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 1

February 2018

CDM Smith

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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 2018. This report should be read alongside the Silvermines Data Report (Document Ref: 118174/40/DG/02, dated April 2018) 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, 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 of Ireland (GSI) 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 21 February 2018 as listed in Table 1 and shown on Map 2 in Appendix A. Water levels were measured at an additional seven monitoring wells, 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 C 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 perimeter of the TMF.

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, 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 on the Groundwater Purging and Sampling Form. Field sheets are contained in Appendix H and physico-chemical field data are summarised in Appendix A of the Data Report.

After the well was purged and the parameters have stabilised, the flow is 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.

In February 2018, TMF1 borehole was an exception to the low flow sampling procedure. The borehole was damaged approximately 1m from the surface. A major obstruction exists and the pump could not 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

Thirty five water locations were sampled between 19 and 22 February 2018, as listed in Table 2 and shown on Maps 2 to 5 in **Appendix A**. Two opportunistic samples were collected; "Gort-TMF-Seep" collected at the seeps located at the southern edge of Gortmore TMF and "SW15-Shal" collected from the water discharging into the mine road upgradient of "SW6-Shal" at Shallee. "SW14-Shal" was not sampled due to health and safety access concerns ("SW15-Shal" was sampled as a substitute).

Surface water sampling was conducted in accordance with the Surface Water Sampling Procedure (SOP 1-1) as detailed in the Monitoring Plan. The predetermined surface water sampling locations were located in the field using a GPS. Photographs were taken of the surface water sampling location (Appendix D 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 in the field notebook (Appendix H of the Data Report) and are summarised in Appendix A of the Data Report.

Table 2 Location of Surface Water Monitoring Points in Silvermines

Site Name	Area	Easting	Northing	Sample Site Notes	Chemical Analysis	Field Parameters	Flow
SW10-Gort-US	GM	180206	172396	Immediately upstream of the outfall on the Kilmastulla River	Yes	Yes	No
SW10-Gort-Discharge	GM	180205	172393	Wetland discharge prior to outfall	Yes	Yes	Yes
SW10-Gort-DS	GM	180189	172365	20m downstream of the outfall, on the Kilmastulla River	Yes	Yes	No
SW12-Gort-Discharge	GM	179562	172165	Sample of wetland discharge prior to outfall	Yes	Yes	Yes
SW12-Gort-DS	GM	179532	172137	20m downstream of the outfall, on the Kilmastulla River	Yes	Yes	No
SW14-Gort	GM	179336	172164	Site located on Kilmastulla River, downstream of TMF	Yes	Yes	No
SW17-Gort	GM	180538	173038	Site located on Kilmastulla River, upstream of TMF	Yes	Yes	No
SW18-Gort	GM	179772	172666	Site of discharge from the main pond on the TMF	No	Yes	No
SW19-Gort	GM	180097	172982	Discharge to TMF wetlands. DS of decant.	No	Yes	Yes
DS-Gort	GM	178501	171870	Site located on Kilmastulla River, downstream of TMF	Yes	Yes	Yes
Gort-TMF-Seep	GM	179826	172176	Seeps at the southern edge of Gortmore TMF – discharging to wetlands	Yes	No	No
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Yes	Yes
SW2-SM-South	BG	184244	171584	Discharge from 'Southern' adit.	Yes	Yes	Yes
SW3-SM	BG	184258	171412	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)	Yes	Yes	Yes
SW5-SM	BG	184303	171691	Site on Silvermines Stream (downstream of main Ballygown workings and of North adit)	Yes	Yes	Yes
SW6-SM	BG	184121	172051	Site on Silvermines Stream (downstream of main Ballygown workings and of North adit)	Yes	Yes	Yes
SW4-SM-GA	BG	183961	172483	Site on Silvermines Stream (downstream of all mine workings)	Yes	Yes	Yes
SW6-Mag	MG	182776	171399	Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road.	Yes	Yes	No
SW1-Gar	GA	182116	171322	Stream sampled south of R499 road (south of old Mogul Yard)	Yes	Yes	No
SW3-Gar	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Yes	Yes
SW5-Gar	GA	181950	171418	Discharge from Knight Shaft	Yes	Yes	No
SW7-Gar	GA	181523	171493	Discharge from smaller settlement pond	Yes	Yes	Yes
SW10-Gar	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Yes	Yes

Site Name	Area	Easting	Northing	Sample Site Notes	Chemical Analysis	Field Parameters	Flow
SW12-Gar	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Yes	Yes
US-Shal	ShS	180749	171783	Yellow River upstream of ShS	Yes	Yes	Yes
SW1-Shal	ShS	180703	171776	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.	Yes	Yes	Yes
SW4-Shal	ShS	180324	171089	Water-course occurring west of 'Drum Dump' and Shallee South workings.	Yes	Yes	Yes
SW5-Shal	ShS	180574	171301	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.	No	Yes	Yes
SW6-Shal	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Yes	Yes
SW9-Shal	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Yes	Yes
SW12-Shal	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Yes	Yes
DS-Shal	ShS	180609	171845	Yellow River downstream of ShS and BG	Yes	Yes	Yes
SW13-Shal	ShS	180709	171775	Stream draining the eastern section of the tailings impoundment (adjacent to SW1-Shal in northern most corner)	Yes	Yes	Yes
SW15-Shal	ShS	180606	171343	Stream downgradient of the drum dump and SW5-Shal in the Shallee mining area	Yes	Yes	Yes
DS-Gorteenadiha	GTD	180749	171785	Stream downgradient of Gorteenadiha	Yes	Yes	Yes

Abbreviations: GM- Gortmore; BG- Ballygown; MG- Magcobar; GA- Garryard; ShS- Shallee South; GTD - Gorteenadiha

Flow Measurements

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). Flow could not be measured at the discharge from one shaft (SW5-GAR) due to the grating covering it (refer to Table 2).

Surface water flow results are discussed in Section 5.1 and the data and measurement methodologies are contained in Appendix B 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. At locations with greater flow, a Marsh McBirney meter was used to measure flow velocities and depths at regular intervals across the stream.

The float method was used when the river was unsafe to wade (e.g. DS-Gort). 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 Vegetation and Soil Sampling

Vegetation and soil sampling are scheduled to be undertaken at Gortmore TMF in Round 2, 2018 (August/September).

2.1.4 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 G of the Data Report).
- One water blank was collected of the DI water during the sampling event. An additional filtration blank was collected in order to try 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		
SMGD01.10	GW Duplicate	Duplicate of TMF2
SMDB01.10	GW Decontamination blank	DI water (Lennox Lab Supplies: Batch No. 710-7192) pumped through groundwater pump after final decon at site TMF2
SMSD01.10	SW Duplicate	Duplicate of SW12-Gort-DS
SMSD02.10	SW Duplicate	Duplicate of SW6-Shal
SMSD03.10	SW Duplicate	Duplicate of SW12-Gar
SMDB02.10	SW Decontamination blank	DI water (Lennox Lab Supplies: Batch No: 710-7129) poured over SW composite sample bottle after final decon at SW1-SM
SMSR01.10	Standard Reference Material	Water ERA “Trace Metals” Lot #P268-740B
SMSR02.10	Standard Reference Material	Water ERA “Trace Metals” Lot #P268-740B
WB01.10	Filtration blank	Deionised water filtered onsite (Lennox Lab Suppliers. Batch No: 710-7192)
WB02.10	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: 710-7192)

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 E of the Data Report.

2.3 Sample Analysis

2.3.1 ALS Laboratory

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 F 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 reflects 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 samples were created in the field and submitted blind to the laboratory (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 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 SMSR01.10 and SMSR02.10) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P268-740B (Metals). The Certificate of Analysis is provided in Appendix G 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. Note if both the original and duplicate results were less than the limit of detection (LOD) then the RPD was zero. In addition, if one of the values was less than the LOD, the LOD value is used to calculate the RPD.

