the laboratory are usually 65 % to 135 %. Acceptable RPD values for field duplicates are usually 50 % to 150 %. The higher values for field duplicates reflect the difficulty in generating homogeneous duplicates in the field. Both field and laboratory duplicates were generated for this project and are discussed below.

### 3.1.3 Blanks

Several different types of “blank” samples may be generated to assist in evaluating general data usability. Periodic analysis of laboratory method blanks ensures there is no carryover of contaminants between samples because of residual contamination on the instrument or from contaminants introduced in the laboratory. Laboratory method blanks are typically laboratory pure water, acids or sand that have been processed through all of the procedures, materials, reagents and labware used for sample preparation and analysis. In addition to the laboratory blanks, DI water blanks and DI filtration blanks were generated in the field. Decontamination blanks were also generated to evaluate the sampling equipment decontamination process. Each of these types of blanks is discussed below.

### 3.1.4 Field QA/QC Samples

Field QA/QC samples were submitted to the laboratories and analysed to enable the following evaluations:

- Duplicate Samples: Duplicate surface water and groundwater samples were created in the field and submitted blind to the laboratories (see Table 3 for sample IDs). The results are used to evaluate the combined reproducibility of both the laboratory analyses and field sampling.

- Decontamination Blanks: After the surface and ground water sampling equipment was cleaned, DI water was poured over or pumped through the sampling equipment and collected for laboratory analysis (see Table 3 for sample IDs). Analyses of these samples were used to evaluate the adequacy of the sampling equipment decontamination procedure;

- Two certified water SRMs were sent blind to ALS (Sample IDs SMSR01.12 and SMSR02.12) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P282-740B (Metals). The Certificates of Analysis is provided in Appendix D of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.

- One water blank was collected of the DI water during the sampling event. An additional filtration blank using DI water was collected in order to try to quantify any contamination caused by the filtration procedure.

## 3.2 Results of Field QA/QC Samples

### 3.2.1 Duplicates

**Surface water and Groundwater Duplicates**

Four duplicate samples (one groundwater and three surface waters) were generated in the field and sent to ALS for analysis. Table 4 provides the results of the 15 dissolved metals for the four duplicate samples and the calculated RPD between each pair of samples. When a reported value was below the limit of detection (LOD), in calculating the RPD, the LOD value was then substituted with a value of half the LOD; e.g. with a reported value of <1 µg/L, the RPD formula uses a value of 0.5 µg/l for calculating the RPD. Note if both the original and duplicate results were less than the limit of detection then the RPD was zero.

The RPD values are typically very low (less than 10%) with several exceptions as described here. In groundwater duplicate sample SM GD01.12, the following values above 10% were calculated; zinc 19.7%, lead 13.7%, arsenic 19.9% and molybdenum 131%. While the test result for the main sample for molybdenum was below the LOD, with the calculated RPD being larger based on the RPD formula using a value of half the LOD for calculation, and while the RPD value would still be among those in the higher range even without an LOD difference, the value is still within the acceptable range of field duplicates samples (50 to 150%).

In surface water duplicate sample SM SD02.12, the following values above 10% were calculated; lead -34%, aluminium 140% and copper -71.8% (noting the main test sample values for these two parameters were less than the LOD, similarly as described above). In surface water duplicate sample SM SD03.12, the following values were calculated; iron -21.8%, arsenic 27.8%, and aluminium 16.2%. All RPD values for SM SD01.12 and SM SD03.12 were within the acceptable range of 50 to 150%. No RPD values in SM SD01.12 were above 10%.

Noting the values described above, it can be observed for the RPD values shown in Table 4 that all values are within the acceptable range, and the RPDs values for the key parameters were calculated as follows: dissolved aluminium (- 140% to 16.2%), dissolved arsenic -27.8% to 13.7%, dissolved cadmium (0% to 6.8%), dissolved copper (-71.8% to 1.2%), dissolved lead (-34% to 19.9%), dissolved nickel (-6.3% to 10.6%) and dissolved zinc (-1% to 19.7%).

The highest reported value of the duplicate pair is selected for interpretive use in Section 4 therefore providing a conservative evaluation.

Overall acceptable precision was observed, and the values can be used for the intended purposes (see Table 4).

**Table 4 Water Duplicate Pairs Reported Values (µg/l) and Calculated % RPD**

| Dissolved Metal | LOD µg/l | TMF 2 | SMGD 01.12 | % RPD | SW12 Shal | SMSD 01.12 | % RPD | SW7 Gar | SMSD 02.12 | % RPD | SW12 GORT D/S | SMSD 03.12 | % RPD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminium | <10 | <10 | <10 | 0 | 107 | 117 | -8.9 | <10 | 28.5 | -140 | 14 | 11.9 | 16.2 |
| Antimony | <1 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Arsenic | <0.5 | 5.29 | 4.6 | 13.7 | <0.5 | <0.5 | 0 | 0.795 | 0.726 | 9.1 | 0.685 | 0.906 | -27.8 |
| Barium | <0.2 | 629 | 600 | 4.7 | 349 | 349 | 0 | 95.5 | 92.6 | 3.1 | 165 | 167 | -1.2 |
| Cadmium | <0.08 | <0.08 | <0.08 | 0 | 0.287 | 0.268 | 6.8 | 0.49 | 0.46 | 6.3 | 1.12 | 1.12 | 0 |
| Chromium | <1 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Cobalt | <0.5 | 0.63 | 0.57 | 10.3 | 0.715 | 0.730 | -2.1 | <0.5 | <0.5 | 0 | <0.5 | <0.5 | 0 |
| Copper | <0.3 | <0.3 | <0.3 | 0 | 1.64 | 1.62 | 1.2 | <0.3 | 0.318 | -71.8 | 2.44 | 2.58 | -5.58 |
| Iron | <19 | 269 | 242 | 10.6 | <19 | <19 | 0 | <19 | <19 | 0 | 47.5 | 59.1 | -21.8 |
| Lead | 0.2 | 1.49 | 1.2 | 19.9 | 101 | 98 | 2.9 | 0.266 | 0.375 | -34.0 | 2.9 | 3.02 | -3.4 |
| Manganese | <3 | 1110 | 1050 | 5.6 | 232 | 233 | -0.4 | 35.6 | 35.5 | 0.3 | 47.6 | 48 | -0.8 |
| Molybdenum | <3 | 7.18 | <3 | 131 | <3 | <3 | 0 | <3 | <3 | 0 | <3 | <3 | 0 |
| Nickel | <0.04 | 0.69 | 0.6 | 10.6 | 3.01 | 3.06 | -1.6 | 1.68 | 1.79 | -6.3 | 2.5 | 2.66 | -5.4 |
| Vanadium | <1 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Zinc | <1 | 4.2 | 3.48 | 19.7 | 50 | 46.1 | 8.1 | 177 | 173 | 2.3 | 294 | 297 | -1.0 |

**Notes: Bold** indicates an exceedance in the Duplicate RPD acceptance criteria

### 3.2.2 Decontamination Blanks

**Surface Water and Groundwater**

Two decontamination blanks were created by pouring DI water over (for surface water) and pumping DI water through (groundwater) the sampling equipment after decontamination and these were sent to ALS for analysis. Table 5 provides the results of the 15 metals for the decontamination blank samples, the DI water blank and filtration blank samples and associated laboratory method blank samples. The majority of reported concentrations were below the limits of detection. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. Limits of detection ranged from 1 µg/l to 19 µg/l.

In the filtered blank water sample (WB 01.12), nickel and zinc were detected at concentrations of 1.4 µg/l and 3.22 µg/l (with LODs of <0.4 µg/land <1 µg/l respectively). In the unfiltered blank water sample (WB 02.12), the zinc concentration was 2.07 µg/l (LOD <1 µg/l) and nickel was <0.4 µg/l.

**Table 5 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l)**

| Sample Description<br>Dissolved Metal | LOD (µg/l) | Filtration Blank WB01.12 (µg/l) | Water Blank WB02.12 (µg/l) | Labor-atory Method Blank (µg/l) | Decon blank SMDB01.12 (µg/l) | Labor-atory Method Blank (µg/l) | Decon blank SMDB02.12 (µg/l) | Labor-atory Method Blank (µg/l) |
|---|---|---|---|---|---|---|---|---|
| | ***Sample Batch:*** | 190213-62 | 190213-62 | | 190222-52 | | 190222-52 | |
| Aluminium | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| Antimony | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Arsenic | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Barium | <0.2 | <0.2 | <0.2 | <0.2 | **0.42** | <0.2 | **0.49** | <0.2 |
| Cadmium | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 |
| Chromium | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Cobalt | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Copper | <0.3 | <0.3 | <0.3 | <0.3 | **1.39** | <0.3 | <0.3 | <0.3 |
| Iron | <19 | <19 | <19 | <19 | <19 | <19 | <19 | <19 |
| Lead | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | **0.41** | <0.2 |
| Manganese | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Molybdenum | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Nickel | <0.4 | **1.4** | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| Vanadium | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Zinc | <1 | **3.22** | **2.07** | <1 | **2.34** | <1 | **5.09** | <1 |

Notes: **Bold** indicates a detection.

Decontamination blank samples were collected after field equipment decontamination, a groundwater decon blank sample (SM DB01.12) and a surface water decon blank sample (SM DB02.12). In the groundwater blank sample, barium concentration was 0.42 µg/l (LOD <0.2 µg/l), copper concentration was 1.39 µg/l (LOD <0.3 µg/l), and zinc concentration was 2.34 µg/l (LOD <1 µg/l). In the surface water blank sample, the barium concentration was 0.49 µg/l (LOD <0.2 µg/l), lead concentration was 0.41 µg/l (LOD <0.2 µg/l) and zinc concentration was 5.09 µg/l (LOD <1 µg/l).

The zinc concentration (2.07 µg/l) in the water blank was above the LOD of 1 µg/l in the deionized water supplied by VWR (Table 3). The other samples had similar concentrations as a result of the zinc in the deionized water. During the previous sampling round in September 2018, 1.03 µg/l of zinc was detected in the deionized water. The supplier (VWR) will be contacted concerning the zinc and new deionized water will be purchased. The zinc concentrations detected were very small and near the detection limit. Overall, the site decontamination procedure was acceptable and the data can be used for the intended purposes.

### 3.2.3 Standard Reference Materials

#### SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.12 and SMSR02.12) to evaluate laboratory accuracy. The ALS laboratory reports are provided in Appendix D of the Data Report. Table 6 summarises the SRM results and provides the calculated %R values for the 15 requested metals.

Reported values for dissolved aluminium, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel and zinc are in good agreement with the certified value (%R ranged from 85 to 107%). One of the reported values for vanadium (89%) was slightly outside the acceptable range; however, the corresponding reported values for the second SRM were within acceptable ranges and therefore the interpretation of the results is not affected.

Overall, the laboratory accuracy was acceptable and the data can be used for the intended purposes.

**Table 6 Water SRM Reported Values (µg/l) and Calculated % R**

| Dissolved Metal | Certified Value (µg/l) | Acceptance Limits | | 18349956 SMSR01.12 (µg/l) | % R | 18329587 SMSR02.12 (µg/l) | % R |
|---|---|---|---|---|---|---|---|
| | | Lower (%) | Upper (%) | | | | |
| Aluminium | 1,630 | 88 | 113 | 1,700 | 104 | 1,700 | 104 |
| Antimony | 305 | 87 | 110 | 288 | 94 | 287 | 94 |
| Arsenic | 586 | 87 | 110 | 534 | 91 | 564 | 96 |
| Barium | 1,620 | 91 | 108 | 1,520 | 94 | 1,740 | 107 |
| Cadmium | 121 | 89 | 107 | 118 | 98 | 130 | 107 |
| Chromium | 596 | 91 | 109 | 602 | 101 | 621 | 104 |
| Cobalt | 714 | 93 | 111 | 711 | 100 | 680 | 95 |
| Copper | 525 | 91 | 109 | 572 | 109 | 551 | 105 |
| Iron | 1,380 | 91 | 111 | 1,420 | 103 | 1,440 | 104 |
| Lead | 755 | 90 | 110 | 833 | 110 | 780 | 103 |
| Manganese | 777 | 93 | 110 | 794 | 102 | 820 | 106 |
| Molybdenum | 115 | 90 | 108 | 111 | 97 | 111 | 97 |
| Nickel | 1200 | 91 | 109 | 1,190 | 99 | 1,190 | 99 |
| Vanadium | 1,600 | 91 | 107 | 1,420 | **89** | 1,700 | 106 |
| Zinc | 1,160 | 91 | 110 | 1,240 | 107 | 1,260 | 109 |

Notes:
**Bold** indicates an exceedance in acceptance limits

# 3.3 Laboratory QA/QC Samples

## 3.3.1 ALS Laboratories

ALS conducts a range of activities associated with both quality control and assessment to assure the quality of test results.  Specifically, ALS conduct the following analyses on water samples:

- Analytical Quality Control Samples (AQC) including, Certified Reference Material (CRM), Internal Reference Material (IRM) and Matrix spiked material. For batch sizes of 20 samples or less, a minimum of one AQC and for batches of greater than 20 samples, one AQC every additional twenty samples or part thereof. They are introduced into the sample batch on a random basis where possible. They are prepared at the same time as the rest of the batch and by the same person who prepares the batch;
- Process Blanks: A process blank was included with each batch of samples. The blanks are matrix matched where possible and were taken through the entire analytical system;
- Instrument Blanks: An instrument blank was run to check for any contamination within the instrument;
- Independent Check Standard: An independent check standard was included with every instrumental run of samples. This standard is prepared from a different standard than the calibration standards and is used as a check on the validity of the calibration standards. The acceptance criteria for this standard was method specific; and
- Replicate samples (samples tested more than once using the same method) were included at the same frequency as the AQCs.

All ALS laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding time (7 days) was exceeded by two to three days, dependent on the sample delivery group, for Total Organic Carbon (TOC) for all but one of the surface water samples scheduled to be tested for TOC and it is recommended that a faster turnaround is specified for this parameter in future sampling rounds. The holding time is conservative and the delay does not likely impact the results significantly, which are considered acceptable for assessment.

The laboratory provided the associated analytical quality control samples (AQC) data associated with the water samples. The percentage recovery results for the AQC samples that were performed with the regular environmental samples were checked against the individual lower control and upper control limits. ALS advised that the AQC samples have two limits, a warning limit and a failure limit. Tests which exceed the failure limit are immediately re-run but tests that exceed the warning limit can still be reported. The test only fails automatically if there are multiple warning limit exceedances. Laboratory analysts check the individual cases where the warning limit is exceeded and report the results if they are satisfied with all other factors involved. The laboratory quality control checks indicate that all results are acceptable for their intended use. The results of method blanks were also assessed as described in Section 3.2.2 above.

The laboratory also provided the results of the associated analytical quality control samples which included certified reference materials, internal reference materials, process blanks and replicates. The laboratory quality control checks indicate that all results are acceptable for their intended use.

## 3.4 Summary of Data Checks

### 3.4.1 Field Physico-chemical Versus Laboratory Data

Table 7 summarises the field and laboratory results for pH and provides the calculated %RPD values between the two results. Note that pH measurements in the laboratory were taken from the unpreserved sample and therefore the results do not affect the results of samples from preserved bottles (e.g. metals).

Field pH is more representative of actual conditions and is used for interpretive purposes. The RPDs between laboratory and field pH were excellent. Only four of the %RPD values were above 10%; three cases where the field pH was lower than the laboratory pH, 7.06 vs 7.83 (10.34%), 6.15 vs 6.99 (12.79%) and 4.26 vs 5.09 (17.75%), and one case where the field pH was higher, 8.32 vs 7.47 (10.77%). All of these values were below 20% and are considered acceptable. The remaining values were all below 10% RPD. Recordings of pH in the field are typically lower than the laboratory due to some carbon dioxide degassing during transport or within the laboratory itself. Overall, the %RPDs between the field and laboratory data are considered satisfactory.

**Table 7 Field Physico-chemical Data and Laboratory Reported Values and Calculated % RPD**

| | pH<br>Lab | pH<br>Field | % RPD |
|---|---|---|---|
| Sample Description | (pH Units) | | |
| SW18-GORT | 7.92 | 7.61 | -3.99 |
| SW19-GORT | 7.87 | 7.89 | 0.25 |
| SW17-GORT | 7.83 | 7.06 | -10.34 |
| SW10-GORT US | 7.99 | 7.99 | 0.00 |
| SW10-GORT DISCHARGE | 7.68 | 7.50 | -2.37 |
| SW10-GORT DS | 7.98 | 8.02 | 0.50 |
| GORT-TMF-SEEP | 3.18 | 3.24 | 1.87 |
| SW12-GORT DISCHARGE | 7.5 | 6.95 | -7.61 |
| SW12-GORT DS | 7.95 | 7.94 | -0.13 |
| SW14-GORT | 7.99 | 7.95 | -0.50 |
| DS-GORT | 7.98 | 7.94 | -0.50 |
| SW6-MAG | 7.54 | 7.63 | 1.19 |
| US-SHAL | 7.87 | 8.11 | 3.00 |
| SW4-SHAL | 6.95 | 6.60 | -5.17 |
| SW5-SHAL | 6.93 | 6.86 | -1.02 |
| SW6-SHAL | 6.88 | 6.35 | -8.01 |
| SW15-SHAL | 6.99 | 6.15 | -12.79 |
| SW9-SHAL | 7.41 | 7.67 | 3.45 |
| SW12-SHAL | 5.09 | 4.26 | -17.75 |
| SW13-SHAL | 7.7 | 7.63 | -0.91 |
| SW1-SHAL | 7.56 | 7.80 | 3.13 |
| DS-SHAL | 7.56 | 7.22 | -4.60 |
| DS-GORTEENADHIA | 7.47 | 8.32 | 10.77 |
| SW1-GAR | Dry | Dry | Dry |
| SW5-GAR | 7.57 | 6.99 | -7.97 |
| SW12-GAR | 7.61 | 7.74 | 1.69 |
| SW10-GAR | 7.85 | 8.13 | 3.50 |
| SW7-GAR | 7.94 | 7.79 | -1.91 |
| SW3-GAR | 7.76 | 8.03 | 3.42 |
| SW1-SM | 7.77 | 7.61 | -2.08 |
| SW3-SM | 7.81 | 7.73 | -1.03 |
| SW2-SM-SOUTH | 7.51 | 7.15 | -4.91 |
| SW5-SM | 7.8 | 7.73 | -0.90 |
| SW6-SM | 8.09 | 7.90 | -2.38 |
| SW4-SM-GA | 8.07 | 8.00 | -0.87 |
| TMF1 | 7.77 | 7.40 | -4.88 |
| TMF2 | 7.51 | 7.03 | -6.60 |

# Section 4

# Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater and surface water and a comparison of the analytical results against selected assessment criteria. An evaluation of measured concentrations against bioavailable EQS for key parameters is also provided. An analysis of loading and time trends is provided in Section 5 and groundwater levels are discussed in Section 6.

All the laboratory reports and analytical data are contained in Appendix D of the Data Report.