All of the RPD values shown in Table 4 are below 50 % which is excellent. The RPDs for the key parameters are as follows: Aluminium (0 to 7.2%), cadmium (0 to 3.4%), copper (0 to 19.5%), iron (0 to 6%), lead (2.1 to 46.1%), nickel (0 to 10%) and zinc (0 to 13.2%).

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

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

Dissolved Metal	LOD (µg/l)	TMF2	SMGD01.10	% RPD	SW12-GORT-DS	SMSD01.10	% RPD	SW6-SHAL	SMSD02.10	% RPD	SW12-GAR	SMSD03.10	% RPD
Aluminium	<2	<2	<2	0	9.36	8.73	-7.0	39.2	37.2	-5.2	<2	<2	0
Antimony	<0.1	<0.1	<0.1	0	0.254	0.171	-39.1	1.01	0.929	-8.4	1.89	1.77	-6.6
Arsenic	<0.5	4.45	4.17	-6.5	<0.5	<0.5	0	0.827	0.844	2.0	<0.5	<0.5	0
Barium	<0.2	619	610	-1.5	154	149	-3.3	232	223	-4.0	21.7	21.5	-0.9
Cadmium	<0.08	<0.08	<0.08	0	0.456	0.472	3.4	1.3	1.27	-2.3	28.5	29.1	2.1
Chromium	<1	1.15	1.09	-5.4	<1	<1	0	<1	<1	0	<1	<1	0
Cobalt	<0.15	0.599	0.565	-5.8	0.164	0.238	36.8	1.94	2.01	3.5	5.02	5.13	2.2
Copper	<0.3	<0.3	<0.3	0	1.25	1.25	0.0	16.9	13.9	-19.5	2.32	2.22	-4.4
Iron	<19	0.183	0.183	0.0	0.037	0.0393	6.0	0.0667	0.0675	1.2	<0.019	<0.019	0
Lead	<0.2	1.17	1.87	46.1	1.98	2.04	3.0	417	397	-4.9	0.391	0.383	-2.1
Manganese	<1	929	943	1.5	54.3	57	4.9	82.5	77.5	-6.3	405	419	3.4
Molybdenum	<0.5	0.536	0.73	30.6	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5	0
Nickel	<0.4	1.4	1.4	0.0	2.08	2.3	10.0	8.97	8.34	-7.3	59.2	60.9	2.8
Vanadium	<1	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0
Zinc	<1	5.45	6.22	13.2	225	227	0.9	250	236	-5.8	14,400	14,400	0.0

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 (surface water) and pumping DI water through (groundwater) the sampling equipment after decontamination and sent to ALS for analysis. Table 5 provides the results of the 15 metals for the two decontamination blank samples, the DI water blank and filtration blank samples and the 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. The limits of detection ranged from 0.08 to 2 µg/l except for iron with a detection limit of 19 µg/l.

No detections of dissolved metals were recorded in either SMDB01.10 (groundwater) or SMDM02.10 (surface water) samples which indicates that the decontamination procedures in the field were adequate. Dissolved zinc (1.16 µg/) was detected in the DI water filtration blank and dissolved copper (1.74 µg/) and zinc (1.99 µg/) were detected in the DI water blank (unfiltered). However, these concentrations are significantly below the assessment criteria and therefore, do not affect the interpretation of results.

The results from the laboratory instrumentation blank were obtained from ALS to determine if any contamination occurred within the laboratory (Table 5). There were no detections in the laboratory instrumentation blank.

Overall, the decontamination blank samples indicate that the results are considered acceptable for their intended use.

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

Sample Description Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.10 (µg/l)	Water Blank WB02.10 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB01.10 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB02.10 (µg/l)	Laboratory Method Blank (µg/l)
	Sample batch:	***180310-46***			***180227-75***		**180223-100**	
Aluminium	<2	<2	<2	<10	<2	<10	<2	<10
Antimony	<0.1	<1	<1	<1.0	<0.1	<1.0	<0.1	<1.0
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	<0.2	<0.2	<0.2	<0.2
Cadmium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.03	<0.08	<0.08
Chromium	<1	<1	<1	<1.0	<1	<1.0	<1	<1.0
Cobalt	<0.15	<0.15	<0.15	<0.5	<0.15	<0.5	<0.15	<0.5
Copper	<0.3	<0.3	**1.74**	<0.3	<0.3	<0.3	<0.3	<0.3
Iron	<19	<19	<19	<0.2	<0.019	<0.2	<0.019	<0.2
Lead	<0.2	<0.2	<0.2	<3.0	<0.2	<3.0	<0.2	<3.0
Manganese	<1	<1	<1	<3.0	<1	<3.0	<1	<3.0
Molybdenum	<0.5	<0.5	<0.5	<0.4	<0.5	<0.4	<0.5	<0.4
Nickel	<0.4	<0.4	<0.4	<1.0	<0.4	<1.0	<0.4	<1.0
Vanadium	<1	<1	<1	<1.0	<1	<1.0	<1	<1.0
Zinc	<1	**1.16**	**1.99**	<10	<1	<10	<1	<10

Notes:
Bold indicates a detection. ***Bold and italics*** indications a detection of a parameter also detected in the laboratory method blank.
Italics indicates a detection of in the lab method blank that was also detected in a field water or decontamination blank in the same batch

3.2.3 Standard Reference Materials

SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.10 and SMSR02.10) to evaluate laboratory accuracy. The ALS laboratory reports are provided in Appendix F 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, barium, cadmium, chromium, cobalt, copper, molybdenum, vanadium and zinc are in good agreement with the certified value (%R ranged from 89 to 106%). One of the reported values for dissolved arsenic (86%), iron (87%), lead (111%), manganese (89%) were 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. Both of the reported values for dissolved nickel (89% and 84%) were outside of the acceptable range (low) but close to the acceptance limit. This indicates that values for nickel may be biased low and any use of these values should be noted with this observation.

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

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits		SMSR01.10 (µg/l)	% R	SMSR02.10 (µg/l)	% R
		Lower (%)	Upper (%)				
Aluminium	1,020	86	113	1,080	106	1,060	104
Antimony	702	87	110	741	106	636	91
Arsenic	322	87	110	323	100	277	**86**
Barium	200	91	108	206	103	203	102
Cadmium	997	89	107	935	94	887	89
Chromium	632	91	109	631	100	612	97
Cobalt	651	93	111	659	101	641	98
Copper	535	91	109	539	101	512	96
Iron	543	91	111	529	97	470	**87**
Lead	424	91	110	470	**111**	403	95
Manganese	668	93	110	658	99	595	**89**
Molybdenum	397	90	108	364	92	385	97
Nickel	1,280	91	109	1,140	**89**	1,080	**84**
Vanadium	1,010	91	107	1,000	99	960	95
Zinc	961	90	110	966	101	930	97

Notes:
Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALS Laboratory

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 of the 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 for Total Organic Carbon by typically three days and it is recommended that a faster turnaround is specified for this parameter in future sampling rounds.

The laboratory provided the associated analytical quality control samples (AQC) data. 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.

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).

The RPDs between laboratory and field pH were very good at less than 10%. Over 95% of samples had calculated %RPD values of less than 5% which is excellent. Field pH is more representative of actual conditions and is used for interpretive purposes. 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

Sample Description	pH Lab	pH Field	% RPD
	(pH Units)		
DS-GORT	7.93	7.82	-1.4
SW10-GORT DISCHARGE	7.63	7.64	0.1
SW10-GORT DS	7.87	7.79	-1.0
SW10-GORT US	7.92	7.79	-1.7
SW12-GORT DISCHARGE	7.41	7.17	-3.3
SW12-GORT DS	7.89	7.8	-1.1
SW14-GORT	7.89	7.83	-0.8
SW17-GORT	7.74	7.59	-2.0
SW18-GORT	7.92	8.04	1.5
SW19-GORT	7.83	8.04	2.6
SW6-MAG	7.52	7.76	3.1
DS-GORTEENADHIA	7.61	7.67	0.8
DS-SHAL	7.72	7.53	-2.5
SW12-SHAL	5.79	5.5	-5.1
SW13-SHAL	7.8	7.55	-3.3
SW15-SHAL	6.94	6.83	-1.6
SW1-SHAL	7.51	7.65	1.8
SW4-SHAL	7.36	7.11	-3.5
SW5-SHAL	6.96	7.07	1.6
SW6-SHAL	6.83	6.54	-4.3
SW9-SHAL	7.35	7.48	1.8
US-SHAL	7.79	7.84	0.6
SW10-GAR	7.83	7.89	0.8
SW12-GAR	7.64	7.51	-1.7
SW1-GAR	7.46	7.64	2.4
SW3-GAR	7.88	7.88	0.0
SW5-GAR	7.32	6.97	-4.9
SW7-GAR	7.49	7.59	1.3
SW1-SM	7.61	7.69	1.0
SW2-SM-SOUTH	7.58	7.5	-1.1
SW3-SM	7.83	7.83	0.0
SW4-SM-GA	7.91	7.99	1.0
SW5-SM	7.71	7.8	1.2
SW6-SM	7.83	7.86	0.4

Notes:
Bold indicates an exceedance in acceptance limits

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 F 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 the reported values were below the detection limit, the values were 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	<2	2	0	1	1	-
Antimony	<0.1	2	0	0.05	0.05	-
Arsenic	<0.5	2	2	2.2	4.5	3.3
Barium	<0.2	2	2	154	619	387
Cadmium	<0.08	2	0	0.04	0.04	-
Chromium	<1	2	1	0.5	1.2	0.8
Cobalt	<0.15	2	2	0.16	0.60	0.38
Copper	<0.3	2	0	0.15	0.15	-
Iron	<19	2	2	99	183	141
Lead	<0.2	2	1	0.1	1.17	0.64
Manganese	<1	2	2	80.5	929	505
Molybdenum	<0.5	2	1	0.25	0.54	0.39
Nickel	<0.4	2	1	0.2	1.4	0.8
Vanadium	<1	2	0	0.5	0.5	-
Zinc	<1	2	1	0.5	5.45	2.98

Notes:
If less than LOD minimum value taken to be half LOD.

Elevated concentrations of dissolved barium (619 µg/l) and manganese (929 µg/l) were recorded at TMF2 (downgradient of the TMF) and were significantly higher than the concentrations at TMF1 (upgradient of the TMF). Furthermore, the concentrations of dissolved arsenic, lead and zinc were higher in TMF2 compared to TMF1.

4.1.2 Surface Water Sample Results

Surface water samples were collected for two major categories: the first comprised of mine adit discharges and discharges from wetlands as well as some drainage ditches, and the second comprised of rivers and streams. Table 9 provides a summary of the results of the 15 discharge/ drainage samples, and Table 10 provides a summary of the reported results of the 19 river and stream samples. Included in the tables 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. The highest reported value of the field duplicate pair was used where applicable.

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	<2	15	7	1	50.4	16.2	11.8
Antimony	<0.1	15	14	0.05	2.29	0.76	0.90
Arsenic	<0.5	15	3	0.25	0.827	0.19	0.34
Barium	<0.2	15	15	20.4	464	135	152
Cadmium	<0.08	15	15	0.08	32.3	12.8	10.1
Chromium	<1	15	0	0.5	0.5	-	-
Cobalt	<0.15	15	9	0.08	6.46	2.48	1.93
Copper	<0.3	15	13	0.15	24.5	7.58	4.86
Iron	<19	15	4	9.5	66.7	19.8	20.5
Lead	<0.2	15	13	0.1	417	106	34
Manganese	<1	15	15	0.5	768	258	210
Molybdenum	<0.5	15	2	0.25	1.07	-	-
Nickel	<0.4	15	15	1.09	73.6	25.9	22.9
Vanadium	<1	15	0	0.5	0.5	-	-
Zinc	<1	15	15	16.5	17,400	5,858	4,546

Notes:
If less than LOD minimum value taken to be half LOD.

SW5-Gar (Knights Shaft) had the highest concentrations of dissolved cadmium (32.3 µg/l), nickel (73.6 µg/l) and zinc (17,400 µg/l). The highest dissolved lead was recorded at SW6-Shal (Field Shaft) with a value of 417 µg/l. SW5-Shal had the highest concentration of dissolved manganese (768 µg/l).

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	<2	19	17	1	34.1	10.2	9.6
Antimony	<0.1	19	14.0	0.05	1.16	0.3	0.4
Arsenic	<0.5	19	1	0.25	0.51	-	-
Barium	<0.2	19	19	33.5	281	129	68.4
Cadmium	<0.08	19	17	0.04	26.2	3.6	6.7
Chromium	<1	19	0	0.50	0.50	-	-

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Cobalt	<0.15	19	9	0.08	2.2	0.5	0.7
Copper	<0.3	19	13	0.15	15.9	3.1	4.6
Iron	<19	19	11	9.5	57.3	27.6	17.4
Lead	<0.2	19	16	0.1	260	28.9	72.1
Manganese	<1	19	19	1.95	220	49.2	53.4
Molybdenum	<0.5	19	3	0.25	1.09	0.3	0.2
Nickel	<0.4	19	18	0.2	37.2	8.5	11.8
Vanadium	<1	19	1	0.5	1.15	-	-
Zinc	<1	19	18	0.5	9,860	1,570	2,846

Notes:
If less than LOD minimum value taken to be half LOD.

SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and had notably lower concentrations of zinc (<1 and 3.59 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 59.5 µg/l and 185 µg/l, respectively.

SW3-Gar had the highest concentrations of cadmium (26.2 µg/l), manganese (220 µg/l) nickel (37.2 µg/l) and zinc (9,860 µg/l). The highest concentration of lead (260 µg/l) was found at SW9-Shal, located downstream of the field shaft. DS-Gorteenadiha had the highest concentration of dissolved copper (15.9 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 zinc 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, manganese and uranium (Table 11).

For hardness-dependent metals (copper, zinc and cadmium), the hardness is taken into account 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 12. 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 are 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 11 and 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) 0.08 (Class 2) 0.09 (Class 3) 0.15 (Class 4) 0.25 (Class 5)	≤0.45 (Class 1) 0.45 (Class 2) 0.6 (Class 3) **0.9** (Class 4) 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, Class 4: 100 to <200 mg CaCO3/l 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; 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; 50 µg/l for water hardness >10 mg/l CaCO3 and ≤ 100 mg/l CaCO3; and 100 µg/l elsewhere.
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

Parameter	Unit	AA	MAC (or 95%-ile)	Source	Description
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)
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 <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 as described in Section 4.2. The results and exceedances are discussed in this section.

Table B-1 in **Appendix B** highlights the exceedances of the 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 described in Section 4.2. Table B-2 in **Appendix B** 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 human health (6.5 to 9.5 pH units) criteria, with an average of pH 7.3. The specific conductance ranged from 0.42 to 0.5 mS/cm, which was well below the threshold for human health of 2.5 mS/cm. Sulphate was within normal ranges, with values ranging from 3.3 to 12.7 mg/l, which was well below the criteria for human health of 250 mg/l. Ammonia was less than the limit of detection in both monitoring wells.

For dissolved metal concentrations, barium and manganese exceeded the ecological assessment criteria in TMF1 (upgradient) and TMF2 (downgradient). For both parameters, concentrations were significantly higher in TMF2 with a value of 619 µg/l for barium and 929 µg/l for manganese. Dissolved zinc was below the limit of detection in TMF1 and a value of 5.45 µg/l was measured in TMF2 which is significantly below the ecological criteria of 100 µg/l.