## 4.1 Statistical Summary of Analytical Results

### 4.1.1 Groundwater Sample Results

Table 8 provides a summary of the reported results of the two groundwater samples. Included in the table are the minimum, maximum and mean dissolved metal concentrations. Where one reported value was below the detection limit, the value was substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

**Table 8 Summary of Dissolved Metal Concentrations in Groundwater**

| Dissolved Metal | LOD (µg/l) | Number | Number of Detections | Minimum (µg/l) | Maximum (µg/l) | Mean (µg/l) |
|---|---|---|---|---|---|---|
| Aluminium | <10 | 2 | 0 | <10 | <10 | <10 |
| Antimony | <1 | 2 | 0 | <1 | <1 | <1 |
| Arsenic | <0.5 | 2 | 2 | 2.3 | 5.3 | 3.8 |
| Barium | <0.2 | 2 | 2 | 151 | 629 | 390 |
| Cadmium | <0.08 | 2 | 0 | <0.08 | <0.08 | <0.08 |
| Chromium | <1 | 2 | 0 | <1 | <1 | <1 |
| Cobalt | <0.5 | 2 | 1 | <0.5 | 0.63 | 0.44 * |
| Copper | <0.3 | 2 | 0 | <0.3 | <0.3 | <0.3 |
| Iron | <19 | 2 | 2 | 156 | 269 | 213 |
| Lead | <0.2 | 2 | 1 | <0.2 | 1.49 | 0.80 * |
| Manganese | <3 | 2 | 2 | 96 | 1110 | 603 |
| Molybdenum | <3 | 2 | 1 | <3 | 7.18 | 4.34 * |
| Nickel | <0.4 | 2 | 2 | 0.48 | 0.69 | 0.58 |
| Vanadium | <1 | 2 | 0 | <1 | <1 | <1 |
| Zinc | <1 | 2 | 2 | 2.1 | 4.2 | 3.2 |

Notes: ***** Where one value is <LOD, half the LOD is used for calculations

The concentrations of dissolved arsenic, cobalt, lead, molybdenum, nickel, zinc and barium were higher in TMF2 compared to TMF1, as were iron and manganese (not of human health concern).

### 4.1.2 Surface Water Sample Results

Samples were collected for two major categories. The first comprised of mine adit discharges and discharges from wetlands as well as some drainage ditches.

Table 9 provides a summary of the results of the 16 discharge/ drainage samples, and Table 10 provides a summary of the results of the 18 river and stream samples.

## Discharges and Drainage

### Table 9 Summary of Dissolved Metal Concentrations in Discharges and Drainage

| Dissolved Metal | LOD (µg/l) | Number | Number of Detections | Minimum (µg/l) | Maximum (µg/l) | Mean (µg/l) | SDEV |
|---|---|---|---|---|---|---|---|
| Aluminium | <10 | 16 | 4 | <10 | 963 | 79 * | 237 * |
| Antimony | <1 | 16 | 4 | <1 | 1.62 | 0.72 * | 0.41 * |
| Arsenic | <0.5 | 16 | 11 | <0.5 | 27.8 | 2.5 * | 6.8 * |
| Barium | <0.2 | 16 | 16 | 9.0 | 411 | 146 | 138 |
| Cadmium | <0.08 | 16 | 16 | 0.10 | 118 | 16 | 30 |
| Chromium | <1 | 16 | 1 | <1 | 2.79 | 0.6 * | N/A |
| Cobalt | <0.5 | 16 | 9 | <0.5 | 16 | 2.3 * | 4.0 * |
| Copper | <0.3 | 16 | 15 | <0.3 | 269 | 21 * | 66 * |
| Iron | <19 | 16 | 5 | <19 | 59400 | 3735 * | 14844 * |
| Lead | <0.2 | 16 | 15 | <0.2 | 406 | 41 * | 101 * |
| Manganese | <3 | 16 | 15 | <3 | 1920 | 293 * | 462 * |
| Molybdenum | <3 | 16 | 0 | <3 | <3 | <3 | N/A |
| Nickel | <0.4 | 16 | 16 | 1.41 | 167 | 29 * | 42 * |
| Vanadium | <1 | 16 | 0 | <1 | <1 | <1 | N/A |
| Zinc | <1 | 16 | 16 | 35 | 35000 | 5504 | 9009 |

Notes: * Where one value is <LOD, half the LOD is used for calculations. Where 1 or 2 detections only, there is no calculation of standard deviation.

## Rivers and Streams

### Table 10 Summary of Dissolved Metal Concentrations in Rivers and Streams

| Dissolved Metal | LOD (µg/l) | Number | Number of Detections | Minimum (µg/l) | Maximum (µg/l) | Mean (µg/l) | SDEV |
|---|---|---|---|---|---|---|---|
| Aluminium | <10 | 18 | 12 | <10 | 26 | 13 * | 6.6 * |
| Antimony | <1 | 18 | 2 | <1 | 1.2 | 0.57 * | N/A |
| Arsenic | <0.5 | 18 | 11 | <0.5 | 1.6 | 0.66 * | 0.41 * |
| Barium | <0.2 | 18 | 18 | 43 | 246 | 139 | 68 |
| Cadmium | <0.08 | 18 | 16 | <0.08 | 38 | 5.4 * | 10.9 * |
| Chromium | <1 | 18 | 0 | <1 | <1 | <1 | N/A |
| Cobalt | <0.5 | 18 | 6 | <0.5 | 2.9 | 0.69 * | 0.75 * |
| Copper | <0.3 | 18 | 16 | <0.3 | 17.2 | 4.6 * | 4.8 * |
| Iron | <19 | 18 | 14 | <19 | 66 | 38 * | 20 * |
| Lead | <0.2 | 18 | 17 | <0.2 | 233 | 28 * | 65 * |
| Manganese | <3 | 18 | 17 | 1.5 | 493 | 77 | 119 |
| Molybdenum | <3 | 18 | 2 | <3 | 8 | 2.0 * | N/A |
| Nickel | <0.4 | 18 | 18 | 0.55 | 31 | 6.9 | 9.0 |
| Vanadium | <1 | 18 | 0 | <1 | <1 | <1 | N/A |
| Zinc | <1 | 18 | 18 | 3.3 | 8150 | 1264 | 2380 |

Notes: * Where one value is <LOD, half the LOD is used for. Where 1 or 2 detections only, there is no calculation of standard deviation.

Included in Table 9 and Table 10 are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metal concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection for calculation of mean values and standard deviations. The highest reported value of the field duplicate pair was used where applicable. Where the set of results for a parameter had only 1 or 2 positive results detected, the standard deviation was not calculated.

Within the drainage / discharges monitoring locations, the sample from Gort-TMF-Seep had the highest concentrations of aluminium (963 µg/l), arsenic (27.8 µg/l), cadmium (118 µg/l), chromium (2.79 µg/l), cobalt (16.2 µg/l), copper(269 µg/l), nickel (167 µg/l) and zinc (35,000 µg/l) as well as iron (59,400) and manganese (1,920 µg/l) (not a health concern). The highest concentration of antimony (1.62 µg/l) was from the sample at SW5-Gar. The sample from SW6-Shal had the highest concentration of lead (406 µg/l) within the drainage network.

The rivers / stream monitoring locations SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and had notably lower concentrations of Zinc (3.3 and 7.99 µg/l, respectively) than the rest of the rivers and streams sampled in the mining area. SW1-SM and SW17-Gort had background concentrations of barium of 55.9 µg/l and 225 µg/l, respectively.

Within the rivers and streams, the highest concentration of copper (17.2 µg/l) was found at DS-Gorteenadiha. Several of the highest concentration of metals in the rivers / streams were detected in samples from the Shallee mining area. SW9-Shal, located downstream of the field shaft had the highest concentration of arsenic (0.93 µg/l), copper (12.7 µg/l) and lead (233 µg/l), while SW1-Shal had the highest concentration of aluminium (25.5 µg/l). The upstream location, US-Shallee, had the highest concentrations of cadmium (37.8 µg/l), cobalt (2.86 µg/l), nickel (30.8 µg/l) and zinc (8,150 µg/l).

## 4.2 Assessment Criteria

### 4.2.1 Groundwater and Surface Water Assessment Criteria

To assess the analytical results of the groundwater and surface water samples, assessment criteria have been selected to screen reported values against both ecological and human health. To assess ecological criteria, the environmental quality standards (EQS) from the European Communities Environmental Objectives (Surface Water) Regulations, 2009 (S.I. 272 of 2009) and amendments were utilised, as shown in Table 11. These include standards for physico-chemical conditions supporting the biological elements, general conditions and standards for specific pollutants. In the case of metals, the EQS refers to the dissolved concentration. Compliance with the standards in the surface water regulations is either based on an annual average (AA), a maximum allowable concentration (MAC) or a 95-percentile standard. The MAC or 95 percentile (95%-ile) was selected as the assessment criteria, where possible, because it is the most appropriate threshold when assessing only one value; however, the AA was used in the absence of the MAC or 95%-ile. Additionally, the AA was selected for lead and nickel to assess these parameters against the bioavailable EQS (S.I. No. 386 of 2015). To supplement the Irish legislation, screening criteria were selected from Oak Ridge National Laboratory (Suter and Tsao, 1996) for certain metals including aluminium, barium, cobalt and manganese (Table 11).

For hardness-dependent metals (copper, zinc and cadmium), the hardness is considered when selecting the appropriate EQS value. The average hardness in the rivers and streams in the Silvermines mining is 165 mg/l $CaCO_3$ (CDM Smith, 2013) and therefore the EQSs for hardness greater than 100 mg/l were selected, as shown in Table 11. The appropriate ecological assessment criteria are highlighted in bold in Table 11.

To assess the potential human health risks, the Drinking Water Regulations, 2007 (S.I. No. 106 of 2007) and amendments were utilised and are listed in Table 112. These values are the maximum permissible values for a drinking water source. In the case of metals, the standards are for total metals, however they apply post-treatment (including filtration) and therefore the dissolved portion is used in the assessment in Section 4.

The current Drinking Water Regulations (2007) set limit values for iron and manganese but they are categorised as Indicator Parameters. Indicator Parameters are not considered to be important health criteria but rather exceedances can affect the aesthetic quality of drinking water supplies. Iron and manganese are commonly found above the drinking water limit in groundwaters in Ireland and some surface waters are intermittently above the standard.

The two main receptors of groundwater at Gortmore TMF are surface water bodies and the groundwater resource as a drinking water supply. Therefore, to assess the potential impact of the groundwater quality on relevant groundwater receptors, the same standards and guidelines as mentioned for surface water were utilised for screening purposes (Table 12).

**Table 11 Surface Water and Groundwater Assessment Criteria for Biological Elements**

| Parameter | Unit | AA | MAC (or 95%-ile) | Source | Description |
|---|---|---|---|---|---|
| Ammonia as N | mg/l | 0.065 | **0.14** | S.I. No. 272 of 2009 | Good status |
| pH | pH units | | **> 4.5** and < 9.0 | S.I. No. 272 of 2009 | Within range |
| Dissolved Oxygen | % Sat | | **80** to **120** | S.I. No. 272 of 2009 | Within range |
| Arsenic | µg/l | **25** | - | S.I. No. 272 of 2009 | |
| Cadmium | µg/l | ≤0.08 (Class 1)<br>0.08 (Class 2)<br>0.09 (Class 3)<br>0.15 (Class 4)<br>0.25 (Class 5) | ≤0.45 (Class 1)<br>0.45 (Class 2)<br>0.6 (Class 3)<br>**0.9** (Class 4)<br>1.5 (Class 5) | S.I. No. 386 of 2015 | Hardness measured in mg/l CaCO3 (Class 1: <40 mg CaCO3/l, Class 2: 40 to <50 mg CaCO3/l, Class 3: 50 to <100 mg CaCO3/l,<br>Class 4: 100 to <200 mg CaCO3/l<br>and Class5: ≥200 mg CaCO3/l) |
| Chromium | µg/l | **3.4** | | S.I. No. 272 of 2009 | |
| Copper | µg/l | 5 or **30** | - | S.I. No. 272 of 2009 | 5 µg/l applies where the water hardness measured in mg/l CaCO3 is ≤ 100;<br>30 µg/l applies where the water hardness > 100 mg/l CaCO3. |
| Lead | µg/l | **1.2** | 14 | S.I. No. 386 of 2015 | Bioavailable EQS |
| Nickel | µg/l | **4** | 34 | S.I. No. 386 of 2015 | Bioavailable EQS |
| Zinc | µg/l | 8 or 50 or **100** | - | S.I. No. 272 of 2009 | 8 µg/l for water hardness with annual average values ≤ 10 mg/l CaCO3;<br>50 µg/l for water hardness >10 mg/l CaCO3 and ≤ 100 mg/l CaCO3; and<br>100 µg/l elsewhere. |

| Parameter | Unit | AA | MAC (or 95%-ile) | Source | Description |
|---|---|---|---|---|---|
| **Supplementary standards:** | | | | | |
| Aluminium | µg/l | - | **1900** | Oak Ridge National Laboratory | Invertebrates only - Lowest Chronic Value for Daphnids |
| Barium | µg/l | - | **4** | Oak Ridge National Laboratory | Invertebrates and Salmon fish |
| Cobalt | µg/l | - | **5.1** | Oak Ridge National Laboratory | Invertebrates only - Lowest Chronic Value for Daphnids |
| Manganese | µg/l | - | **1,100** | Oak Ridge National Laboratory | Invertebrates only - Lowest Chronic Value for Daphnids |

**Notes: Bold** indicates the selected assessment criteria for ecological health

**Table 12 Surface Water and Groundwater Assessment Criteria for Drinking Water**

| Parameter | Unit | Parametric value |
|---|---|---|
| pH | pH units | >6.5 to <9.5 |
| Conductivity | mS/cm | 2.5 |
| Ammonium | mg/l | 0.3 |
| Sulphate | mg/l | 250 |
| Aluminium | µg/l | 200 |
| Antimony | µg/l | 5 |
| Arsenic | µg/l | 10 |
| Cadmium | µg/l | 5 |
| Chromium | µg/l | 50 |
| Copper | µg/l | 2,000 |
| Iron | µg/l | 200 |
| Lead | µg/l | 10 |
| Manganese | µg/l | 50 |
| Nickel | µg/l | 20 |

### 4.2.2 Livestock Drinking Water Assessment Criteria

There are currently no Irish or European guidelines for the quality of drinking water for livestock. Recommendations for levels of toxic substances in drinking water for livestock are available from the US National Academy of Sciences (1972). Table 13 summarises the recommended levels for metals where limits have been established, and for total dissolved solids and sulphate.

**Table 13 Assessment Criteria for Livestock Drinking Water Quality**

| Parameter | Unit | Parametric Value | Source | Comment |
|---|---|---|---|---|
| Aluminium | µg/l | 5,000 | NAS 1972 | |
| Arsenic | µg/l | 200 | NAS 1972 | |
| Cadmium | µg/l | 50 | NAS 1972 | |
| Chromium | µg/l | 1,000 | NAS 1972 | |
| Cobalt | µg/l | 1,000 | NAS 1972 | |
| Copper | µg/l | 500 | NAS 1972 | |
| Lead | µg/l | 100 | NAS 1972 | Lead is accumulative, and problems may begin at threshold value of 0.05 mg/l. (Soltanpour and Raley, 2007) |

| Parameter | Unit | Parametric Value | Source | Comment |
|---|---|---|---|---|
| Vanadium | µg/l | 100 | NAS 1972 | |
| Zinc | µg/l | 24,000 | NAS 1972 | |
| Sulphate | mg/l | 500 | Higgins *et. al.* 2008 | <500 mg/l for calves<br><1,000 mg/l for adults |

## 4.3 Comparison to Assessment Criteria

A comparison of the groundwater and surface water analytical results was performed against the relevant assessment criteria for ecological and human health given in Section 4.2. Table B-1 in **Appendix B** highlights the exceedances of the ecological and human health assessment criteria. Where there was an exceedance of the ecological assessment criteria, the result is highlighted in purple; for an exceedance of the human health criteria the result is highlighted in blue. In some cases, the reported values exceed both the ecological and human health criteria and these results are highlighted in pink.

A comparison of the surface water analytical results was made against the relevant assessment criteria for livestock drinking water as given in Section 4.2. Table B-2 in **Appendix B** provides results for all samples (both discharges and surface waters/rivers) and highlights the exceedances of the assessment criteria. Where there was an exceedance of the livestock assessment criteria, the result is highlighted in green.

### 4.3.1 Groundwater Assessment

The groundwater pH was within the acceptable ranges for ecological (4.5 to 9 pH units) and drinking water (6.5 to 9.5 pH units) criteria, with an average of pH 7.2. The specific conductance ranged from 0.45 to 0.49 mS/cm, which was well below the threshold for drinking water of 2.5 mS/cm.

Sulphate was within normal ranges, with values of 3.3 mg/l (TMF2) to 19.7 mg/l (TMF1), which was well below the criteria for drinking water of 250 mg/l. Ammonia was below the limit of detection in both monitoring wells. For barium and manganese, concentrations were higher in TMF2, 629 µg/l for barium and 1,110 µg/l for manganese versus 151 µg/l and 96.3 µg/l respectively for TMF1. Dissolved zinc concentrations were 2.09 µg/l TMF1 and 4.24 µg/l in TMF2.

### 4.3.2 Surface Water Assessment

A total of thirty four locations were sampled for chemical analyses, including discharges / drainage locations (16 samples) and river / stream locations (18 samples). Full details of the results are given in **Appendix B,** with locations identified in the table as being either drainage or river / stream.

In addition to detailed results given in **Appendix B,** Table 14 provides a summary, for the river/stream locations only in the different mining areas, of a number of key parameters (ammonia, sulphate) and dissolved metals (cadmium, lead, manganese, nickel, zinc) which exceeded the relevant ecological and drinking water assessment criteria. Footnotes in both tables (Tables B-1 and Table 14) describe which assessment criterion is colour highlighted within the table in each case. For the sampling locations refer to the maps in **Appendix A**.

The field pH from these sampling locations in the Silvermines mining area ranged from 3.24 to 8.32 with a median of 7.73. Four of the field pH values were outside the pH range (pH 6.5 to 9.5) given in the Drinking Water assessment criteria (SI 106 of 2017), the field pH at SW12-Shal (pH 4.26), pH at SW6-Shal (pH 6.35), pH at SW15-Shal (pH 6.15) and pH at Gort-TMF-Seep (pH 3.24).

The conductivity at all locations, including discharges, ranged from 0.057 mS/cm to 3.269 mS/cm with an average value of 0.561 mS/cm and a median of 0.484 mS/cm; the highest conductivity was at the discharge location Gort-TMF-Seep (3.269 mS/cm) and the highest conductivity in the river/ stream channels was at location SW3-Gar (0.944 mS/cm), (Table B-1 in **Appendix B**).

The dissolved oxygen values cited in S.I. No. 272 of 2009 Environmental Objectives Surface Water Regulations for ecological health give a range from 80 to 120%; four river / stream sampling locations (marked river/ stream in Table B-1 in **Appendix B**) were not within the range (SW12-GORT Discharge 46.8 %, SW6-Shal 65.1%, SW5-Gar 58.3 % and SW2-SM-South 58.9 %). The remaining locations were within the expected range. At the river and stream locations, other than those exceptions listed above, there was an average dissolved oxygen saturation value of 98%.