4.3.2 Surface Water Assessment

The pH in surface waters (rivers/streams, drainage and discharges) in the Silvermines mining area ranged from 5.5 to 8 with an average of 7.54. There was one exceedance of the assessment criteria for pH at SW12-Shal (pH 5.5), which was below the acceptable range for human health (pH 6.5 to 9.5). The conductivity ranged from 0.131 to 1.343 mS/cm with an average of 0.51 mS/cm. Dissolved oxygen in rivers and stream sampling locations were within the acceptable range (80-100%) for ecological health with an average value of 98%.

The ecological and human health assessment criteria for ammonia (0.14 mg/l and 0.3 mg/l, respectively) were exceeded at SW5-SM, with a value of 0.413 mg/l. Waste water discharge from an upstream treatment plant (A0178-01) may be contributing to elevated levels of ammonia at SW5-SM. The ecological criterion was exceeded at SW12-Gort-Discharge with a value of 0.213 mg/l.

Sulphate exceeded the criteria for human health (250 mg/l) at both wetland discharges in the Gortmore area (311 mg/l at SW10-Gort-Discharge and 351 mg/l at SW12-Gort-Discharge). The sulphate threshold was exceeded at all locations within the Garryard area with values ranging from 332 to 768 mg/l. US-Shal, located downstream of the Garryard area, exceeded the threshold with a sulphate concentration of 327 mg/l. The highest sulphate result was recorded at SW1-Gar (768 mg/l), located upgradient of the Garryard processing area.

Dissolved Metals Assessment

There were exceedances of dissolved barium, cadmium, cobalt, lead, manganese, nickel and zinc, as discussed below, and see the Table B-1 in Appendix B for the full listing. Table 14 provides a summary of the reported values for rivers and streams at the upstream and downstream locations at the different mining areas that exceeded the relevant ecological and human health assessment criteria for dissolved metals. For the locations refer to the maps in Appendix A.

The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with high results even at upstream locations SW1-SM (59.5 µg/l) and SW17-Gort (185 µg/l). These barium concentrations are similar to those recorded in previous monitoring rounds. Exceedances of dissolved barium are not discussed further. Dissolved arsenic was detected at four surface water locations (SW18-Gort, SW6-Shal, SW9-Shal and SW5-Gar) but was notably lower than both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria. The highest dissolved arsenic concentration was recorded at SW5-Gar (0.827 µg/l).

In the Ballygown area (Map 5 of Appendix A) where the Silvermines stream is located, there were exceedances of dissolved cadmium, lead, nickel and zinc. There were no exceedances at the upstream site, SW1-SM (except barium). At the southern Adit (SW2-SM-South), concentrations of dissolved cadmium (5.56 µg/l), lead (1.69 µg/l), nickel (6.74 µg/l) and zinc (2,040 µg/l) exceeded the ecological assessment criteria, respectively. The concentration of zinc at the three sites downstream of the discharge (SW5-SM, SW6-SM and SW4-SM-GA), which ranged from 203 µg/l to 217 µg/l, exceeded the ecological assessment criteria of 100 µg/l. Dissolved cadmium downgradient of the southern adit was detected but significantly below the assessment criteria.

The concentrations of dissolved cadmium, manganese, nickel and zinc at SW6-Mag, which is downstream of the Magcobar mining area, was also above the ecological assessment criteria, at 1.78 µg/l, 51.9 µg/l, 8.51 µg/l and 795 µg/l, respectively.

At Gortmore TMF (Map 2 of Appendix A), dissolved manganese, lead, nickel and zinc exceeded the assessment criteria at several locations. Dissolved manganese exceeded the human health assessment criteria (50 µg/l) at SW12-Gort-Discharge with a value of 346 µg/l. Dissolved lead exceeded the ecological (1.2 µg/l) assessment criteria at four locations and exceeded the ecological and human (10 µg/l) assessment criteria at SW18-Gort with a value of 27 µg/l. The SW18-Gort sample captures the drainage from the surface of the TMF. Dissolved zinc exceeded the ecological assessment criteria at both wetland discharges; 794 µg/l at SW10-Gort-Discharge and 701 µg/l at SW12-Gort-Discharge. Similarly, dissolved nickel exceeded the ecological criteria (4 ug/L) at both wetland discharges with concentrations of 5.44 µg/l (SW10-Gort-Discharge) and 7.38 µg/l (SW12-Gort-Discharge).

The concentration of zinc increased on the Kilmastulla River from 3.59 µg/l at the upstream location, SW17-Gort, to 225 µg/l at the downstream location, SW12-Gort-DS; the latter exceeding the ecological assessment criteria (100 µg/l). SW12-Gort-DS is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The loading from these areas are discussed in Section 5.

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**	**-**
Ballygown	SW1-SM	Upstream	22/02/2018	0.1	4.1	0.04	0.1	4.92	0.2	0.5
Ballygown	SW3-SM	DS (workings & Adits)	22/02/2018	0.1	5.2	0.27	1.68	3.08	0.615	90.6
Ballygown	SW5-SM	DS (workings & Adits)	22/02/2018	0.413	9.7	0.358	0.823	2.93	1.11	217
Ballygown	SW6-SM	DS (workings & Adits)	22/02/2018	0.1	10.1	0.294	1.5	3.96	1.08	213
Ballygown	SW4-SM-GA	Downstream (all incl. tailings deposit)	22/02/2018	0.1	10	0.301	1.23	3.71	1.06	203
Magcobar	SW6-Mag	Downstream	19/02/2018	0.1	184	1.78	0.1	51.9	8.51	795
Garryard	SW1-GAR	Upstream	21/02/2018	0.1	768	7.79	4.43	28.9	32.1	4400
Garryard	SW3-GAR	Downstream (all)	21/02/2018	0.1	362	26.2	2.98	220	37.2	9860
Shallee	SW4-SHAL	Upstream	20/02/2018	0.1	2	0.701	6.39	73.2	5.51	87.1
Shallee	SW5-SHAL	DS (drum dump)	20/02/2018	0.1	92.7	24.1	22.4	768	56.6	8710
Shallee	SW9-SHAL	Downstream	20/02/2018	0.1	26.3	3.58	260	110	13	1060
Shallee	SW1-SHAL	Downstream (all)	20/02/2018	0.1	28.3	3.41	198	101	12.3	969
Garryard/ Shallee	US SHAL	Downstream of SW3-GAR	20/02/2018	0.1	327	15.5	2.05	92.2	29.4	7910
Garryard/ Shallee	DS SHAL	Downstream of SW3-GAR and SW1-SHAL	20/02/2018	0.1	128	6.81	41.3	61.2	13.7	3240
GTD	DS-Gorteenadiha	Downstream of GTD	20/02/2018	0.1	8.6	0.901	28.7	28	2.21	134
Gortmore	SW17-GORT	Upstream	19/02/2018	0.1	11.5	0.04	0.1	1.95	0.643	3.59
Gortmore	SW12-GORT-DS	Downstream (TMF)	19/02/2018	0.1	50.4	0.456	1.98	54.3	2.08	225
Gortmore	SW14-GORT	Downstream (TMF and Yellow River)	19/02/2018	0.1	33.7	0.414	1.96	39.9	1.77	186
Gortmore	DS-Gort	Downstream (TMF and Yellow River)	19/02/2018	0.1	34	0.476	1.82	40.7	1.76	190

Notes:

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Metals are dissolved

At Shallee (Map 3 of Appendix A), dissolved lead exceeded both the ecological (1.2 µg/l) and human health (10 µg/l) assessment criteria at five locations, with concentrations ranging from 23 to 417 µg/l. The highest concentration (417 µg/l) was recorded at the Field Shaft discharge (SW6-Shal). Additionally, the ecological criteria was exceeded at a further four locations with values ranging from 2.05 µg/l to 11.1 µg/l. With the exception of SW12-Shal (stone lined drainage channel), SW13-Shal (drainage channel) and SW4-Shal (upstream of mining area), dissolved zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 250 to 8,710 µg/l. Manganese was found to be above the criteria for human health (50 µg/l) at the majority of sampling locations including upstream (US Shal: 92.2 µg/l) and downstream (DS-Shal: 61.2 µg/l) of the Shallee Mining Area. Dissolved cadmium exceeded the ecological criteria (0.9 µg/l) at three locations, with values ranging from 1.3 µg/l to 3.58 µg/l, and exceeded both the ecological criteria and human health criteria (5 µg/l) at four locations ranging from 6.81 to 24.1 µg/l.

DS-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 exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria with a concentration of 41.3 µg/l. The dissolved zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 3,240 µg/l.

Sampling location DS-Gorteenadiha is located downstream of the Gorteenadiha mining area and upstream the Shallee mining area. Elevated concentrations of dissolved cadmium (0.901 µg/l; slightly exceeded the ecological assessment criteria of 0.9 µg/l), lead (28.7 µg/l; exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria) and zinc (134 µg/l; exceeded ecological health criteria of 100 µg/l) were recorded at this location.

Some of the highest concentrations of dissolved metals were observed in the Garryard area (Map 4 of Appendix A). All sites in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l, ranging from 4,400 µg/l (SW1-Gar) to 17,400 µg/l (SW5-Gar). All six locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 5.95 to 32.3 µg/l). Dissolved nickel exceeded both the ecological and human health assessment criteria of 20 µg/l, at five locations, ranging from 32.1 µg/l (SW1-Gar) to 73.6 µg/l (SW5-Gar). Dissolved manganese exceeded the human health criteria (50 µg/l) but was significantly below the ecological assessment criteria (1,100 µg/l) at four locations; SW10-Gar (197 µg/l), SW12-Gar (405 µg/l), SW3-Gar (220 µg/l) and SW5-Gar (444 µg/l). Additionally, dissolved lead exceeded the ecological assessment criterion value of 1.2 µg/l at SW10-Gar, SW1-Gar and SW3-Gar.

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 417 µg/l and the sampling location on the stream SW9-Shal, which is just downstream of the Field Shaft, had concentration of 260 µg/l. Further downstream at SW1-Shal, which is located downgradient of the Shallee tailings impoundment, the concentration of dissolved lead was 198 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). Findings based on the results obtained in March 2018, are as follows:

- No exceedances of the livestock threshold values for any dissolved metals were found. However, it is important to note that tailings are located directly beneath the two surface water ponds and therefore, any livestock drinking from these ponds are likely disturbing the sediments and being exposed to high concentrations of metals via sediment ingestion. Total metals were not sampled for while horses were disturbing the sediments;

- The maximum recommended sulphate levels for calves is 500 mg/l and for adults is 1,000 mg/l. No sampling location at Gortmore TMF exceeded the recommended values in February 2018. The guidelines for sulphates in water are not well defined but high concentrations cause diarrhoea; 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.

It should be noted that sulphate concentrations exceeded the recommended values at SW1-Gar with a result of 768 mg/l. SW1-Gar is located upstream of the Garryard mining area and is typically dry during the summer months.

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. 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 concentrations (dissolved) is compared to the current single values $EQS_{bioavailable}$ 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 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 used in the program (but can be adjusted by the user). 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.

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
DS-Gort	Pb	1.82	9.15	0.24	No	Yes	No
	Zn	190	27.4	75.1	Yes	Yes	No
	Ni	1.76	8.13	0.87	No	No	No
SW10-Gort-DS	Pb	0.442	9.15	0.06	No	No	No
	Zn	75.1	34.6	23.3	No	No	No
	Ni	1.28	8.13	0.63	No	No	No
SW10-Gort-US	Pb	0.38	9.15	0.05	No	No	No
	Zn	51.2	34.6	15.8	No	No	No
	Ni	1.13	8.13	0.56	No	No	No
SW12-Gort-DS	Pb	1.98	9.15	0.26	No	Yes	No
	Zn	225	34.6	70.6	Yes	Yes	No
	Ni	2.08	8.13	1.02	No	No	No
SW14-Gort	Pb	1.96	6.45	0.36	No	Yes	No
	Zn	186	27.2	74.2	Yes	Yes	No
	Ni	1.77	6.32	1.12	No	No	No
SW17-Gort	Pb	<0.2	6.78	0.02	No	No	No
	Zn	3.59	24.8	1.1	No	No	No
	Ni	0.64	7.44	0.35	No	No	No
SW6-Mag	Pb	<0.2	3.63	0.03	No	No	No
	Zn	795	17.3	501	Yes	Yes	Yes
	Ni	8.51	4.16	8.19	Yes	Yes	Yes
DS-Shal	Pb	41.3	2.96	16.7	Yes	Yes	Yes
	Zn	3,240	19.5	1,806	Yes	Yes	Yes
	Ni	13.7	5.22	10.49	Yes	Yes	Yes
SW1-Shal	Pb	198	4.23	56.2	Yes	Yes	Yes
	Zn	969	15.6	678	Yes	Yes	Yes
	Ni	12.3	4.66	10.56	Yes	Yes	Yes
SW9-Shal	Pb	260	4.09	76.3	Yes	Yes	Yes
	Zn	1,060	13.8	835	Yes	Yes	Yes
	Ni	13	5.88	8.84	Yes	Yes	Yes
US-Shal	Pb	2.05	3.19	0.77	No	Yes	No
	Zn	7,910	32.5	2,653	Yes	Yes	Yes
	Ni	29.4	4.16	28.28	Yes	Yes	Yes
SW10-Gar	Pb	2.41	3.33	0.87	No	Yes	No
	Zn	10,600	32.5	3,555	Yes	Yes	Yes
	Ni	42.5	3.71	42.5	Yes	Yes	Yes
SW1-Gar	Pb	4.43	3.07	1.73	No	Yes	Yes
	Zn	4,400	32.7	1,465	Yes	Yes	Yes
	Ni	32.1	4.66	27.57	Yes	Yes	Yes
SW3-Gar	Pb	2.98	3.33	1.07	No	Yes	No
	Zn	9,860	32.5	3,307	Yes	Yes	Yes
	Ni	37.2	3.71	37.2	Yes	Yes	Yes
SW1-SM	Pb	<0.2	4.23	0.03	No	No	No
	Zn	<1	14.4	-0.4	No	No	No
	Ni	0.2	4.66	0.17	No	No	No
SW3-SM	Pb	1.68	3.79	0.53	No	Yes	No
	Zn	90.6	15.6	62.5	Yes	No	No
	Ni	0.62	4.16	0.59	No	No	No
SW4-SM-GA	Pb	1.23	3.79	0.39	No	Yes	No

Site	Metal	Measured Conc.	HC5	Bioavailable Conc.	Bioavailable Conc. Exceedance of HC5	Measured Conc. Exceedance of current EQS*	Bioavailable Conc. Exceedance of current EQS
	Zn	203	16.4	134	Yes	Yes	Yes
	Ni	1.06	3.71	1.06	No	No	No
SW5-SM	Pb	0.823	3.63	0.27	No	No	No
	Zn	217	16.4	143	Yes	Yes	Yes
	Ni	1.11	4.16	1.07	No	No	No
SW6-SM	Pb	1.5	3.63	0.50	No	Yes	No
	Zn	213	16.4	141	Yes	Yes	Yes
	Ni	1.08	4.16	1.04	No	No	No
DS-Gorteenadiha	Pb	28.7	4.23	8.15	Yes	Yes	Yes
	Zn	134	14.4	100	Yes	Yes	Yes
	Ni	2.21	4.66	1.9	No	No	No

* 1.2 µg/L for Pb, 100 µg/L for Zn and 4 µg/L for Ni.

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 (and potential EQSbioavailable) are in all cases, higher (less stringent) than the current EQS of 1.2 µg/L. For Ni, the HC5 (and potential EQSbioavailable) are in all cases, higher (less stringent) than the current EQS of 4 µg/L. For Zn, the HC5 (and potential EQSbioavailable) are significantly lower (more stringent) than the current EQS of 100 µg/L at all locations.