**Table 14 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria**

| Area | Sample Description | Sample Location | Date Sampled Units | Ammoniacal Nitrogen as N mg/l | Sulphate mg/l | Cadmium (diss.filt) µg/l | Lead (diss.filt) µg/l | Manganese (diss.filt) µg/l | Nickel (diss.filt) µg/l | Zinc (diss.filt) µg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Ecological Criteria** | **0.14** | - | **0.9** | **1.2** | **1100** | **4** | **100** |
| | | | **Human Health Criteria** | **0.3** | **250** | **5** | **10** | **50** | **20** | - |
| Gortmore | SW17-GORT | Upstream | 20/02/2019 | 0.1 | 30.3 | 0.04 | 1.6 | 35 | 0.969 | 7.99 |
| | SW12-GORT-DS | Downstream (TMF) | 20/02/2019 | 0.1 | 64.9 | 1.12 | 3.02 | 48 | 2.66 | 297 |
| | SW14-GORT | Downstream (TMF and Yellow River) | 20/02/2019 | 0.1 | 51.3 | 1.03 | 2.75 | 41 | 2.57 | 253 |
| | DS-Gort | Downstream (TMF and Yellow River) | 20/02/2019 | 0.1 | 52.8 | 0.852 | 2.46 | 41.8 | 2.19 | 234 |
| Magcobar | SW6-Mag | Downstream | 19/02/2019 | 0.1 | 211 | 1.81 | 0.1 | 57.5 | 9.74 | 893 |
| Shallee | US SHAL | Downstream of SW3-GAR | 19/02/2019 | 0.1 | 368 | 37.8 | 5.82 | 493 | 30.8 | 8150 |
| Shallee | SW4-SHAL | Upstream | 18/02/2019 | 0.1 | 11.3 | 0.793 | 55.4 | 43.9 | 4.84 | 80.4 |
| | SW5-SHAL | DS (drum dump) | 18/02/2019 | 0 | 63.2 | 16.3 | 21.1 | 461 | 38.7 | 5220 |
| | SW9-SHAL | Downstream | 18/02/2019 | 0.1 | 26.7 | 3.39 | 233 | 72.3 | 12.6 | 944 |
| | SW1-SHAL | Downstream (all) | 18/02/2019 | 0.1 | 29 | 2.86 | 171 | 77.8 | 11.2 | 9 |
| Garryard/ Shallee | DS SHAL | Downstream of SW3-GAR and SW1-SHAL | 19/02/2019 | 0.1 | 149 | 15.1 | 28 | 217 | 14.3 | 3420 |
| GTD | DS-Gorteenadiha | Downstream of GTD | 18/02/2019 | 0.1 | 16.3 | 1.05 | 28.6 | 26.4 | 3.06 | 173 |
| Garryard | SW1-GAR | Upstream | 19/02/2019 | [1] | [1] | [1] | [1] | [1] | [1] | [1] |
| | SW3-GAR | Downstream (all) | 19/02/2019 | 0.201 | 325 | 29.1 | 16 | 183 | 25.7 | 6650 |
| Ballygown | SW1-SM | Upstream | 19/02/2019 | 0.1 | 7.8 | 0.04 | 0.695 | 5.1 | 0.546 | 3.33 |
| | SW3-SM | DS (workings & Adits) | 19/02/2019 | 0.1 | 9.4 | 0.281 | 1.68 | 1.5 | 0.887 | 96.1 |
| | SW5-SM | DS (workings & Adits) | 19/02/2019 | 3.09 | 21.2 | 0.465 | 1.32 | 7.45 | 1.34 | 216 |
| | SW6-SM | DS (workings & Adits) | 19/02/2019 | 0.1 | 13.1 | 0.641 | 1.79 | 6.6 | 1.31 | 258 |
| | SW4-SM-GA | Downstream (all incl. tailings deposit) | 19/02/2019 | 0.1 | 13.9 | 0.564 | 1.72 | 5.99 | 1.31 | 242 |

Notes: [1] No flow and no sample during monitoring round

xx Exceeds Ecological Assessment Criteria

xx Exceeds Drinking Water Assessment /Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Less than the Limit of Detection (LOD) - Value given is 0.5 of LOD

Metals are dissolved

Ammonia was detected in one of the discharges; Gort-TMF-Seep (0.68 mg/l N) (Table B-1 in **Appendix B**) and in two of the stream samples SW5-Gar (3.09 mg/l N) and SW3-Gar (0.2 mg/l N). The ecological assessment criteria for Ammonia is 0.14 mg/l as N and each of the samples with Ammonia detected exceeded the threshold. Ammonia was below the limit of detection in samples from the remaining river and stream locations and the remaining discharges/ drainage locations.

Sulphate exceeded the criteria for drinking water (250 mg/l) at the wetland discharges in the Gortmore area at five locations, with the values over 250 mg/l ranging from 462 mg/l (SW19-Gort) to 2,490 mg/l (Gort-TMF-Seep) (Table B-1 in **Appendix B**). Within the Garryard area, three discharges exceeded the sulphate threshold with the values ranging from 284 to 404 mg/l, and one of the river locations, downstream location SW3-GAR, exceeded the threshold with a sulphate concentration of 325 mg/l. Within the river locations in the Shallee area, the sulphate concentration exceeded the threshold at US-Shal (284 mg/l).

### Dissolved Metals Assessment

As noted above, Table 14 provides a summary for a number of key parameters and dissolved metals, for the river/stream locations only, see the Table B-1 in **Appendix B** for the full listing of all parameters.

Vanadium was not detected in samples collected, and antimony, chromium, and molybdenum were detected in a small number of samples, and below their respective assessment criteria.

Dissolved arsenic (Table B-1 in **Appendix B**) was detected at twenty two of the sampling locations, with a median value of 0.74 µg/l. The discharge from Gort-TMF-Seep had an arsenic concentration of 27.8 µg/l and exceeded both the ecological assessment criteria (25 µg/l) and human health criteria (10 µg/l); there were no arsenic exceedances of either the ecological assessment criteria or human health criteria at the remaining locations.

Further to the exceedances described above, there were exceedances above the assessment criteria for barium, cadmium, lead, nickel and zinc, as well as for manganese, not a human health concern, at a number of locations described here further. Results for barium testing are given in the Table B-1 in **Appendix B**. The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with a median value of 148 µg/l, with elevated values at upstream locations SW10-Gort Upstream (164 µg/l) and US-Shal (48 µg/l), as well as elevated concentrations at other locations SW4-Shal (411 µg/l) and SW12-Shal (349 µg/l). Barium was detected at all locations including at background locations. This is typically observed at many sites. Exceedances of dissolved barium are not discussed further.

With the exception of the discharge location sample at Gortmore, Gort-TMF-Seep, the highest concentrations of cadmium, lead, manganese, nickel and zinc (Table 14) were in the Garryard and Shallee areas as described later in this section.

In the Ballygown area (Map 5 of **Appendix A**) where the Silvermines stream is located, cadmium concentration exceeded both the ecological and human health criteria (5 µg/l), with a concentration of 5.67 µg/l. There were also exceedances of dissolved lead, nickel and zinc. Other than for barium, there were no exceedances at the upstream site, SW1-SM. At the southern Adit (SW2-SM-South) (Table B-1 in **Appendix B)**, concentrations of dissolved lead (1.39 µg/l), nickel (6.7 µg/l) and zinc (2,000 µg/l) exceeded the ecological assessment criteria, respectively. Dissolved zinc concentrations exceeded the ecological assessment criteria of 100 µg/l at the three sites downstream of the discharge (SW5-SM, SW6-SM and SW4-SM-GA) (Table 14), and values ranged from 216 µg/l to 258 µg/l. Dissolved lead concentrations were measured at the downstream locations (SW5-SM, SW6-SM and SW4-SM-GA) ranging from 1.32 µg/l to 1.79 µg/l, relative to the ecological assessment criteria of 1.2 µg/l.

The concentration of dissolved zinc at SW6-Mag (893 µg/l), which is downstream of the Magcobar mining area, exceeded the ecological assessment criteria of 100 µg/l. Nickel also exceeded the ecological assessment criteria (4 µg/l) with a concentration of 9.74 µg/l.

At Gortmore TMF (Map 2 of **Appendix A**), dissolved cadmium, lead, nickel and zinc exceeded the ecological assessment criteria at several locations (Table B-1 in **Appendix B**).

Manganese concentrations (not a human health concern), ranged from 66 µg/l to 314 µg/l in the Gortmore area, with the exception of the Gort-TMF-Seep location, discussed below.

Concentrations of dissolved metals measured in the sample from Gort-TMF-Seep were elevated relative to either or both the ecological and human health criteria (Table B-1 in **Appendix B**). The sample from Gort-TMF-Seep had the following concentrations of dissolved metals;  aluminium, 963 µg/l (exceeding the human health criteria of 200 µg/l but not the ecological assessment criteria of 1,900 µg/l), arsenic, 27.8 µg/l (exceeding the ecological assessment criteria of 25 µg/l and the human health criteria of 10 µg/l), cadmium, 118 µg/l (exceeding the ecological assessment criteria of 0.9 µg/l and the human health criteria of 5 µg/l), copper, 269 µg/l (exceeding the ecological assessment criteria of 30 µg/l but not the human health criteria of 2,000 µg/l), lead of 13.5 µg/l (exceeding the ecological assessment criteria of 1.2 µg/l and the human health criteria of 10 µg/l), nickel of 167 µg/l (exceeding the ecological assessment criteria of 4 µg/l and the human health criteria of 20 µg/l), cobalt, 16.2 µg/l (exceeding the ecological assessment criteria of 5.1 µg/l) and zinc 35,000 µg/l (exceeding the ecological assessment criteria 100 µg/l). Manganese concentration, 1,920 µg/l exceeded the ecological assessment criteria of 1,100 µg/l and the drinking water criteria of 50 µg/l and iron, 59,400 µg/l exceeded the drinking water criteria of 200 µg/l.

Sulphate concentration in the Gort-TMF-Seep sample was 2,490 mg/l and pH and EC were 3.25 and 3.269 µS/cm respectively.

There were no further exceedances for aluminium, arsenic, cobalt, copper and iron in the Gortmore area, other than the sample from the seep. Other parameters are discussed below.

Cadmium exceeded the ecological assessment criteria (0.9 µg/l) at four locations in the Gortmore area ranging from 1.03 µg/l (SW14-Gort) to the highest value of 4.67 µg/l (SW18-Gort).

Dissolved lead exceeded the ecological (1.2 µg/l) assessment criteria at five locations in the Gortmore area; SW19-Gort  (3.9 µg/l), SW17-Gort (1.6 µg/l), SW12-Gort-DS (3.02 µg/l), SW14-Gort (2.75 µg/l) and Downstream at DS-Gort (2.46 µg/l) (Table B-1 in **Appendix B**), as well exceeding the human health criteria of 10 µg/l and ecological (1.2 µg/l) assessment criteria at SW18-Gort (11.4 µg/l) and at Gort-TMF-Seep.

Dissolved zinc concentrations in the Gortmore area ranged from 234 µg/l (DS-Gort) to 1,950 µg/l at SW10-Gort-Discharge and the elevated value at Gort-TMF-Seep (35,000 µg/l). The zinc concentration increased on the Kilmastulla River from 7.99 µg/l at the upstream location, SW17-Gort to 297 µg/l at SW12-Gort-DS (and 234 µg/l at the furthest downstream location, DS-Gort).

SW12-Gort-DS is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The mass loads (g/day) from these areas are discussed in Section 5.

At Garryard, cadmium exceeded the human health criteria (5 µg/l) and ecological (0.9 µg/l) assessment criteria at four of the five locations sampled, ranging from 24.5 µg/l to 44.5 µg/l. Other metals were also elevated in the Garryard area, including lead, nickel and zinc. For those locations which exceeded the ecological assessment criteria and the human health criteria (SW5-Gar, SW12-Gar, SW10-Gar and SW3-Gar), concentrations of dissolved lead ranged from 2.34 µg/l (relative to the ecological criteria of 1.2 µg/l) to 16 µg/l (relative to the human health criteria of 10 µg/l). For those same locations, dissolved nickel concentrations ranged from 25.7 µg/l to 59.8 µg/l, relative to the ecological assessment criteria (4 µg/l) and the human health criteria of 20 µg/l.

Within Garryard, dissolved zinc concentrations ranged from 177 µg/l to 12,900 µg/l with a median value of 9,010 µg/l relative to the ecological criteria of 100 µg/l.

At Shallee (Map 3 of **Appendix A**), there were exceedances of the ecological assessment criteria for cadmium, lead, nickel and zinc for almost all locations and drinking water criteria were exceeded for cadmium, lead, nickel and manganese (not a human health concern) as described below. Three locations had dissolved cadmium concentrations above both the ecological assessment criteria (0.9 µg/l) and the human health criteria (5 µg/l); SW5-Shal (16.3 µg/l), SW15-Shal (16.4 µg/l) and DS-Shal (15.1 µg/l). Two locations had dissolved nickel concentrations above both the ecological assessment criteria (4 µg/l) and the human health criteria (20 µg/l); SW5-Shal (38.7 µg/l), SW15-Shal (38.4 µg/l).

Eight of the nine Shallee locations had lead concentrations in excess of both the ecological assessment criteria (1.2 µg/l) and the human health criteria (10 µg/l). Dissolved lead concentrations in the Shallee area ranged from 11 µg/l to 406 µg/l, relative to the drinking water criteria of 10 µg/l. The highest concentrations of lead were at SW6-Shal (406 µg/l) and at SW9-Shal (233 µg/l) with a median lead concentration in the Shallee locations of 55 µg/l. Dissolved zinc concentrations ranged from 211 µg/l to 5,250 µg/l with a median value of 753 µg/l relative to the ecological criteria of 100 µg/l.

Downstream-Shal is located on the Yellow River, downstream of all the discharges from the Shallee and Garryard mining areas and located upstream of the confluence with the Kilmastulla River in the Gortmore area. The dissolved lead concentration at Downstream-Shal (28 µg/l) exceeded both the ecological (1.2 µg/l) and drinking water (10 µg/l) assessment criteria, and the dissolved zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 3,420 µg/l.

### 4.3.3 Livestock Water Quality Assessment

Recommendations on the levels of toxic substances in drinking water for livestock are provided in Table 13. The National Academy of Sciences (1972) recommend a limit of 100 µg/l for lead in drinking water for livestock. However, lead is accumulative, and problems may begin at threshold value of 50 µg/l.

The Field Shaft (SW6-Shal) had a dissolved Lead concentration of 406 µg/l, relative to the livestock criteria (100 µg/l). The sampling location on the stream SW9-Shal, which is just downstream of the Field Shaft, had concentration of 233 µg/l, while the concentration at SW12-Shal was 101 µg/l. Further downstream at SW1-Shal, which is located downgradient of the Shallee tailings impoundment, the concentration of dissolved lead was 171 µg/l. Therefore, livestock should be prevented from drinking water in the stream in the Shallee mining area.

The water quality results of all the sampling locations at Gortmore TMF were assessed against the recommendations for levels of toxic substances in drinking water for livestock from the National Academy of Sciences (1972). It is noted that the maximum recommended sulphate levels for calves is 500 mg/l and for adults is 1,000 mg/l.

At Gort-TMF-Seep, the cadmium concentration (118 µg/l) and zinc concentration (35,000 µg/l) exceeded the respective thresholds (50 µg/l cadmium and 24,000 µg/l zinc). The only sampling location at which sulphate concentration exceeded the criteria, was the sample collected from Gort-TMF-Seep (2,490 mg/l sulphate).

The guidelines for sulphates in water are not well defined but high concentrations cause diarrhea; however, at the levels found in previous sampling rounds in the water bodies at Gortmore TMF it is likely that livestock are accustomed to them. Note, no horses were observed on the Gortmore TMF during the sampling.

## 4.4 Bioavailable EQS Assessment

As discussed in Section 4.2, water quality criteria for metals such as zinc and copper in freshwaters have incorporated hardness in a variety of methods (the different classes shown in Table 11 are one such approach). With the advancement of scientific understanding and testing of the toxicity of metals in the environment during the past 10 to 15 years, hardness alone has been shown to be a poor explanation of chronic affects (Environmental Agency, 2015). The European Union Environmental Objectives (Surface Waters) (Amendments) Regulations (S.I. No 386 of 2015) includes annual average EQS for nickel (Ni) and lead (Pb) in freshwater based on bioavailable concentrations. These values have been adopted by Ireland. Bioavailability under the WFD is a combination of physico-chemical factors governing metal behaviour and the biologic receptor (i.e., the route of entry, duration and frequency of exposure). Overall bioavailability should measure what the ecological receptor in the water actually “experiences” (Environmental Agency, 2015).

A tiered approach to assessing bioavailable EQS has been applied in the UK as follows (Environmental Agency, 2015):

- **Tier 1:** The annual average concentration (dissolved) is compared to the current single value $EQS_{bioavailable}$ for Ni (4 µg/l) and Pb (1.2 µg/l). These values are sometimes referred to as “generic $EQS_{bioavailable}$” or “reference $EQS_{bioavailable}$”. Sites with sample results exceeding the $EQS_{bioavailable}$ progress to Tier 2. Sites with sample results less than the generic $EQS_{bioavailable}$ are deemed good chemical status for Ni and Pb. However, other metals should be evaluated (see below).

- **Tier 2:** A user friendly tool based upon integrated biotic ligand models (BLM) which incorporates site specific data is used to calculate local bioavailable metal concentrations and local HC5 values (value derived from ecotoxicological data at the 5th percentile of a species sensitivity distribution; i.e., this value protects 95% of the species) or local PNEC (predicted no effect concentration). The HC5, PNEC or similar values are used as the scientific basis for developing $EQS_{bioavailable}$. The calculated local bioavailable metal concentration can be compared to the generic $EQS_{bioavailable}$ and/or the local $EQS_{bioavailable}$ (or

HC5, PNEC, etc.). If the calculated bioavailable metal concentrations show at risk concentrations or exceed the local $EQS_{bioavailable}$, the evaluations proceed to Tier 3. User friendly tools are available to evaluate Cu, Ni, Zn and Pb.

- **Tier 3:** This tier is for "local refinement" if Tier 2 exceedances are observed. These refinements may include consideration of background metal concentrations and running a full (versus user friendly) BLM. Full version BLM are available for Cu, Mn, Ni, Pb and Zn.
- **Tier 4:** At this tier, the failure of the site to achieve the $EQS_{bioavailable}$ has been established and appropriate measures to address the situation may be considered.

### 4.4.1 River and Stream Bioavailable EQS Analysis

Appropriate analytical data have been collected at the Silvermines mining site to enable evaluations of $EQS_{bioavailable}$ for selected metals. An example evaluation employing the tier 1 and tier 2 steps follows:

Tier 1: The current single values generic $EQS_{bioavailable}$ for Ni (4 µg/l) and Pb (1.2 µg/l) were based on the most conservative 5th percentile no effect concentrations from data available in EU member states (e.g., 4.0 µg/l for Ni was based on 1,553 measured concentrations from Austria). Compared to previous threshold values (S.I. 272 of 2009), the values for $EQS_{bioavailable}$ Ni and Pb are much lower (e.g., 4.0 vs 20 µg/l for Ni; 1.2 vs 7.2 µg/l for Pb). Typically, dissolved Pb concentrations in the Silvermines area exceed the 1.2 µg/l value and at several locations, exceed the 7.2 µg/l value. Measured dissolved Ni concentrations in the Silvermines area typically exceed the 4 µg/l value in many locations (see **Appendix B**). Overall, Pb and Zn concentrations are the metals of most concern in the rivers and streams at Silvermines when compared to current EQS values and Zn is the metal of most concern when compared to HC5 values (see below evaluation).

Tier 2: Several user-friendly tools are available to assess $EQS_{bioavailable}$ values. For this analysis, at the Silvermines site, the Bio-met Bioavailability Tool, Version 4.0, April 2017 (www.bio-met.net), was used. The spreadsheet calculates bioavailability factors, local HC5 values, risk characterisation ratios and local bioavailable metal concentrations. Cu, Zn, Ni and Pb can be evaluated in the current Bio-met model. The local bioavailable metal concentrations are compared to the generic $EQS_{bioavailable}$. The generic $EQS_{bioavailable}$ values for Pb and Ni are 1.2 and 4 µg/l, respectively, as discussed above (fixed by the WFD). In addition, generic $EQS_{bioavailable}$ values for Cu (1 µg/l) and Zn (10.9 µg/l) are included in the Bio-met Bioavailability Tool but can be adjusted by the user. Note, these values were not used for the comparisons in Table 15, the current EQS values from Table 11 were used. The local bioavailable metal concentrations can also be compared to the local HC5 concentration (as a surrogate for local $EQS_{bioavailable}$). Required input for the Bio-met tool includes measured dissolved metal concentrations, pH, dissolved organic carbon concentrations and dissolved calcium concentrations at the site. The evaluations for dissolved lead, nickel and zinc, the parameters of concern, are presented in Table 15.

As shown in Table 15 the bioavailable Pb, Ni and Zn concentrations are significantly less than the measured Pb, Ni and Zn concentrations. For Pb the HC5 is in all cases, higher (less stringent) than the current EQS of 1.2 µg/l for Pb and is generally higher than the EQS of 4 µg/l for Ni, with a number of exceptions for Ni where the HC5 is close to the EQS (between 2.3 µg/l to 3.7 µg/l for those exceptions). For Zn, the HC5 concentrations are significantly lower (more stringent) than the current EQS of 100 µg/l at all locations.