The following summarises the comparisons provided in the last three columns of Table 15.

- Number of exceedances when comparing bioavailable concentrations to the HC5: Pb =4; Zn = 15; Ni = 8
- Number of exceedances when comparing measured concentrations to the current EQS: Pb = 14; Zn = 15; Ni = 8
- Number of exceedances when comparing bioavailable concentrations to the current EQS: Pb = 5; Zn = 12; Ni = 8

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 relatively the same 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 at Coole (EPA station 25044) which is approximately 10 km downstream of the Silvermines mining area. The flow record between 1 May 2017 and 28 February 2018 at Station 25044 is reproduced in Figure 1. The flow ranged from a maximum of 20.8 m^3/s following rainfall events to less than 0.5 m^3/s during low-flow, with a median flow of approximately 1.7 m^3/s. The Coole gauging station data show that there were high flows during several days in November, December (2017) and January (2018) that were at or above the estimated 5%-ile (high flow) of 6.84 m^3/s following rainfall (note: the 5%-ile (high flow) value is calculated from the dataset 1970 to 2017). The flow during these periods shows a flashy response to rainfall. The highest recorded flow in the monitoring period was on 21 January 2018 with a mean daily flow of 20.8 m^3/s. The lowest flows were recorded in May and July with sustained flows of less than 0.5 m^3/s. the minimum flow (0.268 m^3/s) was recorded on 18 July 2017 which was less than the 95%-ile (low flow) of 0.33 m^3/s. As shown in Figure 1, flows were relatively low from May to September and an increase in heavy rainfall events from November to February resulted in peaks in the hydrograph.

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 m^3/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 m^3/s.

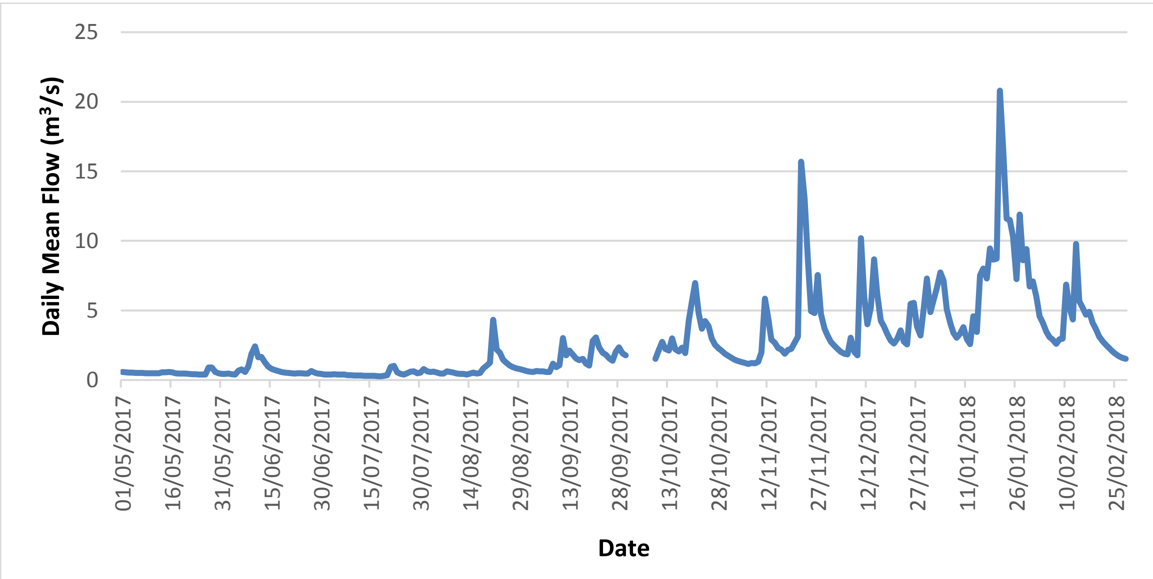

Figure 1 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 01 May 2017 to 28 Feb 2018

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 2018 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 16 Surface Water Flow Value Measured in February 2018

Site Name	Flow l/s	Date
SW10-GORT Discharge	11.3	19/02/2018
SW12-GORT Discharge	10.9	19/02/2018
SW19-GORT	6.3	19/02/2018
DS-GORT	3,620	19/02/2018
SW10-GAR	22.7	19/02/2018
SW12-GAR	15.7	19/02/2018
SW3-GAR	16.6	21/02/2018
SW5-GAR	Not possible to measure flow (grating)	19/02/2018
SW7-GAR	1.3	19/02/2018
DS-Gorteenadiha	33.3	20/02/2018
US-SHAL	28.9	20/02/2018
DS-SHAL	97.2	20/02/2018
SW12-SHAL	2.3	20/02/2018
SW1-SHAL	14.6	20/02/2018
SW4-SHAL	0.1	20/02/2018
SW5-SHAL	1.4	20/02/2018
SW15-Shal*	0.4	20/02/2018
SW6-SHAL	4.6	20/02/2018
SW9-SHAL	11.5	20/02/2018
SW13-SHAL	7.3	20/02/2018
SW1-SM	18.5	22/02/2018
SW3-SM	37.5	22/02/2018
SW5-SM	48.5	22/02/2018
SW6-SM	44.5	22/02/2018
SW2-SM-South	1.7	22/02/2018
SW4-SM-GA	52	22/02/2018

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.

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	pH Units	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
DS-GORT	19/02/2018	3620	7.8	34000	10600000	0.476	149	1.82	569	40.7	12700	1.76	550	190	59400
SW10-GORT-DISC.	19/02/2018	11.3	7.6	311000	304000	0.122	0.12	0.425	0.42	35.7	34.9	5.44	5.32	794	776
SW12-GORT-DISC.	19/02/2018	10.9	7.2	351000	330000	0.519	0.49	0.1	0.09	346	325	7.38	6.93	701	658
SW19-GORT	19/02/2018	6.3	8.0	203000	110000	0.591	0.32	4.21	2.29	5.58	3.03	3.01	1.63	293	159
DS-SHAL	20/02/2018	97.2	7.5	128000	1070000	6.81	57.2	41.3	347	61.2	514	13.7	115	3240	27200
SW12-SHAL	20/02/2018	2.3	5.5	1000	197	0.0826	0.02	23	4.54	44.7	8.82	1.11	0.22	16.5	3.26
SW13-SHAL	20/02/2018	7.3	7.6	38400	24100	0.265	0.17	0.611	0.38	14.9	9.35	1.09	0.68	16.5	10.4
SW15-SHAL	20/02/2018	0.4	6.8	92200	3350	23.3	0.85	11.1	0.4	681	24.7	52.8	1.92	8100	294
SW1-SHAL	20/02/2018	14.6	7.7	28300	35700	3.41	4.31	198	250	101	128	12.3	15.5	969	1220
SW4-SHAL	20/02/2018	0.1	7.1	2000	11.5	0.701	0.004	6.39	0.04	73.2	0.42	5.51	0.03	87.1	0.5
SW5-SHAL	20/02/2018	1.4	7.1	92700	11500	24.1	2.98	22.4	2.77	768	94.9	56.6	6.99	8710	1080
SW6-SHAL	20/02/2018	4.6	6.5	11500	4530	1.3	0.51	417	164	82.5	32.5	8.97	3.53	250	98.5
SW9-SHAL	20/02/2018	11.5	7.5	26300	26200	3.58	3.57	260	259	110	110	13	12.9	1060	1060
US-SHAL	20/02/2018	28.9	7.8	327000	817000	15.5	38.7	2.05	5.12	92.2	230	29.4	73.4	7910	19800
SW10-GAR	21/02/2018	22.7	7.9	390000	764000	27.7	54.3	2.41	4.72	197	386	42.5	83.3	10600	20800
SW12-GAR	21/02/2018	15.7	7.5	397000	538000	28.5	38.6	0.391	0.53	405	549	59.2	80.3	14400	19500
SW3-GAR	21/02/2018	16.6	7.9	362000	519000	26.2	37.6	2.98	4.27	220	315	37.2	53.3	9860	14100
SW7-GAR	21/02/2018	1.3	7.6	353000	40700	5.95	0.69	0.399	0.05	23.7	2.73	16	1.85	4590	529
SW1-SM	22/02/2018	18.5	7.7	4100	6570	0.04	0.06	0.1	0.16	4.92	7.88	0.2	0.32	0.5	0.8
SW2-SM-SOUTH	22/02/2018	1.7	7.5	33200	4960	5.56	0.83	1.69	0.25	0.5	0.07	6.74	1.01	2040	304
SW3-SM	22/02/2018	37.5	7.8	5200	16800	0.27	0.87	1.68	5.44	3.08	9.97	0.615	1.99	90.6	293
SW4-SM-GA	22/02/2018	52.0	8.0	10000	44900	0.301	1.35	1.23	5.52	3.71	16.7	1.06	4.76	203	911
SW5-SM	22/02/2018	48.5	7.8	9700	40600	0.358	1.5	0.823	3.45	2.93	12.3	1.11	4.65	217	909
SW6-SM	22/02/2018	44.5	7.9	10100	38800	0.294	1.13	1.5	5.77	3.96	15.2	1.08	4.15	213	819
DS-GORTEENADIHA	20/02/2018	33.3	7.7	8600	24700	0.901	2.59	28.7	82.5	28	80.5	2.21	6.35	134	385

The dissolved metal with the highest mass loading was zinc ranging from 0.5 to 59,400 g/day with an average of 6,812 g/day overall. The largest mass load of zinc (59,400 g/day) was found at sampling point, DS-Gort, which captures the main mining areas (Gortmore, Shallee, Garryard, Magcobar and Ballygown).

SW10-Gar (the discharge from the tailings lagoon) had a zinc load of 20,800 g/day. It should be noted that in March 2018, the discharge pipe from the tailings lagoon was blocked and therefore, water was discharging over (and possibly through) the western embankment, resulting in concerns over bank stability. Accordingly, the SW10-Gar sampling point was moved slightly downstream to capture all of the discharges from the lagoon. Further downstream at SW3-Gar which is located in a stream containing the SW10-Gar discharge and the western part of the Mogul yard, there was a decrease in zinc loading to 14,100 g/day. The decrease in zinc load between both locations is likely due to metal precipitation. 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 0.8 g/day, which increases to 293 g/day downstream of the mine workings (SW3-SM). The zinc load at SW5-SM which is located downstream of the southern (304 g/day zinc) and northern adit (not sampled, very low flow) would be expected to be 597 g/day. However, the calculated zinc load at SW5-SM was 909 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. Further downstream the calculated mass load at SW6-SM decreased to 819 g/day which is likely due to a slight underestimation of flow at SW6-SM. Between SW6-SM and SW4-SM-GA, the zinc load increases by 11.2% from 819 g/day to 911 g/day. The increase in dissolved zinc load along this stretch was identified in previous rounds (February 2016, August 2016 and March 2017) 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 19,800 and 385 g/day, respectively. The stream emerging from the Shallee mining area contributed a zinc load of 1,220 g/day. An additional drainage ditch (SW13-Shal) had a zinc load of 10.4 g/day. Therefore, it would be expected that the dissolved zinc load at DS-Shal would be 21,415 g/day. However, the calculated zinc load at DS-Shal was 27,200 g/day indicating a possible additional source of dissolved zinc in this river stretch. Additionally, between Garryard (SW3-Gar) and Shallee (US-Shal), there was an increase in dissolved zinc load from 14,100 to 19,800 g/day. This increase indicates that a diffuse contribution of dissolved zinc is likely along this stretch of river.

The highest load of dissolved lead (569 g/day) was found at DS-Gort. At SW6-Shal (Field shaft) the lead load was estimated to be 164 g/day which increased to 250 g/day downstream at SW1-Shal. A further increase was identified between SW1-Shal and DS-Shal (250 to 347 g/day). The mass load of dissolved lead at US-Shal and DS-Gorteenadiha, located directly upstream of the Shallee mining area was calculated to be 5.12 and 82.3 g/day, respectively. Similar to dissolved zinc, the increase in dissolved lead in this area indicates a possible additional source of dissolved lead in this river stretch.

Of the two wetland discharges at Gortmore TMF, SW10-Gort-Discharge had the highest loading of dissolved zinc at 776 g/day. SW12-Gort-Discharge had 658 g/day of zinc. The stream draining the surface of the TMF (SW19-Gort) had a dissolved zinc load of 159 g/day. Accordingly, an additional diffuse source of dissolved zinc is evident. This is exemplified by the seeps located at the southern edge of the TMF which discharge to the adjacent wetlands. High concentrations of dissolved zinc (2,600 µg/l) were recorded in these seeps in February 2018. Overall, discharges from the Garryard and Shallee area (DS-Shal – 27,200 g/day) provided 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 is 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:
Null Hypothesis: The null hypothesis is that there is no trend.
The p-value is the probability that the null hypothesis is true.
The confidence coefficient is 0.95
The Mann-Kendall test requires the following information for a trend to be calculated: A sample size of at least three value 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 May 2017

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. cadmium	15	0.15	-22	No Trend
	Diss. lead	15	0.44	-4	No Trend
	Diss. manganese	15	0.004	-52	Decreasing
	Diss. nickel	15	0.28	-13	No Trend

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
	Diss. zinc	15	0.38	-6	No Trend
SW10-Gort-Discharge	Diss. cadmium	12	0.02	-32	Decreasing
	Diss. lead	12	0.13	-18	No Trend
	Diss. manganese	12	0.32	8	No Trend
	Diss. nickel	12	0.04	-26	Decreasing
	Diss. zinc	12	0.19	-14	No Trend
SW12-Gort-Discharge	Diss. cadmium	11	0.20	12	No Trend
	Diss. lead	11	0.44	-2	No Trend
	Diss. manganese	11	0.44	3	No Trend
	Diss. nickel	11	0.08	-19	Possibly decreasing
	Diss. zinc	11	0.18	13	No Trend
SW6-Shal	Diss. cadmium	13	0.18	16	No Trend
	Diss. lead	13	0.34	8	No Trend
	Diss. manganese	13	0.18	-16	No Trend
	Diss. nickel	13	0.34	-8	No Trend
	Diss. zinc	13	0.38	-6	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	12	n/a	n/a	Not Calculated
	Diss. lead	12	0.27	10	No Trend
	Diss. manganese	12	0.19	14	No Trend
	Diss. nickel	12	0.06	-24	Possibly decreasing
	Diss. zinc	12	0.37	-6	No Trend

The results of the Mann-Kendall test show that:

- Dissolved manganese concentrations are decreasing at SW10-Gar;
- Dissolved cadmium and nickel are decreasing at SW10-Gort-Discharge;
- Dissolved nickel is possibly decreasing at SW12-Gort-Discharge;
- No statistically significant trend was observed in the data for SW6-Shal; and
- Dissolved nickel is possibly decreasing at SW14-Gort.

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

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 and May 2017 and the low flow sampling event in August 2013, September 2014, August 2015 and August 2016. The following points detail the February 2018 sampling event (high flow) in the context of previous results:

- In March 2018, dissolved metal concentrations in SW2-SM-South were similar to the maximum values previously recorded (2013-2017) during high flow with dissolved lead (1.69 µg/l) higher than previous results;

- The dissolved lead concentration at SW6-Shal (417 µg/l) was higher than average (383 µg/l) with the calculated lead load of 164 g/day close to the average load (189 µg/l) estimated during high flow;
- At SW10-Gar, the dissolved zinc concentration (10,600 µg/l) and estimated load (20,800 g/day) in February 2018 were higher than the respective average of 8,414 µg/l and 18,283 g/day during high flows; and
- SW10-Gort-discharge and SW12-Gort-Discharge drain the Gortmore wetlands into the Kilmastulla River. At SW10-Gort-Discharge, the dissolved zinc concentration of 794 µg/l was slightly below the average (798 µg/l), as shown in Table 20. The calculated zinc load of 776 g/day was above the average (628 g/day). At SW12-Gort-Discharge, the dissolved zinc concentration (701 µg/l) and estimated load (658 g/day) were above the average values of 518 µg/l and 554 g/day, respectively.