**Table 15 Results from the Bio-Met Model at River and Stream Locations in the Silvermines Area**

| Site | Metal | Measured Conc. | HC5 | Bioavailable Conc. | Bioavailable Conc. Exceedance of HC5 | Measured Conc. Exceedance of current EQS* | Bioavailable Conc. Exceedance of current EQS* |
|---|---|---|---|---|---|---|---|
| SW17-Gort | Pb | 1.60 | 7.94 | 0.24 | No | Yes | No |
| | Zn | 7.99 | 31.2 | 2.44 | No | No | No |
| | Ni | 0.97 | 12.2 | 0.32 | No | No | No |
| SW10-Gort-US | Pb | 0.84 | 9.6 | 0.11 | No | No | No |
| | Zn | 68.3 | 37.9 | 19.4 | No | No | No |
| | Ni | 1.63 | 7.6 | 0.86 | No | No | No |
| SW10-Gort-DS | Pb | 0.85 | 9.6 | 0.11 | No | No | No |
| | Zn | 92.4 | 35.8 | 27.9 | No | No | No |
| | Ni | 1.80 | 7.06 | 1.02 | No | No | No |
| SW12-Gort-DS | Pb | 0.10 | 9.57 | 0.01 | No | No | No |
| | Zn | 263 | 35.2 | 81.2 | Yes | Yes | No |
| | Ni | 4.34 | 7.60 | 2.28 | No | Yes | No |
| SW14-Gort | Pb | 2.75 | 19.2 | 0.17 | No | Yes | No |
| | Zn | 2.57 | 59.8 | 46.0 | No | No | No |
| | Ni | 253 | 13.8 | 0.75 | No | Yes | No |
| DS-Gort | Pb | 2.46 | 9.57 | 0.31 | No | Yes | No |
| | Zn | 234 | 34.5 | 73.7 | Yes | Yes | No |
| | Ni | 2.19 | 7.60 | 1.15 | No | No | No |
| SW6-Mag | Pb | 0.10 | 3.07 | 0.04 | No | No | No |
| | Zn | 893 | 18.3 | 531 | Yes | Yes | Yes |
| | Ni | 9.74 | 4.66 | 8.37 | Yes | Yes | Yes |
| US-Shal | Pb | 5.82 | 3.33 | 2.10 | No | Yes | Yes |
| | Zn | 8150 | 32.5 | 2733 | Yes | Yes | Yes |
| | Ni | 30.8 | 3.31 | 30.8 | Yes | Yes | Yes |
| SW9-Shal | Pb | 233 | 4.23 | 66 | Yes | Yes | Yes |
| | Zn | 944 | 15.6 | 661 | Yes | Yes | Yes |
| | Ni | 12.6 | 4.66 | 10.8 | Yes | Yes | Yes |
| SW1-Shal | Pb | 171 | 4.40 | 46.6 | Yes | Yes | Yes |
| | Zn | 753 | 15.6 | 527 | Yes | Yes | Yes |
| | Ni | 11.2 | 4.16 | 10.8 | Yes | Yes | Yes |
| DS-Shal | Pb | 28.0 | 2.89 | 11.6 | Yes | Yes | Yes |
| | Zn | 3420 | 20.9 | 1779 | Yes | Yes | Yes |
| | Ni | 14.3 | 7.48 | 7.65 | Yes | Yes | Yes |
| DS-Gorteenadiha | Pb | 28.6 | 4.83 | 7.10 | Yes | Yes | Yes |
| | Zn | 173 | 14.7 | 127 | Yes | Yes | Yes |
| | Ni | 3.06 | 2.26 | 3.06 | Yes | No | No |
| SW1-Gar | Pb | [1] | [1] | [1] | [1] | [1] | [1] |
| | Zn | [1] | [1] | [1] | [1] | [1] | [1] |

| Site | Metal | Measured Conc. | HC5 | Bioavailable Conc. | Bioavailable Conc. Exceedance of HC5 | Measured Conc. Exceedance of current EQS* | Bioavailable Conc. Exceedance of current EQS* |
|---|---|---|---|---|---|---|---|
| | Ni | [1] | [1] | [1] | [1] | [1] | [1] |
| SW10-Gar | Pb | 2.34 | 3.33 | 0.84 | No | Yes | No |
| | Zn | 9010 | 32.49 | 3022 | Yes | Yes | Yes |
| | Ni | 34.4 | 2.91 | 34.4 | Yes | Yes | Yes |
| SW3-Gar | Pb | 16.0 | 8.8 | 2.2 | No | Yes | Yes |
| | Zn | 6650 | 39.9 | 1816 | Yes | Yes | Yes |
| | Ni | 25.7 | 8.69 | 11.8 | Yes | Yes | Yes |
| SW1-SM | Pb | 0.70 | 4.23 | 0.20 | No | No | No |
| | Zn | 3.33 | 14.1 | 1.80 | No | No | No |
| | Ni | 0.55 | 5.22 | 0.42 | No | No | No |
| SW3-SM | Pb | 1.68 | 3.49 | 0.58 | No | Yes | No |
| | Zn | 96.1 | 15.6 | 66.3 | Yes | No | No |
| | Ni | 0.89 | 4.66 | 0.76 | No | No | No |
| SW5-SM | Pb | 1.32 | 14.53 | 0.11 | No | Yes | No |
| | Zn | 216 | 33.7 | 69.5 | Yes | Yes | No |
| | Ni | 1.34 | 8.69 | 0.62 | No | No | No |
| SW6-SM | Pb | 1.79 | 3.79 | 0.57 | No | Yes | No |
| | Zn | 258 | 17.3 | 162 | Yes | Yes | Yes |
| | Ni | 1.31 | 3.71 | 1.31 | No | No | No |
| SW4-SM-GA | Pb | 1.72 | 3.79 | 0.54 | No | Yes | No |
| | Zn | 242 | 17.3 | 152 | Yes | Yes | Yes |
| | Ni | 1.31 | 3.71 | 1.31 | No | No | No |

**Notes**: * 1.2 µg/l for Pb, 100 µg/l for Zn and 4 µg/l for Ni. [1] No flow, no sample at SW1-GAR.

The following summarises the data within Table 15;

- Number of exceedances when comparing the bioavailable concentrations of the metals to the HC5: Pb =4; Zn = 14; Ni =6.
- Number of exceedances when comparing the measured concentrations of the metals to the current EQS: Pb = 14; Zn = 13; Ni = 10.
- Number of exceedances when comparing the bioavailable concentrations of the metals to the current EQS: Pb = 8; Zn = 9; Ni = 7.

When using local HC5 and bioavailable concentrations, the number of locations with exceedances for Pb is reduced significantly. This is due to the much higher HC5 values and much lower bioavailable concentrations for Pb. The number of exceedances for Zn and Ni are more broadly similar for the different comparisons. The large number of exceedances for Zn are caused by the much higher concentrations of Zn compared to Pb and Ni at many locations.

# Section 5

# Flows, Loads and Trend Analysis

## 5.1 Surface Water Flows

No river flow gauging stations exist within the Silvermines mining area. The nearest gauge is on the Kilmastulla River, approximately 10 km downstream of the Silvermines mining area, at Coole (EPA station 25044) for which the flow record was downloaded, including long term data from 1970 onwards. A plot showing data from this station from November 2017 to June 2019 is shown in Figure 1, noting that there is a gap in the available flow data from the station during January 2019. The flow response plotted indicates a flashy response to rainfall.

For the period from 22 February 2018 to 22 February 2019 (just after the end of sampling), maximum and minimum flows were calculated; the minimum flow value (22/2/18 to 22/2/19) was 0.16 $m^3$/s, on 14 August 2018, and a maximum in the same period of 8.92 $m^3$/s, on 6 April 2018. There were two higher peaks just outside the February-February period (20.8 $m^3$/s on 21st January 2018 and 18.9 $m^3$/s on 16th March 2019).

The estimated 5%-ile (high flow) was calculated to be 6.83 $m^3$/s and the 95%-ile (low flow) to be 0.30 $m^3$/s (calculated from the dataset 1970 to February 2019), with a long-term median flow value of 1.31 $m^3$/s . The data show that the minimum value of 0.16 $m^3$/s in the period (22/2/18 to 22/2/19) is about half the long term minimum flow value.

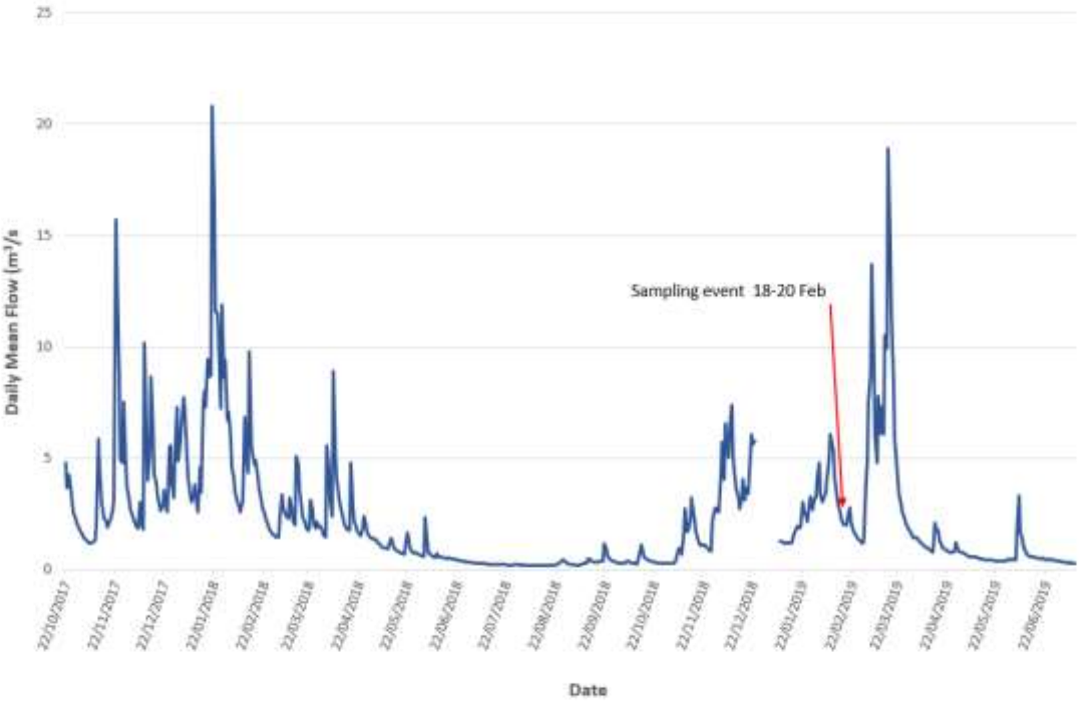

Figure 1 Mean Daily Flow ($m^3$/s) at Coole, Kilmastulla (Station 25044) from Oct 2017 to Jun 2019

The flows in the Kilmastulla River in the Silvermines mining area are expected to be lower than that recorded at the EPA Station 10 km downstream, as many small tributaries drain from the surrounding mountains between the mining area and the gauging station. The EPA tool for ungauged catchments was utilised to estimate the 95%-ile flow (low flow) of the Kilmastulla River at the location just downstream of the Gortmore TMF. This estimated 95%-ile flow (low flow) is 0.16 m3/s. This tool was also used to calculate the 5%-ile flow (high flow) of the Kilmastulla River at the location just downstream of the Gortmore TMF, which was 4.36 m3/s.

Flow was measured directly in the field using different methodologies depending upon the quantity of flow to be measured and any safety concerns, as described in Section 2.1.2. Table 16 presents a summary of the results from the flow measured in February 2019 at the time of sampling. Appendix A of the Data Report contains details of methodologies used per site and associated calculations.

**Table 16 Surface Water Flow Values Measured in February 2019**

| Site Name | Flow l/s | Date | Method |
|---|---|---|---|
| SW19-Gort | 5.83 | 20/02/2019 | Flume Method |
| SW17-Gort | Not Measured | 20/02/2019 | Not Measured |
| SW10-GORT Discharge | 4.71 | 20/02/2019 | Bucket Stopwatch |
| SW12-GORT Discharge | 7.93 | 20/02/2019 | Bucket Stopwatch |
| DS-Gort | 1762.53 | 20/02/2019 | Float Method |
| US-Shal | 25 | 18/02/2019 | Flow Meter |
| SW4-Shal | 352.49 | 18/02/2019 | Bucket Stopwatch |
| SW5-Shal | 1.21 | 18/02/2019 | Flume Method |
| SW6-Shal | 6.07 | 18/02/2019 | Bucket Stopwatch |
| SW15-Shal | 0.87 | 18/02/2019 | Bucket Stopwatch |
| SW9-Shal | 11 | 18/02/2019 | Flow Meter |
| SW12-Shal | 1.64 | 18/02/2019 | Bucket Stopwatch |
| SW13-Shal | 4 | 18/02/2019 | Flow Meter |
| SW1-Shal | 11 | 18/02/2019 | Flow Meter |
| DS-Shal | 71 | 18/02/2019 | Flow Meter |
| DS-Gorteenadiha | 41 | 18/02/2019 | Flow Meter |
| SW1-Gar | Dry | 19/02/2019 | Dry |
| SW5-Gar | [2] | [2] | [2] |
| SW12-Gar | 8.87 | 19/02/2019 | Flume Method |
| SW10-Gar | 14 | 19/02/2019 | Flow Meter |
| SW7-Gar | 0.16 | 19/02/2019 | Bucket Stopwatch |
| SW3-Gar | 31.75 | 19/02/2019 | Flume Method |
| SW1-SM | 19 | 19/02/2019 | Flow Meter |

| Site Name | Flow l/s | Date | Method |
|---|---|---|---|
| SW3-SM | 47 | 19/02/2019 | Flow Meter |
| SW2-SM-South | 1.14 | 19/02/2019 | Bucket Stopwatch |
| SW5-SM | 47 | 19/02/2019 | Flow Meter |
| SW6-SM | 42 | 19/02/2019 | Flow Meter |
| SW4-SM-GA | 111 | 19/02/2019 | Flow Meter |

Notes: [1] SW5-Gar is covered by a grate and flow measurement is not possible.

## 5.2 Loading Analysis

### 5.2.1 Loading Analysis Methodology, Results and Discussion

Mass loads (g/day) were calculated for the locations with measured flows using the measured flow and concentration data, as follows:

Load (g/day) = [C (µg/L) * F (L/day)] / 1,000,000 µg/g

where: C = the concentration of the parameter in the water
F = the flow rate of the input

The calculated mass loads in Table 17 aid with the interpretation of the loading of Sulphate and dissolved cadmium, lead, manganese, nickel and zinc to rivers.

The dissolved metal with the highest mass loading was zinc ranging from 2.5 g to 35.6 kg/day with a median value of 754 g/day overall. The largest mass load of zinc was found at sampling point, Downstream-Gort.

SW10-Gar (the discharge from the tailings lagoon) had a zinc load of 793 g/day. In March 2018, the discharge pipe from the tailings lagoon was blocked and water was discharging over, and possibly through, the western embankment, resulting in concerns over bank stability. Accordingly, since Spring 2018, the SW10-Gar sampling point has been moved slightly downstream to capture all the discharges from the lagoon. Downstream at SW3-Gar, (located in a stream containing the SW10-Gar discharge and the western part of the Mogul yard), zinc loading was 18.2 kg/day, similar to the loading at the same location in Spring 2018 of 14.1 kg/day. The stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 5.47 g/day, which increases to 390 g/day downstream of the mine workings (SW3-SM). The zinc loading at SW2-SM-South (southern adit) was 198 g/day, while the northern adit was not sampled. Downstream of these locations, at SW5-SM, the zinc load would be expected to be a combination (approximately 600 g/day) of the individual loads from locations SW3-SM, the northern adit discharge (when sampled) and SW2-SM-South. However, the calculated zinc load (based on measured values) at SW5-SM was 877 g/day which indicates that there may be another source of dissolved zinc contributing to this stretch such as groundwater seeps in proximity to the adit discharges. Similarly, downstream the calculated dissolved zinc load at SW6-SM was calculated at 936 g/day, which indicates a potential additional zinc source.

**Table 17 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day**

| Site Description | Date Sampled | Flow l/s | Sulphate | | Cadmium | | Lead | | Manganese | | Nickel | | Zinc | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day |
| SW19-GORT | 20/02/19 | 5.83 | 462,000 | 232,715 | 2.7 | 1.4 | 3.9 | 2.0 | 48.7 | 24.5 | 8.8 | 4.4 | 1,350 | 680 |
| SW10-GORT Disch | 20/02/19 | 4.71 | 719,000 | 292,573 | 0.2 | 0.1 | 0.3 | 0.1 | 66.3 | 27.0 | 13.5 | 5.5 | 1,950 | 793 |
| SW12-GORT Disch | 20/02/19 | 7.93 | 479,000 | 328,078 | 0.1 | 0.1 | 0.1 | 0.1 | 165 | 113 | 4.3 | 3.0 | 263 | 180 |
| DS-GORT | 20/02/19 | 1763 | 52,800 | 8,040,521 | 0.9 | 130 | 2.5 | 375 | 42 | 6,365 | 2.2 | 333 | 234 | 35,634 |
| US-SHAL | 18/02/19 | 25.0 | 368,000 | 794,880 | 37.8 | 81.6 | 5.8 | 12.6 | 493 | 1,065 | 30.8 | 66.5 | 8,150 | 17,604 |
| SW4-SHAL | 18/02/19 | 352 | 11,300 | 344,145 | 0.8 | 24.2 | 55.4 | 1,687 | 43.9 | 1,337 | 4.8 | 147 | 80.4 | 2,449 |
| SW5-SHAL | 18/02/19 | 1.21 | 63,200 | 6,619 | 16.3 | 1.7 | 21.1 | 2.2 | 461 | 48.3 | 38.7 | 4.1 | 5,220 | 547 |
| SW6-SHAL | 18/02/19 | 6.07 | 13,200 | 6,925 | 1.2 | 0.6 | 406 | 213 | 68.7 | 36.0 | 9.0 | 4.7 | 211 | 111 |
| SW15-Shal | 18/02/19 | 0.87 | 64,600 | 4,868 | 16.4 | 1.2 | 11.0 | 0.8 | 394 | 29.7 | 38.4 | 2.9 | 5,250 | 396 |
| SW9-SHAL | 18/02/19 | 11.0 | 26,700 | 25,376 | 3.4 | 3.2 | 233 | 221 | 72.3 | 68.7 | 12.6 | 12.0 | 944 | 897 |
| SW12-SHAL | 18/02/19 | 1.64 | 7,400 | 1,047 | 0.3 | 0.04 | 101 | 14 | 233 | 33.0 | 3.0 | 0.4 | 50.0 | 7.1 |
| SW13-SHAL | 18/02/19 | 4.0 | 28,200 | 9,746 | 0.3 | 0.1 | 3 | 1 | 10 | 3 | 1 | 0 | 35 | 12 |
| SW1-SHAL | 18/02/19 | 11.0 | 29,000 | 27,562 | 3 | 3 | 171 | 163 | 77.8 | 73.9 | 11.2 | 10.6 | 753 | 716 |
| DS-SHAL | 18/02/19 | 71.0 | 149,000 | 914,026 | 15.1 | 93 | 28.0 | 172 | 217 | 1,331 | 14.3 | 87.7 | 3,420 | 20,980 |
| DS-Gorteenadiha | 18/02/19 | 41.0 | 16,300 | 57,741 | 1.1 | 3.7 | 28.6 | 101 | 26.4 | 93.5 | 3.1 | 10.8 | 173 | 613 |
| SW1-GAR | 19/02/19 | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry | [1] Dry |
| SW5-GAR | 19/02/19 | [2] | 284,000 | [2] | 24.5 | [2] | 12.2 | [2] | 422 | [2] | 59.8 | [2] | 12,900 | [2] |
| SW12-GAR | 19/02/19 | 8.87 | 345,000 | 264,385 | 26.4 | 20.2 | 5.8 | 4.4 | 353 | 271 | 55.8 | 42.8 | 12,700 | 9,732 |
| SW10-GAR | 19/02/19 | 14.0 | 404,000 | 488,678 | 44.5 | 53.8 | 2.3 | 2.8 | 146 | 177 | 34.4 | 41.6 | 9,010 | 10,898 |
| SW7-GAR | 19/02/19 | 0.16 | 183,000 | 2,608 | 0.5 | 0.01 | 0.4 | 0.01 | 35.6 | 0.5 | 1.8 | 0.0 | 177 | 2.5 |
| SW3-GAR | 19/02/19 | 31.7 | 325,000 | 891,443 | 29.1 | 79.8 | 16.0 | 43.9 | 183 | 502 | 25.7 | 70.5 | 6,650 | 18,240 |
| SW1-SM | 19/02/19 | 19.0 | 7,800 | 12,804 | 0.0 | 0.1 | 0.7 | 1.1 | 5.1 | 8.4 | 0.5 | 0.9 | 3.3 | 5.5 |
| SW3-SM | 19/02/19 | 47.0 | 9,400 | 38,172 | 0.3 | 1.1 | 1.7 | 6.8 | 1.5 | 6.1 | 0.9 | 3.6 | 96 | 390 |
| SW2-SM-South | 19/02/19 | 1.14 | 31,400 | 3,101 | 5.7 | 0.6 | 1.4 | 0.1 | 1.5 | 0.1 | 6.7 | 0.7 | 2,000 | 198 |
| SW5-SM | 19/02/19 | 47.0 | 21,200 | 86,089 | 0.5 | 1.9 | 1.3 | 5.4 | 7.5 | 30.3 | 1.3 | 5.4 | 216 | 877 |
| SW6-SM | 19/02/19 | 42.0 | 13,100 | 47,537 | 0.6 | 2.3 | 1.8 | 6.5 | 6.6 | 24.0 | 1.3 | 4.8 | 258 | 936 |
| SW4-SM-GA | 19/02/19 | 111 | 13,900 | 133,307 | 29.1 | 5.4 | 16.0 | 16.5 | 6.0 | 57.4 | 1.3 | 12.6 | 242 | 2,321 |

Between SW6-SM and SW4-SM-GA, the zinc load increases by 148% from 936 g/day to 2,321 g/day. The increase in dissolved zinc load along this stretch was identified in previous rounds (February 2016, August 2016 and March 2017, February 2018, September 2018) and indicates an additional source of dissolved zinc load. The likely source of this increase is a heavily contaminated deposit located directly east of the stream downgradient of SW6-SM. The Silvermines stream contributes this load to the Kilmastulla River.

The streams emerging from the Garryard mining area (US-Shal) and the Gorteenadiha mining area (DS-Gorteenadiha) area had dissolved zinc loads of 17.6 kg/day and 613 g/day, respectively. The stream emerging from the Shallee mining area (SW1-Shal) contributed a zinc load of 716 g/day. An additional drainage ditch (SW13-Shal) had a zinc load of 12 g/day. The calculated load of zinc at DS-Shal was 20.9 kg/day only slightly less than the combined loads (18.9 kg/day) discussed above and within the accuracy of the measurements. Between the Garryard SW3-Gar location and Upstream-Shal location, there was a decrease in dissolved zinc load from 18.2 kg/day to 17.6 kg/day.

The mass loads of dissolved lead at US-Shal and DS-Gorteenadiha, located directly upstream of the Shallee mining area were calculated to be 12.6 g/day and 101 g/day, respectively. The highest load of dissolved lead (1,687 g/day) was found at SW4-Shal. At SW6-Shal (Field shaft) the lead load was estimated to be 213 g/day which decreased to 163 g/day downstream at SW1-Shal. The lead load increased between SW1-Shal and DS-Shal (163 to 172 g/day).

Flow measurement and sample collection were undertaken at SW19-Gort, the stream draining the surface of the TMF, during this monitoring round. The zinc load at SW19-Gort was 680 g/day. Of the two discharges from the wetland at Gortmore TMF, SW10-Gort-Discharge (793 g/day) had the higher loading of dissolved zinc, relative to the loading from the flow at SW12-Gort-Discharge (180 g/day). These values are more similar to those significantly found during Spring 2018 monitoring, during the previous high flow monitoring, with the highest zinc loading during Spring 2018 found SW10-Gort-Discharge (776 g/day). The flow measured at DS-Gort in February (1,762 l/s) was less than half that measured at that location the previous Spring (3,620 l/s, Feb 2018) and dissolved metals loads were also lower as a result.

During Spring 2019, discharges from the Garryard and Shallee mining areas contributed the greatest mass loads of dissolved zinc to the Kilmastulla River.

## 5.3 Trend Analysis

### 5.3.1 Historical Trends

This section discusses concentration time trends for select locations including the main discharges (SW2-SM South, SW6-SHAL, SW10-GAR, SW10-Gort-Disc. and SW12-Gort-Disc.) and SW14-Gort which are located on the Kilmastulla River, downstream of the primary mining areas (Gortmore, Shallee, Garryard, Magcobar and Ballygown). The Mann-Kendall test was performed on the surface water data. The Mann-Kendall test is a non-parametric test that is well suited to use in water quality data analysis. The analysis was performed for dissolved cadmium, lead, manganese, nickel and zinc. The Mann-Kendall test results in the identification of a trend (if one exists) and the probability of that trend being real. Table 18 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

**Table 18 Reporting the Mann-Kendall Results**

| Trend | P value | Trend |
|---|---|---|
| Decreasing | 0 <= p < 0.05 | Decreasing |
| | 0.05 <= p < 0.1 | Likely Decreasing |
| | p >= 0.1 | No Trend |
| Increasing | 0 <= p < 0.05 | Increasing |
| | 0.05 <= p < 0.1 | Likely Increasing |
| | p >= 0.1 | No Trend |
| No Trend | p = 1 | No Trend |
| Not Calculated | n/a | Not Calculated |

Notes: The confidence coefficient is 0.95
Null Hypothesis: The null hypothesis is that there is no trend.
The p-value is the probability that the null hypothesis is true.
The Mann-Kendall test requires the following information for a trend to be calculated: A sample size of at least three values and a maximum of 50% of the sample set is reported as non-detect.

Trend analysis was conducted for all the available data since November 2006. The Mann-Kendall test results are presented in Table 19 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

**Table 19 Mann-Kendall Trend Analysis of data from November 2006 to February 2019**

| Sample Location | Parameter | Reported values (n) | p value | s value | Trend |
|---|---|---|---|---|---|
| SW10-Gar | Diss. Cadmium | 17 | 0.088 | -34 | Likely Decreasing |
| | Diss. Lead | 17 | 0.388 | - 9 | No Trend |
| | Diss. Manganese | 17 | 0 | - 80 | Decreasing |
| | Diss. Nickel | 17 | 0.102 | -33 | No Trend |
| | Diss. Zinc | 17 | 0.245 | -19 | No Trend |
| SW10-Gort-Discharge | Diss. Cadmium | 14 | 0.018 | -39 | Decreasing |
| | Diss. Lead | 14 | 0.259 | -13 | No Trend |
| | Diss. Manganese | 14 | 0.374 | 7 | No Trend |
| | Diss. Nickel | 14 | 0.063 | -29 | Likely Decreasing |
| | Diss. Zinc | 14 | 0.194 | -17 | No Trend |
| SW12-Gort-Discharge | Diss. Cadmium | 13 | 0.383 | - 7 | No Trend |
| | Diss. Lead | 13 | 0.295 | 11 | No Trend |
| | Diss. Manganese | 13 | 0.476 | 3 | No Trend |
| | Diss. Nickel | 13 | 0.029 | -32 | Decreasing |
| | Diss. Zinc | 13 | 0.476 | 2 | No Trend |
| SW6-Shal | Diss. Cadmium | 14 | 0.164 | 21 | No Trend |
| | Diss. Lead | 14 | 0.349 | 9 | No Trend |
| | Diss. Manganese | 14 | 0.164 | -21 | No Trend |
| | Diss. Nickel | 14 | 0.385 | -7 | No Trend |
| | Diss. Zinc | 14 | 0.218 | -17 | No Trend |
| SW14-Gort (Kilmastulla River) | Diss. Cadmium | 14 | 0.457 | - 3 | No Trend |
| | Diss. Lead | 14 | 0.140 | 21 | No Trend |
| | Diss. Manganese | 14 | 0.415 | -5 | No Trend |
| | Diss. Nickel | 14 | 0.079 | -27 | Likely Decreasing |
| | Diss. Zinc | 14 | 0.457 | -3 | No Trend |

The results of the Mann-Kendall test show that:

- Dissolved Manganese concentration is decreasing at SW10-Gar;

- Dissolved Cadmium is decreasing at SW10-Gort-Discharge;
- Dissolved Nickel is decreasing at SW12-Gort-Discharge;
- The results for parameters tested from the current monitoring show no statistically significant trend for other parameters or locations.

Future monitoring data will be incorporated into the analysis to address the cases where there is currently insufficient statistical evidence to detect a trend.

### 5.3.2 Seasonal Trends

The concentrations and loadings for individual sample results from this monitoring event are summarised in Table 17. Table 20 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling events in April 2013, March 2014, February 2015, February 2016, May 2017, February 2018 and February 2019 and the low flow sampling events in August 2013, September 2014, August 2015, August 2016 and September 2018.

The following points detail the February 2019 (high flow) sampling event concentrations and loading values in the context of previous results:

- In February 2019, for the majority of the main discharges, the dissolved metal concentrations were generally similar to the average / or between the average and the minimum value, relative to historic seasonal high flow concentrations (2013-2019);
- Dissolved metal concentrations in SW2-SM-South were closer to the minimum values recorded (2013-2019) during high flows for cadmium, manganese and zinc, and closer to the average values for high flow scenarios for lead;
- The dissolved zinc concentration at SW6-Shal (211 µg/l) was lower than the average for high flows (225 µg/l), with the calculated zinc loading of 111 g/day close to the estimated average load during high flow (105 g/day);
- At SW10-Gar, generally concentrations were close to the average for high flow scenarios, except for the concentration of dissolved cadmium (44.5 µg/l), which for the seasonal high flow concentration (2013-2019), is the highest concentration in that period. Due to lower than average flow value at SW10-Gar, the cadmium loading for this event (53.8 g/day) is closer to the average seasonal high flow loading (57.7 g/day) than the seasonal maximum for high flow events (109 g/day);
- SW10-Gort-discharge and SW12-Gort-Discharge drain the Gortmore wetlands into the Kilmastulla River. At SW10-Gort-Discharge, the dissolved metal concentrations were below the average seasonal high flow concentrations (2013-2019), and in the cases of cadmium and lead at SW10-Gort-Discharge, were closer to the minimum concentrations for high flow conditions (2013-2019);
- At SW12-Gort-Discharge, the dissolved manganese (165 µg/l) and zinc concentrations (263 µg/l) are the minimum seasonal high flow concentrations (2013-2019), and in the case of zinc, the estimated loading (180 g/day) is the minimum calculated loading during high flow events (2013-2019);

- While the concentration measured from a single grab sample can be higher during a low flow event than a high flow event, it is generally the case that the measured concentrations of dissolved cadmium, manganese and lead are higher during high flow events and the concentrations and are also within the same order of magnitude for the two flow regimes. Taking flow values into account, the data for the period 2013 – 2019 show that the loadings of dissolved cadmium, manganese and lead are higher during the higher flow events, though generally the loading of each metal is within the same order of magnitude for the two flow regimes;

- While the same general trend of higher concentrations and loading of dissolved zinc is observed during the higher flow events, the data for the period 2013 – 2019 show that loading of dissolved zinc, at locations SW12-Gort-Discharge, SW-10-Gort-Discharge and SW10-Gar, during the high flow events is an order of magnitude greater than during the lower flow events.

**Table 20 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in primary discharges from 2013-2019**

| | | SW2-SM South | | | | SW6-SHAL | | | | SW10-GAR | | | | SW10-Gort-Discharge | | | | SW12-Gort-Discharge | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | High Flow | | Low Flow | | High Flow | | Low Flow | | High Flow | | Low Flow | | High Flow | | Low Flow | | High Flow | | Low Flow | |
| **Flow** | Min | 1.1 | | 0.20 | | 2.2 | | 3.4 | | 5.5 | | 1.7 | | 4.7 | | 0.1 | | 7.1 | | 1.5 | |
| **(l/s)** | Max | 3.0 | | 1.5 | | 9.2 | | 6.2 | | 50.7 | | 4.4 | | 33.0 | | 4.5 | | 22 | | 7.5 | |
| | Mean | 2.0 | | 0.9 | | 5.4 | | 4.7 | | 22.8 | | 2.9 | | 11.2 | | 1.2 | | 10.9 | | 3.1 | |
| | units | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day | µg/l | g/day |
| **Cd** | Min | 4.72 | 0.56 | 4.32 | 0.08 | 0.91 | 0.25 | 0.80 | 0.24 | 18.8 | 8.9 | 6.9 | 2.0 | 0.12 | 0.06 | 0.04 | 0.0003 | 0.10 | 0.06 | 0.04 | 0.01 |
| | Max | 5.67 | 1.34 | 5.06 | 0.59 | 1.30 | 0.95 | 1.33 | 0.71 | 44.5 | 109 | 21.7 | 5.8 | 44.5 | 18.1 | 0.50 | 0.07 | 0.78 | 1.48 | 0.50 | 0.11 |
| | Mean | 5.28 | 0.88 | 4.67 | 0.37 | 1.17 | 0.54 | 0.97 | 0.41 | 29.8 | 57.7 | 13.8 | 4.0 | 7.6 | 3.28 | 0.12 | 0.02 | 0.41 | 0.47 | 0.16 | 0.04 |
| **Pb** | Min | 1.03 | 0.14 | 0.84 | 0.02 | 236 | 91.0 | 183 | 53.7 | 0.98 | 0.74 | 1.0 | 0.19 | 0.10 | 0.06 | 0.05 | 0.00 | 0.01 | 0.01 | 0.02 | 0.005 |
| | Max | 1.69 | 0.29 | 1.31 | 0.12 | 591 | 470 | 352 | 189 | 2.41 | 9.03 | 8.5 | 2.3 | 2.3 | 1.34 | 0.28 | 0.02 | 0.11 | 0.21 | 0.10 | 0.03 |
| | Mean | 1.24 | 0.20 | 1.02 | 0.08 | 415 | 202 | 259 | 108 | 1.76 | 3.56 | 3.7 | 1.0 | 0.64 | 0.50 | 0.13 | 0.01 | 0.07 | 0.08 | 0.06 | 0.01 |
| **Mn** | Min | 0.50 | 0.07 | 0.38 | 0.02 | 60.7 | 18.7 | 46.4 | 15.1 | 74.1 | 35.0 | 126 | 18.9 | 35.7 | 28.5 | 143 | 1.2 | 165 | 102 | 249 | 66.2 |
| | Max | 1.86 | 0.48 | 1.50 | 0.08 | 97.9 | 71.4 | 99.0 | 53.2 | 273 | 990 | 321 | 68.3 | 146 | 132 | 808 | 314 | 346 | 542 | 5830 | 1620 |
| | Mean | 1.20 | 0.21 | 0.73 | 0.05 | 77.5 | 36.0 | 70.3 | 29.5 | 177 | 408 | 205 | 49.2 | 71.8 | 55.3 | 350 | 62.6 | 241 | 241 | 1835 | 480 |
| **Zn** | Min | 1940 | 198 | 1560 | 28.7 | 179 | 48.1 | 153 | 45.2 | 5390 | 2540 | 2190 | 322 | 607 | 291 | 72.2 | 0.62 | 263 | 180 | 79.5 | 10.3 |
| | Max | 2140 | 503 | 1870 | 238 | 252 | 188 | 253 | 136 | 13000 | 40800 | 7150 | 1920 | 9010 | 3667 | 790 | 229 | 849 | 1610 | 229 | 122 |
| | Mean | 2027 | 340 | 1733 | 138 | 225 | 105 | 184 | 76.8 | 9903 | 20405 | 3415 | 869 | 2167 | 1260 | 363 | 50 | 555 | 591 | 148 | 44.4 |

# Section 6

# Groundwater Levels

Groundwater levels were measured at the two wells outside the Gortmore TMF and seven additional wells located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder. Table 21 provides the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevation outside the TMF decreased from 48.73 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.23 m OD at the downgradient location TMF2. These elevations are consistent with south-westerly groundwater flow through the bedrock, being towards the Kilmastulla River.

The groundwater elevation at TMF1 is the same level as measured during the previous high flow monitoring event in (48.73 m OD, February 2018). The groundwater level at TMF2 was slightly lower than that measured during the previous Springtime at TMF2 (46.04 m OD, February 2018).

Within the tailings area, the water levels generally ranged from approximately 53 m OD to 54 m OD, with the exception of BH3A-GORT (49.31 m OD) (see Map 2 of Appendix A) where deeper water levels were recorded. Groundwater elevations measured during the previous Springtime monitoring, in February 2018, ranged from 48.76 to 54.29 m OD. TMF1 does have a higher water level elevation compared to (48.73 m OD at TMF1 and 46.23 m OD at TMF2), in February 2019 (and e.g. 48.25 m vs 45.69 m in September 2018). However, these are the only two deeper wells (23 and 18 m bgl, respectively). TMF1 and TMF2 apparently do not accurately reflect the groundwater flow direction or water quality from the tailings. The statement of upgradient (TMF1) to downgradient (TMF2) was initially noted by Golder (Golder Tech Memo, 4 April 2007). Additional evaluations are warranted of the groundwater hydrology and in particular the source of the seeps.

**Table 21 Measured Groundwater Levels in September 2019**

| Borehole Identifier | Location Description | Date | Time | Depth to Groundwater (m bTOC) | Depth to Groundwater (m bgl) | Groundwater Elevation (m OD) |
|---|---|---|---|---|---|---|
| TMF1 | Outside the perimeter of the TMF | 20/02/2019 | 15:30 | 0.86 | 0.27 | 48.73 |
| TMF2 | | 20/02/2019 | 16:50 | 2.23 | 1.77 | 46.23 |
| BH1A-GORT-06 | Located within the TMF, near the perimeter of the tailings surface | 20/02/2019 | NR | 2.65 | 2.00 | 53.76 |
| BH2A-GORT-06 | | 20/02/2019 | NR | 3.33 | 2.80 | 52.96 |
| BH3A-GORT-06 | | 20/02/2019 | NR | 7.62 | 7.29 | 49.31 |
| BH4A-GORT-06 | | 20/02/2019 | NR | 4.35 | 3.83 | 52.33 |
| BH5A-GORT-06 | | 20/02/2019 | NR | 3.60 | 3.17 | 53.04 |
| BH6A-GORT-06 | | 20/02/2019 | NR | 2.65 | 1.96 | 54.12 |
| BH6B-GORT-06 | | 20/02/2019 | NR | 2.46 | 1.74 | 54.21 |

Notes: bgl is below ground level. bTOC is below top of casing. OD is Ordnance Datum. NR- not recorded

# Section 7

# Summary and Recommendations

## 7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in February 2019 and water levels were measured in seven additional monitoring wells. Sampling and analysis were undertaken at 34 surface water locations in February 2019 with flows measured at 25 locations. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QA/QC samples and laboratory reports were also reviewed. Overall the data quality is considered acceptable and the data can be used to compare to the assessment criteria and for evaluation of loads.

Statistical summaries of the analytical results for surface water were prepared and results were compared to assessment criteria. Analyses of metal loadings and groundwater levels were also provided.

The overall conclusions are as follows:

- TMF1 (located upgradient of Gortmore TMF) and TMF2 (located downgradient) exceeded the drinking water criteria for manganese (50 µg/l) with concentrations of 96 µg/l and 1,110 µg/l respectively. There is no drinking water threshold for barium in the drinking water regulations (S.I. No. 106 of 2007); however, concentrations of 151 µg/l and 629 µg/l were reported at TMF1 and TMF2, respectively. Overall, dissolved metal concentrations were higher in TMF2 (see next bullet). The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- TMF2 has multiple metal concentrations higher than TMF1 including Ba, Mn, As, Pb, and Ni. However, all of these concentrations and sulphate are relatively low and do not reflect typical tailings pore water contamination. Since February 2015, sulphate ranged from <2 to 34.3 mg/l and pH ranged from 6.61 to 7.48. Based on the previous and current rounds (February 2019) collection of the bank seep sample, the monitoring results show that low pH and very high concentrations of metals and sulphate exist in the pore water of the tailings e.g., the concentration of the zinc in the seep was 35 mg/l, sulphate was 2,490 mg/l, with a pH of 3.25, for the February 2019 sample (see below for additional discussion).

- The water level elevations at TMF1 and TMF2 from Sept 2018 were reviewed. TMF1 has a higher water level elevation compared to TMF2 (48.73 m OD at TMF1 and 46.23 m OD at TMF2, in February 2019 (and e.g. 48.25 m vs 45.69 m in September 2018). However, these are the only two deeper wells (23 and 18 m bgl, respectively). The rest of the monitoring wells are shallow (5 to 10 m bgl) and also have higher water level elevations. TMF1 and TMF2 apparently do not accurately reflect the groundwater flow direction or water quality from the tailings. The statement of upgradient (TMF1) to downgradient (TMF2) was initially noted by Golder (Golder Tech Memo, 4 April 2007). Additional evaluations are warranted of the groundwater hydrology and in particular the source of the seeps.

- Surface water locations SW1-SM and SW17-Gort are located upstream of the mining areas of Ballygown and Gortmore respectively and have significantly lower concentrations of zinc

(3.33 and 7.99 µg/l, respectively) than the rest of the rivers and streams sampled in the mining areas and are both well below the ecological assessment criteria of 100 µg/l.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. Within Garryard, zinc concentrations ranged from 177 µg/l to 12,900 µg/l with a median value of 9,010 µg/l relative to the ecological criteria of 100 µg/l. At Garryard, cadmium exceeded the ecological assessment criteria (0.9 µg/l) and human health criteria (5 µg/l) at four of the five locations sampled, ranging from 24.5 µg/l to 44.5 µg/l. Other metals were also elevated in the Garryard area, including lead, nickel and zinc. For those locations which exceeded the ecological assessment criteria and the human health criteria (SW5-Gar, SW12-Gar, SW10-Gar and SW3-Gar), concentrations of dissolved lead ranged from 2.34 µg/l (relative to the ecological criteria of 1.2 µg/l) to 16 µg/l (relative to the human health criteria of 10 µg/l). For the same locations, dissolved nickel concentrations ranged from 25.7 µg/l to 59.8 µg/l, relative to the ecological criteria of 4 µg/l and the human health criteria of 20 µg/l.

- Within the Shallee mining area, dissolved lead exceeded the ecological criteria of 1.2 µg/l and the drinking water (10 µg/l) assessment criteria at eight of the nine locations, with the exceedances ranging from 11 µg/l to 406 µg/l at SW6-Shal (SW13-Shal did not exceed the drinking water criteria with a value of 2.86 µg/l). In samples from previous monitoring, the lead concentrations have been high in SW6-Shal (237 µg/l Sep 2018, 417 µg/l Feb 2018) and SW9-Shal (151 µg/l Sep 2018, 260 µg/l Feb 2018). The concentrations remained high for the February 2019 sampling; SW6-Shal, 406 µg/l and SW9-Shal, 233 µg/l.

- SW12-Shal is an upgradient location in the Shallee mining area. At this location, the pH at SW12-Shal was low in this round (pH 4.26) relative to a similarly low pH during the last low flow sampling round (pH 4.23 at SW12-Shal in Sept 2018). In Sept 2018, the lead concentration at SW12-Shal, was the highest within the mining area. This was unusual compared to previous sampling rounds. The lead concentration at SW12-Shal in February 2019 was 101 µg/l and was not the highest concentration in the Shallee mining area (see previous bullet). The lower pH at SW12-SHAL would potentially indicate dissolution of metal bearing mineral phases if more exposure/interaction between the water and minerals occurred. However, such low pH values have previously been observed without elevated lead concentrations. The recent sample collected in Feb (Pb, 101 µg/l) is still high but appears to be returning to previous lower values. The lead values in this mining area will continue to be reviewed to assess the values during upcoming monitoring.

- Within the mining areas of Shallee, Garryard and Silvermines, dissolved zinc was detected at all monitoring locations, with concentrations in those mining areas ranging from 3 µg/l to 12,900 µg/l (SW5-GAR), the majority of which locations exceeded the ecological assessment criteria of 100 µg/l. The concentration of dissolved zinc at DS-Shal on the Yellow River tributary was 3,420 µg/l, similar to that concentration found during February 2018.

- On the Kilmastulla River, the concentration of dissolved zinc increased from 7.99 µg/l at the upstream location (SW17-Gort) to 297 µg/l downstream at SW12-Gort-DS in the Gortmore area. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard, Shallee and Gorteenadiha.

- Manganese concentration at Gort-TMF-Seep was 1,920 µg/l and exceeded the ecological assessment criteria of 1,100 µg/l and the drinking water criteria of 50 µg/l and iron, 59,400 µg/l exceeded the drinking water criteria of 200 µg/l. Sulphate concentration in the Gort-TMF-Seep sample was 2,490 mg/l and pH and EC were 3.25 and 3.269 µS/cm respectively.

- The sample from Gort-TMF-Seep had the following concentration of dissolved metals; aluminium, 963 µg/l (exceeding the human health criteria of 200 µg/l but not the ecological assessment criteria of 1,900 µg/l), arsenic, 27.8 µg/l (exceeding the ecological assessment criteria of 25 µg/l and the human health criteria of 10 µg/l), cadmium, 118 µg/l (exceeding the ecological assessment criteria of 0.9 µg/l and the human health criteria of 5 µg/l), copper, 269 µg/l (exceeding the ecological assessment criteria of 30 µg/l but not the human health criteria of 2,000 µg/l), lead of 13.5 µg/l (exceeding the ecological assessment criteria of 1.2 µg/l and the human health criteria of 10 µg/l), nickel of 167 µg/l (exceeding the ecological assessment criteria of 4 µg/l and the human health criteria of 20 µg/l), cobalt, 16.2 µg/l (exceeding the ecological assessment criteria of 5.1 µg/l) and zinc 35,000 µg/l (exceeding the ecological assessment criteria 100 µg/l).

The zinc value at Gort-TMF-Seep of 35 mg/l was the highest observed at Silvermines site. Multiple seeps were observed (red-brown staining and water) in the area over a distance of approximately 90 m, with intermittent seeps and staining over a distance of a further 120 m (see Figure 2). The pH of all the seeps was measured and the seep with the lowest pH was sampled (grab sample) and analysed (see concentrations in above bullet). The flow at the individual seeps was relatively low and it was not possible to complete a flow measurement.

c

**Figure 2 Gort-TMF-Seep location**

- The discharge location SW10-Gort-Discharge within Gortmore had a zinc concentration of 1,950 µg/l, while, SW12-Gort-Discharge had a zinc concentration of 263 µg/l.
- Aside from the sample discharging at Gort-TMF-Seep, the samples from SW10-Gort-Discharge and SW12-GORT-discharge had the highest concentrations of manganese within the Gortmore mining area. The manganese loading however appears seasonally to have greater loading magnitude in the lower flow scenarios of Autumn versus Spring. Manganese values are always higher at lower flow vs higher flow conditions for the same year. Manganese is typically more soluble under reducing conditions. In most cases, the ORP values for low flow conditions are lower than at high flow conditions. However, in most all cases, the ORP values measured reflect manganese reducing conditions (ORP < 300 – 400 mV depending upon pH). The higher concentrations at lower flow rates probably reflect the longer contact time between the water and the mineral phases.
- The dissolved metal with the highest mass loading was zinc ranging from 2.5 g/day to 35.6 kg/day with a median value of 754 g/day. The largest mass load of zinc (35.6 kg/day) was found at DS-Gort which is located on the Kilmastulla River, downstream of Gortmore TMF. The highest load of dissolved lead was found at SW4-Shal (1,687 g/day).
- This monitoring round took place following the Winter 2018-Spring 2019 period. Flows measured in Spring 2019 were lower than in the previous high flow monitoring in Spring 2018, but generally within the same order of magnitude. Flows ranged from 0.16 l/s at SW7-Gar to 111 l/s at SW4-SM-GA.
- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated Lead levels (>50 µg/l).
- Horses were not observed on the Gortmore TMF during this sampling period.
- No seeps or additional drainages were observed during a walkover of the Shallee stream and Yellow Bridge River confluence areas.

## 7.2 Recommendations for the Monitoring Programme

The following recommendations are proposed:

- During this monitoring event, at locations with greater flow, trial use was made of a flow methodology using a HACH digital flow meter; a Marsh McBirney meter was also used along-side to measure flow velocities and depths at regular intervals across stream sections at certain locations. Both the HACH meter and the manual measurement operate on the same flow measurement principle, however, the new HACH meter digitally performs calculations and records readings. It is proposed that locations and flow conditions which currently allow for flow monitoring using the Marsh McBirney will have the flow measurement taken with the HACH digital flow meter, for ease of flow measurement. The use of the digital flow meter from the trial flow testing is being reviewed to confirm the methodology for future use.
- A stream walk survey near the Shallee stream and Yellow Bridge River confluence to confirm absence/presence of additional inflows; this will continue for the next monitoring round to determine if there are any additional flows during the low flow event;

- Continuation of the inspection of the outflow of the Garryard tailings lagoon to ensure the outflow is free flowing and blockages do not exist; and
- Continued request to the laboratory to specify a faster turnaround time for Total Organic Carbon (TOC) analysis to ensure that the sample holding times are not exceeded in future sampling rounds.

In addition, sampling locations were independently reviewed to ensure compliance with health and safety requirements for access. The following locations were noted as requiring action:

- SW6-Shal: Sampling this location previously required crawling under the fence to get access to the discharge using a bucket and stopwatch to measure flow (flow may not be accurately measured). During the February 2019 visit, it was not possible to get a flow measurement downstream of SW6-Shal as the area is unsuitable for flow measurement (wide, pooled area). The sample was collected under the fence, but additional controls were put in place (the sampler wore a hard hat). The site and issues were documented with pictures and notes and will be reviewed with the client and sampling team before the next sampling campaign.
- SW4-Shal: Previously this location was accessed by walking over sheets of galvanised metal under which the conditions are not known. For the February 2019 visit, an alternative access route was used. The sampling site is at the southwestern periphery of the Shallee Mining Site. The sampling team spoke to the farmer who owns the field adjacent to this site. The farmer granted access to the land and this site can now be accessed by walking through fields with no H&S risk. Samplers should call in to the farmer on each sampling occasion before accessing the farmers land.
- SW5-SM: Access to this location previously required crossing a field containing a bull. During February 2019, a safer access route was located via the road to the west or a location downgradient from SW5-SM with safe access. For the February 2019 visit, the bull was not in the field; however as discussed, another access route, that does not require accessing the field where the bull is sometimes located, has been found. This access route will be used going forward.
- As discussed, measurement of flow on the Kilmastulla River downgradient of the Gortmore TMF at sampling locations SW14-Gort and SW12-Gort-DS is not possible due to the typical high flow and no access across the river. It is recommended that EPA is requested to install a permanent gauging station in this river section to more accurately evaluate metal mass loading and impact associated with the Gortmore TMF. Flow measurement and mass loading will also be useful to evaluate improvements in water quality if upgrades to the constructed wetlands are conducted.

# Section 8

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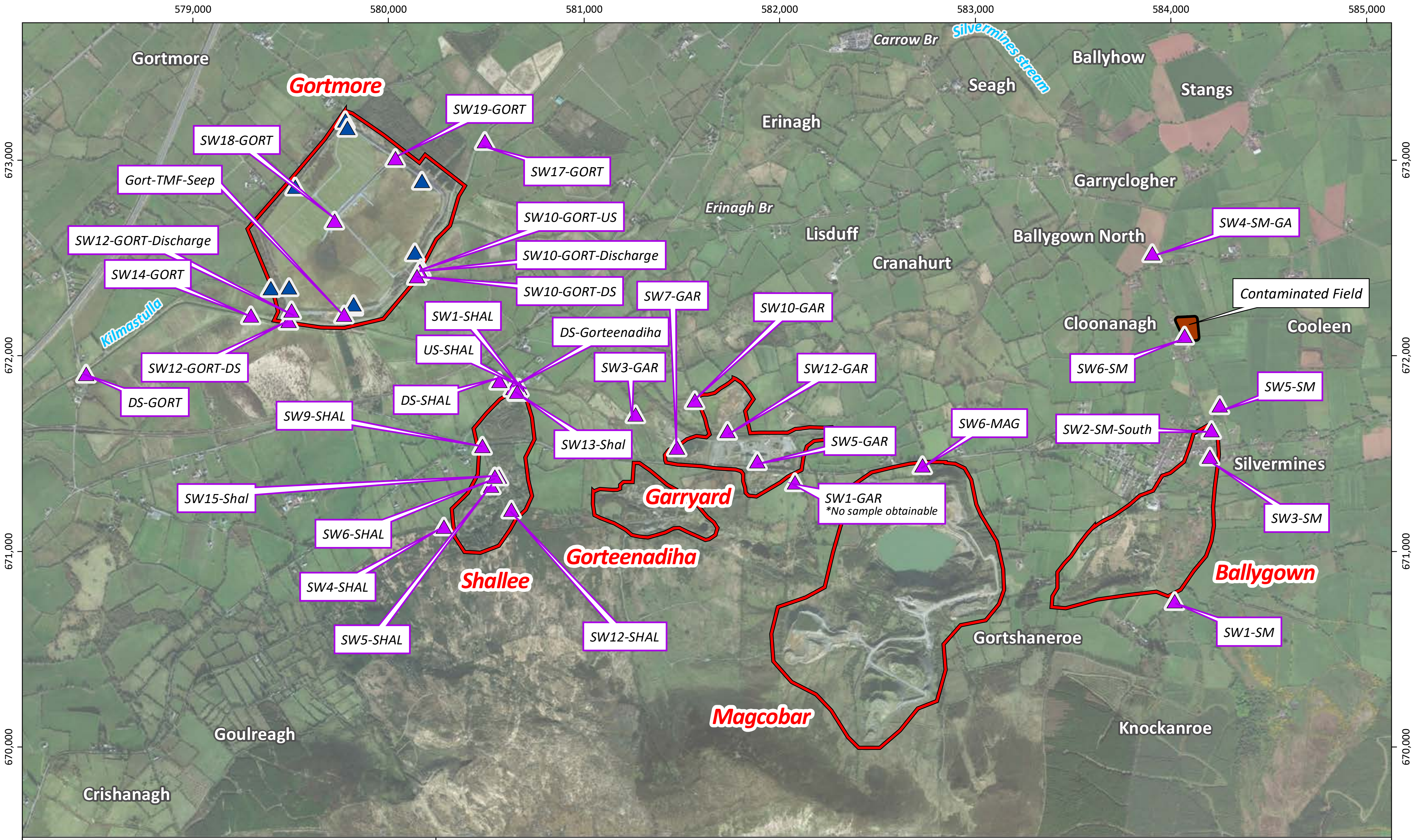
# Appendix A

# Figures



# Map 1 - Silvermines - Overview

*Drawn by: SM Date: 10/07/2019*

*Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\15_MonReport_R3\MXD\01_SilverMon1.mxd*

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CDM Smith

**Legend**

**Sampling Locations**

- ▲ Surface water
- ▲ Groundwater

- Rivers
- Streams
- Pond / Wetland / Pit Lake
- Contaminated Field

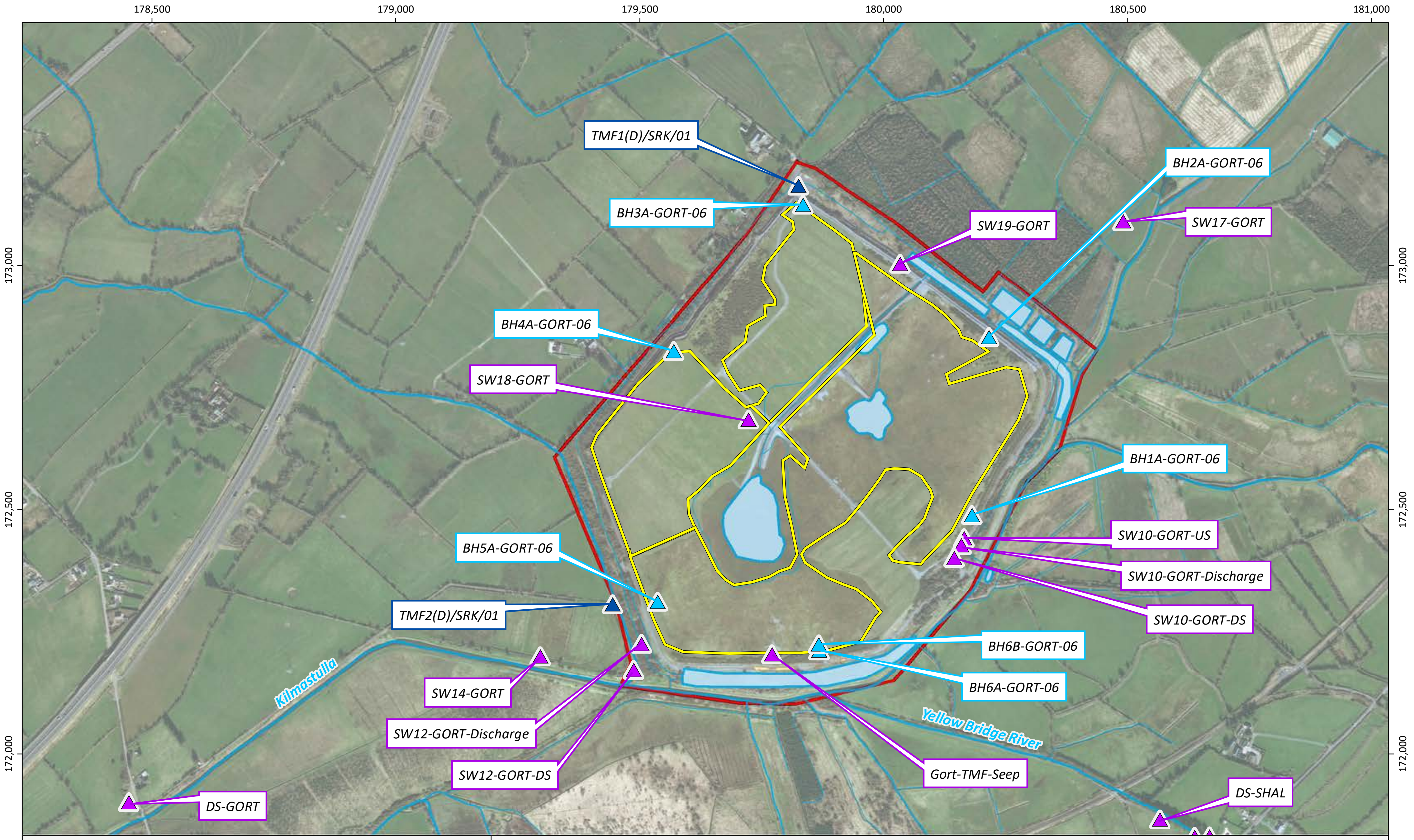
**Mines**

- Mining Areas
- Spoil Heap / Stockpile Dump / Waste Drum Dump / Tailings / Tailings Pond
- Open Pit

*Scale is 1:25,000*

0 125 250 500 m

N W E S



# *Map 2 - Silvermines - Gortmore TMF*

*Drawn by: SM Date: 10/07/2019*

*Internal Project Reference: Q:\118000-118499\118174\
40 Documents Generated\GIS\02_GIS_Tasks\15_MonReport_R3\MXD\
02_SilverMonGM.mxd*

*Source: ESRI World Imagery© ESRI (Vivid imagery courtesy of DigitalGlobe, acquired on 11/03/2014)*

**Legend**

***Sampling Locations***

- ▲ Surface water
- ▲ Groundwater
- ▲ Groundwater *(Levels only)*

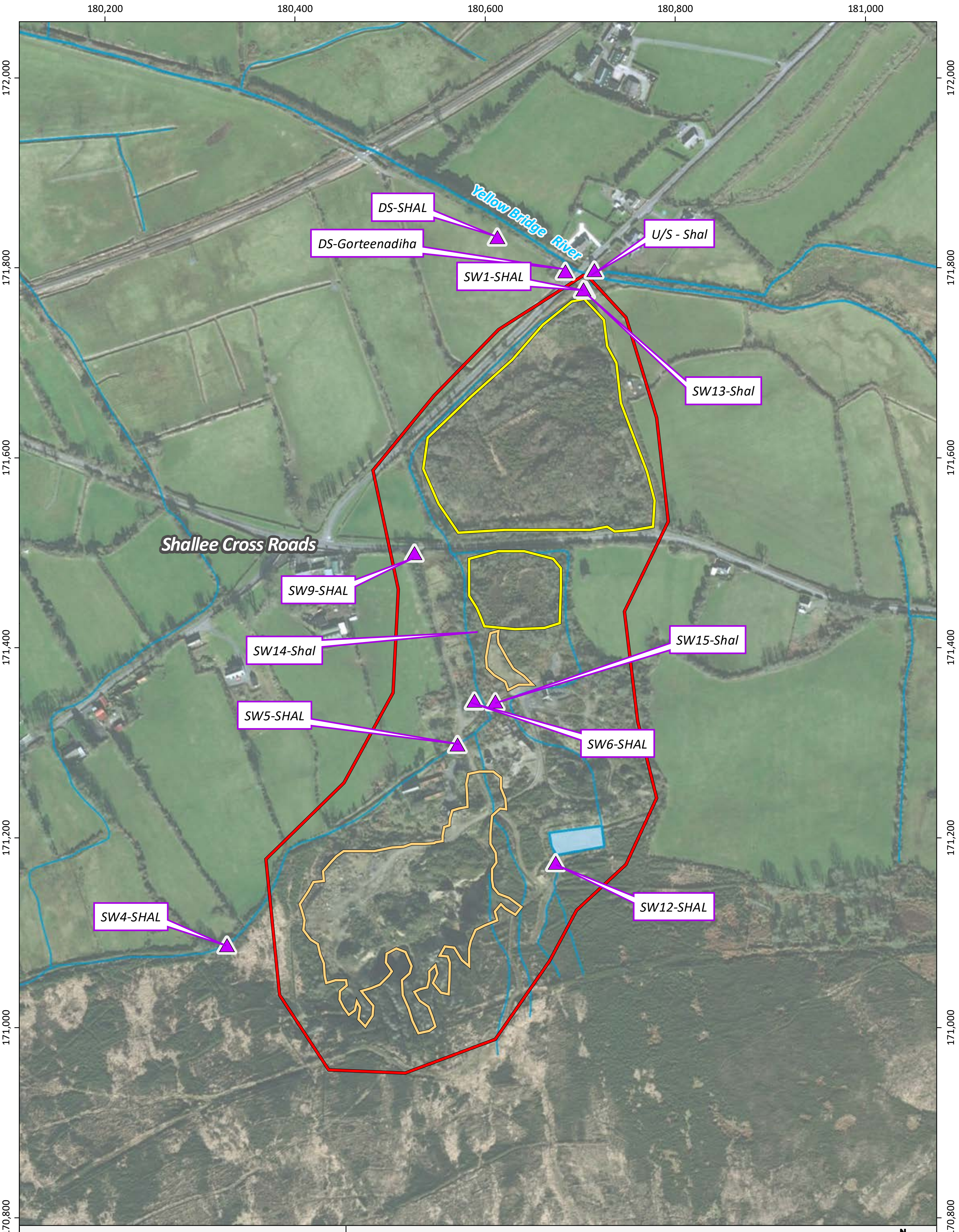
- Rivers
- Streams
- Pond / Wetland / Pit Lake

***Mines***

- Mining Areas

*Scale is 1:10,000*

0 100 200 m



# Map 3 - Silvermines - Shallee South

*Drawn by: SM* *Date: 10/07/2019*

*Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\15_MonReport_R3\MXD\03_SilverMonSh.mxd*

*Source: ESRI World Imagery© ESRI (Vivid imagery courtesy of DigitalGlobe, acquired on 11/03/2014)*

CDM Smith

## Legend

***Sampling Locations***

▲ Surface water

Rivers

Streams

Pond / Wetland

***Mines***

Mining Areas

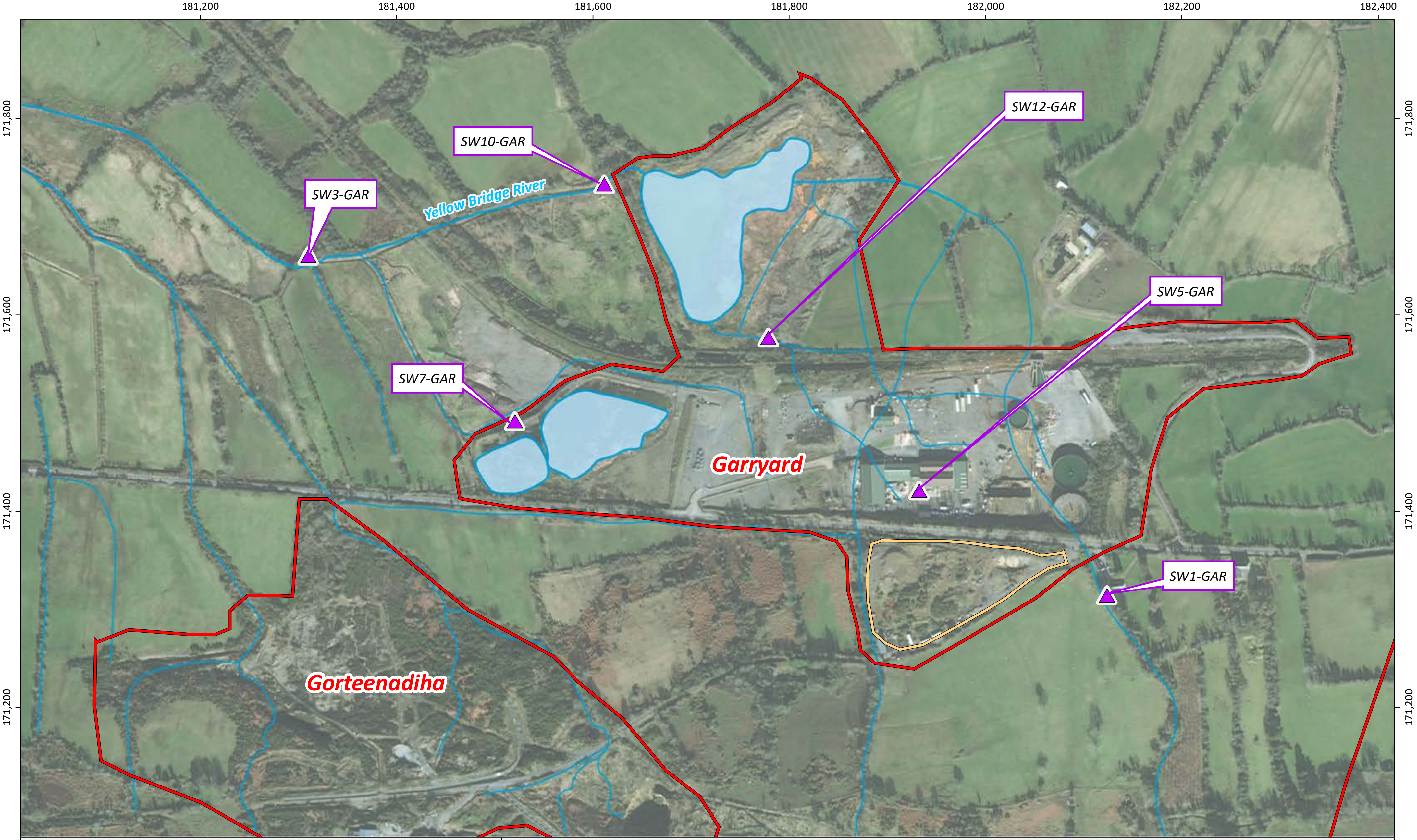
Tailings / Tailings Pond

Spoil Heap / Waste Drum Dump

N W E S

*Scale is 1:5,000*

0 50 100 m



# Map 4 - Silvermines - Garryard

*Drawn by: SM Date: 10/07/2019*

*Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\15_MonReport_R3\MXD\04_SilverMonGAR.mxd*

*Source: ESRI World Imagery© ESRI (Vivid imagery courtesy of DigitalGlobe, acquired on 11/03/2014)*

CDM Smith

***Legend***

***Sampling Locations***

▲ Surface water

Rivers

Streams

Pond / Wetland

***Mines***

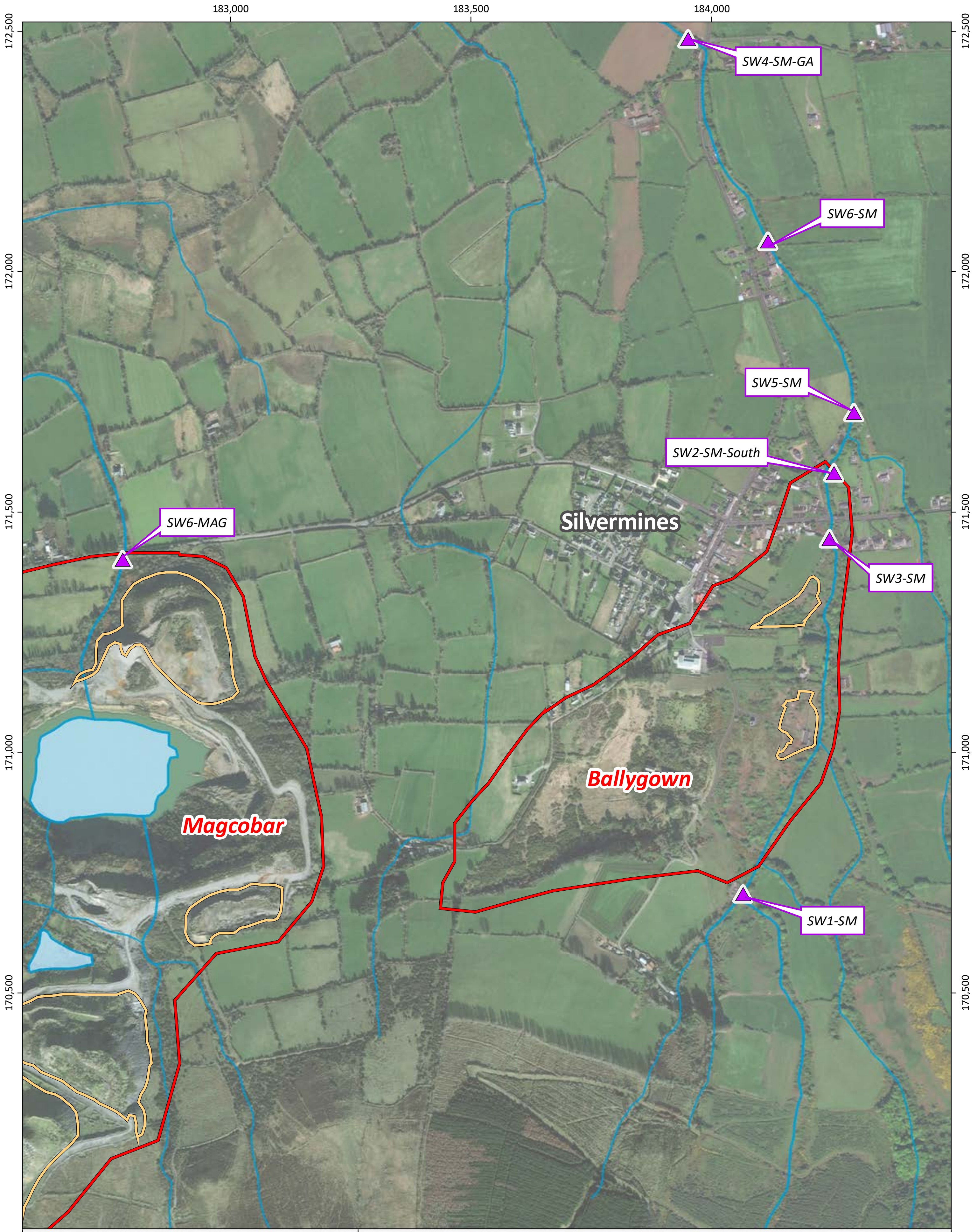
Mining Areas

Stockpile Dump

*Scale is 1:5,000*

0 50 100 m

N S W E



# Map 5 - Silvermines - Magcobar and Ballygown

*Drawn by: SM Date: 10/07/2019*

*Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\15_MonReport_R3\MXD\05_SilverMonMaBG.mxd*

*Source: ESRI World Imagery© ESRI (Vivid imagery courtesy of DigitalGlobe, acquired on 11/03/2014)*

# Appendix B

# Analytical Data Tables and Assessment Criteria

**Table B-1 Comparison of Groundwater and**
**Surface Water Results to Assessment Criteria R3 (Feb 2019)**

| Sample Description | Type | Area | Date Sampled | pH (field) | Conductance @ deg.C (field) | dissolved (field) | Organic Carbon | Ammoniacal Nitrogen as N | Sulphate | Aluminium (diss.filt) | Antimony (diss.filt) | Arsenic (diss.filt) | Barium (diss.filt) | Cadmium (diss.filt) | Calcium (diss.filt) | Chromium (diss.filt) | Cobalt (diss.filt) | Copper (diss.filt) | Iron (diss.filt) | Lead (diss.filt) | Manganese (diss.filt) | Molybdenum (diss.filt) | Nickel (diss.filt) | Zinc (diss.filt) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Units | pH Units | µS/cm | % Sat | mg/l | mg/l | mg/l | µg/l | µg/l | µg/l | µg/l | µg/l | mg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l |
| **Ecological Criteria** |  |  |  | **4.5 to 9** | **-** | **80 to 120*** | **-** | **0.14** | **-** | **1,900** | **-** | **25** | **4** | **0.9** | **-** | **3.4** | **5.1** | **30** | **-** | **1.2** | **1100** | **-** | **4** | **100** |
| **Human Health Criteria** |  |  |  | **6.5 to 9.5** | **2,500** | **-** | **-** | **0.3** | **250** | **200** | **5** | **10** | **-** | **5** | **-** | **50** | **-** | **2000** | **200** | **10** | **50** | **-** | **20** | **-** |
| TMF1 | Groundwater | GM | 20/02/2019 | 7.4 | 454 | 28.8 | 1.5 | 0.1 | 22.3 | 5 | 0.5 | 2.26 | 151 | 0.04 | 71 | 0.5 | 0.25 | 0.15 | 156 | 0.1 | 96.3 | 1.5 | 0.481 | 2.09 |
| TMF2 | Groundwater | GM | 20/02/2019 | 7.03 | 488 | 6.8 | 1.5 | 0.1 | 3.6 | 5 | 0.5 | 5.29 | 629 | 0.04 | 92 | 0.5 | 0.633 | 0.15 | 269 | 1.49 | 1110 | 7.18 | 0.686 | 4.24 |
| SW18-GORT | Drainage | GM | 20/02/2019 | 7.61 | 985 | 100 | - | 0.1 | 467 | 5 | 0.5 | 1.25 | 20.8 | 4.67 | - | 0.5 | 0.25 | 4.16 | 81.4 | 11.4 | 314 | 1.5 | 12.2 | 1860 |
| SW19-GORT | Drainage | GM | 20/02/2019 | 7.89 | 994 | 88.4 | - | 0.1 | 462 | 5 | 0.5 | 1.3 | 21.1 | 2.74 | - | 0.5 | 0.25 | 3.02 | 26.5 | 3.9 | 48.7 | 1.5 | 8.77 | 1350 |
| SW17-GORT | River/Stream | GM | 20/02/2019 | 7.06 | 444 | 96.7 | 4.71 | 0.1 | 30.3 | 14.4 | 0.5 | 1.01 | 225 | 0.04 | 71.6 | 0.5 | 0.25 | 2.1 | 58.3 | 1.6 | 35 | 1.5 | 0.969 | 7.99 |
| SW10-GORT US | River/Stream | GM | 20/02/2019 | 7.99 | 491 | 92.7 | 5.01 | 0.1 | 44.9 | 12.4 | 0.5 | 0.682 | 164 | 0.134 | 85.3 | 0.5 | 0.25 | 1.75 | 60.4 | 0.840 | 32.3 | 1.5 | 1.63 | 68.3 |
| SW10-GORT DISCHARGE | Discharge | GM | 20/02/2019 | 7.5 | 1378 | 82.4 | - | 0.1 | 719 | 5 | 0.5 | 1.66 | 16.4 | 0.238 | - | 0.5 | 0.25 | 0.85 | 9.5 | 0.27 | 66.3 | 1.5 | 13.5 | 1950 |
| SW10-GORT DS | River/Stream | GM | 20/02/2019 | 8.02 | 506 | 97.8 | 4.68 | 0.1 | 54.7 | 14 | 0.5 | 0.25 | 156 | 0.136 | 86.4 | 0.5 | 0.25 | 2 | 57.2 | 0.846 | 33.6 | 3.43 | 1.8 | 92.4 |
| GORT-TMF-SEEP | Seep | GM | 20/02/2019 | 3.24 | 3269 | 95.8 | 1.5 | 0.68 | 2490 | 963 | 0.5 | 27.8 | 9 | 118 | 479 | 2.79 | 16.2 | 269 | 59400 | 13.5 | 1920 | 1.5 | 167 | 35000 |
| SW12-GORT DISCHARGE | Discharge | GM | 20/02/2019 | 6.95 | 1201 | 46.8 | - | 0.1 | 479 | 5 | 0.5 | 1.42 | 197 | 0.10 | - | 0.5 | 0.25 | 0.774 | 81.9 | 0.1 | 165 | 1.5 | 4.34 | 263 |
| SW12-GORT DS | River/Stream | GM | 20/02/2019 | 7.94 | 512 | 96.7 | 4.34 | 0.1 | 64.9 | 14 | 0.5 | 0.906 | 167 | 1.12 | 88.4 | 0.5 | 0.25 | 2.58 | 59.1 | 3.02 | 48 | 1.5 | 2.66 | 297 |
| SW14-GORT | River/Stream | GM | 20/02/2019 | 7.95 | 456 | 101.6 | 7.74 | 0.1 | 51.3 | 15.5 | 0.5 | 0.668 | 169 | 1.03 | 76.5 | 0.5 | 0.25 | 2.34 | 55.56 | 2.75 | 41 | 1.5 | 2.57 | 253 |
| DS-GORT | River/Stream | GM | 20/02/2019 | 7.94 | 462 | 102.5 | 4.4 | 0.1 | 52.8 | 16.6 | 0.5 | 0.723 | 160 | 0.852 | 74.4 | 0.5 | 0.25 | 2.59 | 45.8 | 2.46 | 41.8 | 1.5 | 2.19 | 234 |
| SW6-MAG | River/Stream | Mag | 19/02/2019 | 7.63 | 494 | 100 | 1.5 | 0.1 | 211 | 13.1 | 0.5 | 0.798 | 43.3 | 1.81 | 64 | 0.5 | 0.733 | 6.04 | 9.5 | 0.1 | 57.5 | 1.5 | 9.74 | 893 |
| US-SHAL | River/Stream | Shal | 18/02/2019 | 8.11 | 912 | 104 | 1.5 | 0.1 | 368 | 5 | 0.5 | 1.63 | 47.9 | 37.8 | 149 | 0.5 | 2.86 | 3.36 | 38.4 | 5.82 | 493 | 7.74 | 30.8 | 8150 |
| SW4-SHAL | Drainage | Shal | 18/02/2019 | 6.6 | 92 | 82.3 | - | 0.1 | 11.3 | 14.9 | 0.5 | 0.25 | 411 | 0.793 | - | 0.5 | 0.931 | 2.36 | 9.5 | 55.4 | 43.9 | 1.5 | 4.84 | 80.4 |
| SW5-SHAL | Drainage | Shal | 18/02/2019 | 6.86 | 210 | 98.8 | - | 0.1 | 63.2 | 41.3 | 0.5 | 0.25 | 313 | 16.3 | - | 0.5 | 3.31 | 14.6 | 9.5 | 21.1 | 461 | 1.5 | 38.7 | 5220 |
| SW6-SHAL | Discharge | Shal | 18/02/2019 | 6.35 | 135 | 65.1 | - | 0.1 | 13.2 | 30.8 | 1.01 | 1.17 | 263 | 1.18 | - | 0.5 | 1.84 | 18.6 | 61.6 | 406 | 68.7 | 1.5 | 8.95 | 211 |
| SW15-SHAL | Drainage | Shal | 18/02/2019 | 6.15 | 217 | 98.5 | 1.5 | 0.1 | 64.6 | 25.9 | 0.5 | 0.537 | 270 | 16.4 | 23.3 | 0.5 | 2.83 | 11 | 9.5 | 11 | 394 | 1.5 | 38.4 | 5250 |
| SW9-SHAL | River/Stream | Shal | 18/02/2019 | 7.67 | 172 | 104.5 | 1.5 | 0.1 | 26.7 | 24.3 | 1.08 | 0.934 | 239 | 3.39 | 21.4 | 0.5 | 1.42 | 12.7 | 32.6 | 233 | 72.3 | 1.5 | 12.6 | 944 |
| SW12-SHAL | Drainage | Shal | 18/02/2019 | 4.26 | 57 | 99.5 | - | 0.1 | 7.4 | 117 | 0.5 | 0.25 | 349 | 0.287 | 0.964 | 0.5 | 0.73 | 1.64 | 9.5 | 101 | 233 | 1.5 | 3.01 | 50 |
| SW13-SHAL | Drainage | Shal | 18/02/2019 | 7.63 | 270 | 81.5 | - | 0.1 | 28.2 | 5 | 1.4 | 0.76 | 141 | 0.258 | - | 0.5 | 0.25 | 1.64 | 9.5 | 2.86 | 10 | 1.5 | 1.41 | 34.9 |
| SW1-SHAL | River/Stream | Shal | 18/02/2019 | 7.8 | 185 | 100.6 | 1.5 | 0.1 | 29 | 25.5 | 1.16 | 0.538 | 218 | 2.86 | 21.9 | 0.5 | 1.37 | 9.99 | 47.2 | 171 | 77.8 | 1.5 | 11.2 | 753 |
| DS-SHAL | River/Stream | Shal | 18/02/2019 | 7.22 | 484 | 99.5 | 1.5 | 0.1 | 149 | 12.5 | 0.5 | 0.964 | 168 | 15.1 | 71 | 0.5 | 1.44 | 9.46 | 22.4 | 28 | 217 | 1.5 | 14.3 | 3420 |
| DS-GORTEENADIHA | River/Stream | Gtd | 18/02/2019 | 8.32 | 146 | 97 | 1.5 | 0.1 | 16.3 | 20.8 | 0.5 | 0.25 | 246 | 1.05 | 15.3 | 0.5 | 0.25 | 17.2 | 43.8 | 28.6 | 26.4 | 1.5 | 3.06 | 173 |
| SW1-GAR | River/Stream | Gar | 19/02/2019 | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] |
| SW5-GAR | Discharge | Gar | 19/02/2019 | 6.99 | 797 | 58.3 | - | 0.1 | 284 | 5 | 1.62 | 1.68 | 24.3 | 24.5 | - | 0.5 | 4.51 | 1.71 | 9.5 | 12.2 | 422 | 1.5 | 59.8 | 12900 |
| SW12-GAR | Drainage | Gar | 19/02/2019 | 7.74 | 864 | 90.1 | - | 0.1 | 345 | 5 | 1.49 | 1.14 | 22.8 | 26.4 | - | 0.5 | 3.62 | 1.68 | 9.5 | 5.76 | 353 | 1.5 | 55.8 | 12700 |
| SW10-GAR | Discharge | Gar | 19/02/2019 | 8.13 | 947 | 95.3 | 1.5 | 0.1 | 404 | 5 | 0.5 | 0.25 | 22.8 | 44.5 | 157 | 0.5 | 1.77 | 2.36 | 9.5 | 2.34 | 146 | 1.5 | 34.4 | 9010 |
| SW7-GAR | Drainage | Gar | 19/02/2019 | 7.79 | 625 | 90 | - | 0.1 | 183 | 28.5 | 0.5 | 0.795 | 95.5 | 0.49 | - | 0.5 | 0.25 | 0.318 | 9.5 | 0.375 | 35.6 | 1.5 | 1.79 | 177 |
| SW3-GAR | River/Stream | Gar | 19/02/2019 | 8.03 | 944 | 96.3 | 3.82 | 0.201 | 325 | 5 | 0.5 | 1.28 | 54.2 | 29.1 | 137 | 0.5 | 1.62 | 6.52 | 66.2 | 16 | 183 | 1.5 | 25.7 | 6650 |
| SW1-SM | River/Stream | Bg | 19/02/2019 | 7.61 | 165 | 92.7 | 1.5 | 0.1 | 7.8 | 5 | 0.5 | 0.25 | 55.9 | 0.04 | 17.8 | 0.5 | 0.25 | 0.477 | 27.2 | 0.695 | 5.1 | 1.5 | 0.546 | 3.33 |
| SW3-SM | River/Stream | Bg | 19/02/2019 | 7.73 | 181 | 98.5 | 1.5 | 0.1 | 9.4 | 5 | 0.5 | 0.25 | 63.2 | 0.281 | 25.6 | 0.5 | 0.25 | 0.15 | 9.5 | 1.68 | 1.5 | 1.5 | 0.887 | 96.1 |
| SW2-SM-SOUTH | Discharge | Bg | 19/02/2019 | 7.15 | 511 | 58.9 | - | 0.1 | 31.4 | 5 | 0.5 | 0.25 | 163 | 5.67 | - | 0.5 | 0.25 | 0.15 | 9.5 | 1.39 | 1.5 | 1.5 | 6.7 | 2000 |
| SW5-SM | River/Stream | Bg | 19/02/2019 | 7.73 | 306 | 97.2 | 5.36 | 3.09 | 21.2 | 12.7 | 0.5 | 0.25 | 88.9 | 0.465 | 39.2 | 0.5 | 0.25 | 3.18 | 26 | 1.32 | 7.45 | 1.5 | 1.34 | 216 |
| SW6-SM | River/Stream | Bg | 19/02/2019 | 7.90 | 290 | 93 | 1.5 | 0.1 | 13.1 | 5 | 0.5 | 0.25 | 119 | 0.641 | 45.2 | 0.5 | 0.25 | 0.376 | 9.5 | 1.79 | 6.6 | 1.5 | 1.31 | 258 |
| SW4-SM-GA | River/Stream | Bg | 19/02/2019 | 8 | 296 | 93 | 1.5 | 0.1 | 13.9 | 5 | 0.5 | 0.25 | 119 | 0.564 | 46.2 | 0.5 | 0.25 | 0.15 | 9.5 | 1.72 | 5.99 | 1.5 | 1.31 | 242 |

[1] Dry, no sample

- Not analysed or no assessment criteria

*xx Less than the Limit of Detection (LOD) - Value given is 0.5 of LOD*

* Only applies to rivers or streams (i.e. not discharges)

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health

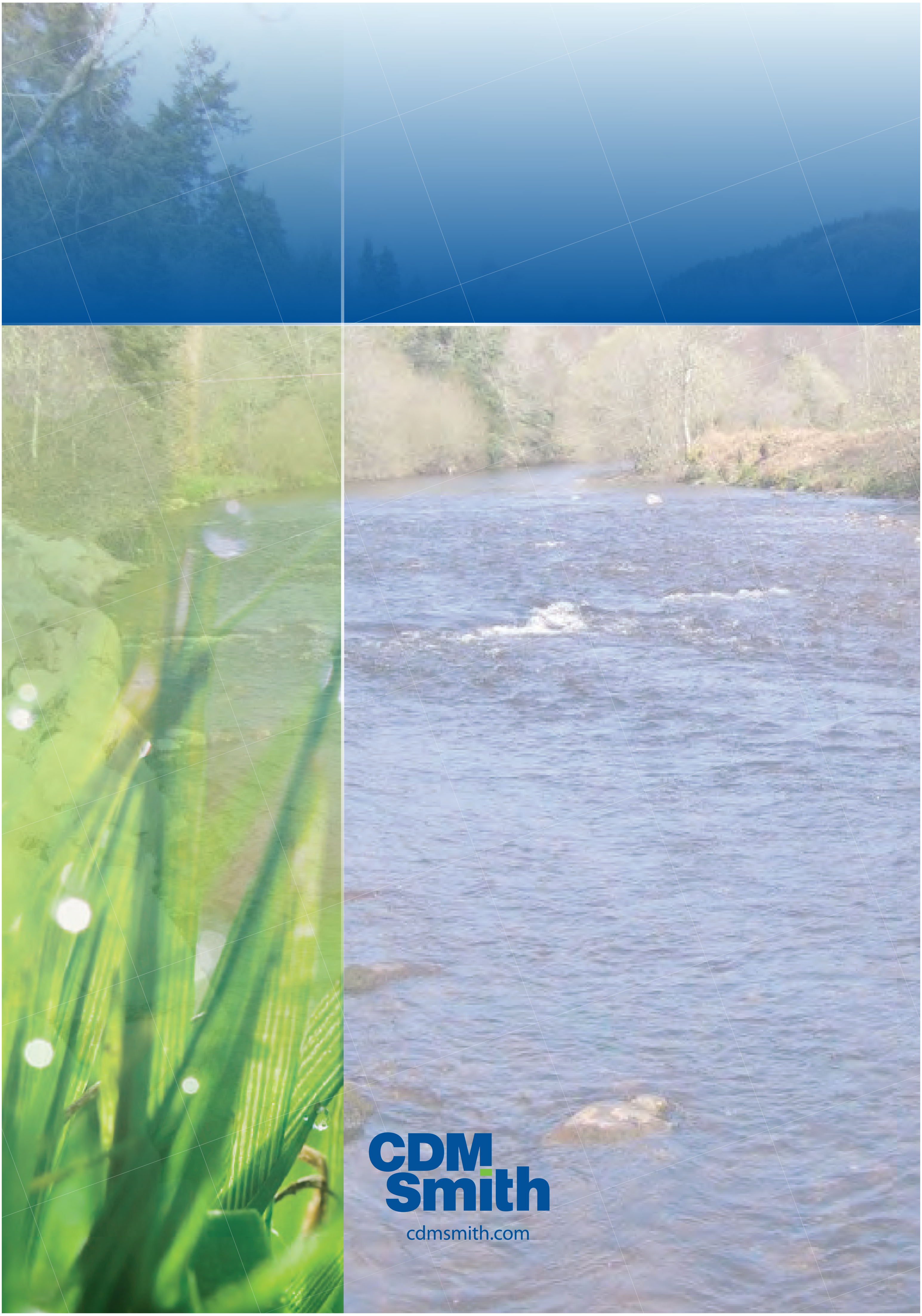
**Table B-2 Comparison of Surface Water Results to Assessment Criteria for Livestock Drinking Water R3 (Feb 2019)**

| Sample Description | Area | Type | Date Sampled Units | Sulphate mg/l | Aluminium (diss.filt) µg/l | Arsenic (diss.filt) µg/l | Cadmium (diss.filt) µg/l | Chromium (diss.filt) µg/l | Cobalt (diss.filt) µg/l | Copper (diss.filt) µg/l | Lead (diss.filt) µg/l | Vanadium (diss.filt) µg/l | Zinc (diss.filt) µg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Livestock Criteria** | | | | **500** | **5000** | **200** | **50** | **1000** | **1000** | **500** | **100** | **100** | **24000** |
| SW18-GORT | Drainage | GM | 20/02/2019 | 467 | 5 | 1.25 | 4.67 | 0.5 | 0.25 | 4.16 | 11.4 | 0.5 | 1860 |
| SW19-GORT | Drainage | GM | 20/02/2019 | 462 | 5 | 1.3 | 2.74 | 0.5 | 0.25 | 3.02 | 3.9 | 0.5 | 1350 |
| SW17-GORT | River/Stream | GM | 20/02/2019 | 30.3 | 14.4 | 1.01 | 0.04 | 0.5 | 0.25 | 2.1 | 1.6 | 0.5 | 7.99 |
| SW10-GORT US | River/Stream | GM | 20/02/2019 | 44.9 | 12.4 | 0.682 | 0.134 | 0.5 | 0.25 | 1.75 | 0.84 | 0.5 | 68.3 |
| SW10-GORT DISCHARGE | Discharge | GM | 20/02/2019 | 719 | 5 | 1.66 | 0.238 | 0.5 | 0.25 | 0.848 | 0.269 | 0.5 | 1950 |
| SW10-GORT DS | River/Stream | GM | 20/02/2019 | 54.7 | 14 | 0.25 | 0.136 | 0.5 | 0.25 | 2 | 0.846 | 0.5 | 92.4 |
| GORT-TMF-SEEP | Seep | GM | 20/02/2019 | 2490 | 963 | 27.8 | 118 | 2.79 | 16.2 | 269 | 13.5 | 0.5 | 35000 |
| SW12-GORT DISCHARGE | Discharge | GM | 20/02/2019 | 479 | 5 | 1.42 | 0.0996 | 0.5 | 0.25 | 0.774 | 0.1 | 0.5 | 263 |
| SW12-GORT DS | River/Stream | GM | 20/02/2019 | 64.9 | 14 | 0.906 | 1.12 | 0.5 | 0.25 | 2.58 | 3.02 | 0.5 | 297 |
| SW14-GORT | River/Stream | GM | 20/02/2019 | 51.3 | 15.5 | 0.668 | 1.03 | 0.5 | 0.25 | 2.34 | 2.75 | 0.5 | 253 |
| DS-GORT | River/Stream | GM | 20/02/2019 | 52.8 | 16.6 | 0.723 | 0.852 | 0.5 | 0.25 | 2.59 | 2.46 | 0.5 | 234 |
| SW6-MAG | River/Stream | Mag | 19/02/2019 | 211 | 13.1 | 0.798 | 1.81 | 0.5 | 0.733 | 6.04 | 0.1 | 0.5 | 893 |
| US-SHAL | River/Stream | Shal | 18/02/2019 | 368 | 5 | 1.63 | 37.8 | 0.5 | 2.86 | 3.36 | 5.82 | 0.5 | 8150 |
| SW4-SHAL | Drainage | Shal | 18/02/2019 | 11.3 | 14.9 | 0.25 | 0.793 | 0.5 | 0.931 | 2.36 | 55.4 | 0.5 | 80.4 |
| SW5-SHAL | Drainage | Shal | 18/02/2019 | 63.2 | 41.3 | 0.25 | 16.3 | 0.5 | 3.31 | 14.6 | 21.1 | 0.5 | 5220 |
| SW6-SHAL | Discharge | Shal | 18/02/2019 | 13.2 | 30.8 | 1.17 | 1.18 | 0.5 | 1.84 | 18.6 | 406 | 0.5 | 211 |
| SW15-SHAL | Drainage | Shal | 18/02/2019 | 64.6 | 25.9 | 0.537 | 16.4 | 0.5 | 2.83 | 11 | 11 | 0.5 | 5250 |
| SW9-SHAL | River/Stream | Shal | 18/02/2019 | 26.7 | 24.3 | 0.934 | 3.39 | 0.5 | 1.42 | 12.7 | 233 | 0.5 | 944 |
| SW12-SHAL | Drainage | Shal | 18/02/2019 | 7.4 | 117 | 0.25 | 0.287 | 0.5 | 0.73 | 1.64 | 101 | 0.5 | 50 |
| SW13-SHAL | Drainage | Shal | 18/02/2019 | 28.2 | 5 | 0.76 | 0.258 | 0.5 | 0.25 | 1.64 | 2.86 | 0.5 | 34.9 |
| SW1-SHAL | River/Stream | Shal | 18/02/2019 | 29 | 25.5 | 0.538 | 2.86 | 0.5 | 1.37 | 9.99 | 171 | 0.5 | 753 |
| DS-SHAL | River/Stream | Shal | 18/02/2019 | 149 | 12.5 | 0.964 | 15.1 | 0.5 | 1.44 | 9.46 | 28 | 0.5 | 3420 |
| DS-GORTEENADIHA | River/Stream | Gtd | 18/02/2019 | 16.3 | 20.8 | 0.25 | 1.05 | 0.5 | 0.25 | 17.2 | 28.6 | 0.5 | 173 |
| SW1-GAR | River/Stream | Gar | 19/02/2019 | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] | [1] |
| SW5-GAR | Discharge | Gar | 19/02/2019 | 284 | 5 | 1.68 | 24.5 | 0.5 | 4.51 | 1.71 | 12.2 | 0.5 | 12900 |
| SW12-GAR | Drainage | Gar | 19/02/2019 | 345 | 5 | 1.14 | 26.4 | 0.5 | 3.62 | 1.68 | 5.76 | 0.5 | 12700 |
| SW10-GAR | Discharge | Gar | 19/02/2019 | 404 | 5 | 0.25 | 44.5 | 0.5 | 1.77 | 2.36 | 2.34 | 0.5 | 9010 |
| SW7-GAR | Drainage | Gar | 19/02/2019 | 183 | 28.5 | 0.795 | 0.49 | 0.5 | 0.25 | 0.15 | 0.266 | 0.5 | 177 |
| SW3-GAR | River/Stream | Gar | 19/02/2019 | 325 | 5 | 1.28 | 29.1 | 0.5 | 1.62 | 6.52 | 16 | 0.5 | 6650 |
| SW1-SM | River/Stream | Bg | 19/02/2019 | 7.8 | 5 | 0.25 | 0.04 | 0.5 | 0.25 | 0.477 | 0.695 | 0.5 | 3.33 |
| SW3-SM | River/Stream | Bg | 19/02/2019 | 9.4 | 5 | 0.25 | 0.281 | 0.5 | 0.25 | 0.15 | 1.68 | 0.5 | 96.1 |
| SW2-SM-SOUTH | Discharge | Bg | 19/02/2019 | 31.4 | 5 | 0.25 | 5.67 | 0.5 | 0.25 | 0.15 | 1.39 | 0.5 | 2000 |
| SW5-SM | River/Stream | Bg | 19/02/2019 | 21.2 | 12.7 | 0.25 | 0.465 | 0.5 | 0.25 | 3.18 | 1.32 | 0.5 | 216 |
| SW6-SM | River/Stream | Bg | 19/02/2019 | 13.1 | 5 | 0.25 | 0.641 | 0.5 | 0.25 | 0.376 | 1.79 | 0.5 | 258 |
| SW4-SM-GA | River/Stream | Bg | 19/02/2019 | 13.9 | 5 | 0.25 | 0.564 | 0.5 | 0.25 | 0.15 | 1.72 | 0.5 | 242 |

Notes: [1] Dry, no sample

xx Exceeds Livestock Assessment Criteria

*xx Less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD*



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