Table 20 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in primary discharges from 2013-2017

		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	1.0		0.6		2.2		3.4		3.5		2.1		0.3		0.1		3.1		1.9	
(l/s)	Max	3		1.5		9.2		6.2		50.7		4.4		33.0		4.5		22.0		7.5	
	Mean	2.0		1.05		5.5		4.4		20.8		3.1		10.3		1.6		9.9		3.5	
	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	4.7	0.46	4	0.25	1	0.25	1	0.24	15.2	4.6	10.6	1.95	0.04	0	0.04	0	0.102	0.04	0.05	0.01
	Max	5.5	1.34	5	0.59	1	0.95	1	0.71	32.6	109	21.7	5.81	0.379	1.08	0.5	0.07	0.781	1.48	0.5	0.11
	Mean	5.10	0.87	4.61	0.42	1.10	0.52	0.96	0.39	24.3	48.6	15.2	3.99	0.22	0.29	0.16	0.02	0.40	0.46	0.19	0.05
Pb	Min	1.03	0.12	0.838	0.05	236	91	183	53.7	0.982	0.74	1.04	0.19	0.05	0	0.05	0	0.01	0.008	0.022	0.00
	Max	1.31	0.29	0.974	0.11	591	470	352	189	2.71	9.03	8.51	2.28	0.471	1.34	0.21	0.02	0.109	0.21	0.073	0.03
	Mean	1.13	0.19	0.90	0.08	383	189	266.5	108	1.70	2.93	3.98	1.13	0.22	0.33	0.11	0.01	0.06	0.06	0.05	0.01
Mn	Min	1	0.08	0	0.02	52	18.7	46	15.1	74.1	35	141	53.1	46.3	7.94	191	3.58	165	66.2	453	102
	Max	2	0.48	1	0.07	98	71.4	99	53.2	273	990	321	68.3	303	132	808	314	285	542	2500	1620
	Mean	1.2	0.2	0.5	0.0	73.1	34.3	73.0	29.5	169.4	384	244	59.6	110	49.0	414	91.6	237	215	1233	514.5
Zn	Min	1870	169	1560	89.2	164	48.1	153	45.2	2260	683	2360	433	607	20.7	175	2.73	229	60.8	99.9	17.7
	Max	2140	503	1840	238	252	188	253	136	13000	40800	7150	1920	1040	1730	590	229	849	1610	189	122
	Mean	1998	341	1718	158	211	98.9	195	78.3	8414	18283	4010	1052	798	628	330	69.8	518	554	145	48.8

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 elevations outside the TMF decreased from 48.73 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.04 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 gradient was calculated to be 0.003, however the level of the river is unknown. The groundwater elevation at TMF1 was 0.40 meters lower than the elevation measured in Spring 2017 (09/02/17). There was no notable difference at TMF2.

Within the tailings area, the water levels generally ranged from 2.38 to 4.42 m below the top of the tailings surface. The exceptions were in BH3A-GORT-06 and BH5A-GORT-06 (see Map 2 of Appendix A) where deeper water levels were recorded. The groundwater elevations within the TMF varied between 48.76 to 54.29 m OD. These groundwater elevations are similar to the elevations measured in Spring 2017 (09/02/17), which ranged from 49.03 to 53.17 m OD.

Table 21 Measures Groundwater Levels in February 2018

Borehole Identifier	Location Description	Date	Time	Depth to Groundwater (m bgl)	Depth to Groundwater (m bTOC)	Groundwater Elevation (m OD)
TMF1	Outside the perimeter of the TMF	21/02/2018	09:30	0.27	0.86	48.73
TMF2		21/02/2018	09:30	1.96	2.42	46.04
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	21/02/2018	13:20	3.0	3.65	52.76
BH2A-GORT-06		21/02/2018	13:00	2.75	3.28	53.01
BH3A-GORT-06		21/02/2018	12:15	7.84	8.17	48.76
BH4A-GORT-06		21/02/2018	12:25	3.63	4.15	52.53
BH5A-GORT-06		21/02/2018	12:40	5.18	5.61	51.03
BH6A-GORT-06		21/02/2018	13:45	3.73	4.42	52.35
BH6B-GORT-06		21/02/2018	14:00	1.66	2.38	54.29

Notes:
m is metres
OD is Ordnance Datum
bgl is below ground level
bTOC is below top of casing

Section 7

Summary and Recommendations

7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in February 2018 and water levels were measured in seven additional monitoring wells. Sampling and analysis was undertaken at 35 surface water locations in February 2018 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 ecological assessment criteria for dissolved barium (154 µg/l and 619 µg/l, respectively) and manganese (80.5 µg/l and 929 µg/l, respectively). Overall, dissolved metal concentrations were higher in TMF2. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- 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 (<1 and <3.59 µg/l, respectively) than the rest of the rivers and streams sampled in the mining area 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. For example, SW5-Gar (Knights Shaft) had the highest concentrations of dissolved cadmium (32.3 µg/l), nickel (73.6 µg/l) and zinc (17,400 µg/l). Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l with values ranging from 4,400 to 17,400 µg/l. All Garryard locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 8.44 to 20.2 µg/l). Dissolved manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all locations with the exception of SW1-Gar and SW7-Gar which did not exceed the criteria. The concentration of dissolved arsenic was only detected at SW5-Gar with a value of 0.656 µg/l.

- Within the Shallee mining area, dissolved lead exceeded both the ecological (1.2 µg/l) and human health (10 µg/l) assessment criteria at four locations; SW12-Shal (23 µg/l), SW1-Shal (198 µg/l), SW6-Shal (417 µg/l) and SW9-Shal (260 µg/l). The highest concentration was from the Field Shaft discharge (SW6-Shal) at 417 µg/l.

- Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the majority of the drainages and discharges, ranging from 16.5 to 17,400 µg/l at SW5-Gar. The concentration of zinc increased on the Kilmastulla River from 3.59 µg/l at the upstream location, SW17-Gort, to 225 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard, Shallee and Gorteenadiha. The concentration at DS-Shal on the Yellow River tributary was significantly higher at 3,240 µg/l.

- One sample was collected from the seeps present at the southern edge of Gortmore TMF. Concentrations of dissolved cadmium (2.84 µg/l), manganese (641 µg/l) and zinc (2,600 µg/l) exceeded the ecological assessment criteria and dissolved nickel (31.3 µg/l) exceeded both the ecological and health assessment criteria.
- The dissolved metal with the highest mass loading was zinc, ranging from 0.5 to 59,400 g/day with an average of 6,812 g/day overall. The largest mass load of zinc (59,400 g/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 SW9-shal (259 g/day), located downstream of SW6-Shal (Field shaft). Measured flows ranged from 0.1 l/s at SW4-Shal to 3,620 l/s at DS-Gort with an average of 164 l/s overall.
- 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 should be restricted from accessing the two ponds located on the surface of the Gortmore TMF because sediments in both water bodies likely contain high concentrations of metals. Horses accessing the ponds disturb the underlying sediments which poses a risk to animal health.

7.2 Recommendations for the Monitoring Programme

The following recommendations are proposed:

- A faster turnaround time for total organic carbon (TOC) analysis to ensure that the holding time is not exceeded;
- Inspection of the outflow of the Garryard tailings lagoon to ensure the outflow is free flowing and blockages do not exist; and
- A stream walk survey in the vicinity of the Shallee stream and Yellow Bridge River confluence to confirm absence/presence of additional inflows.

Section 8
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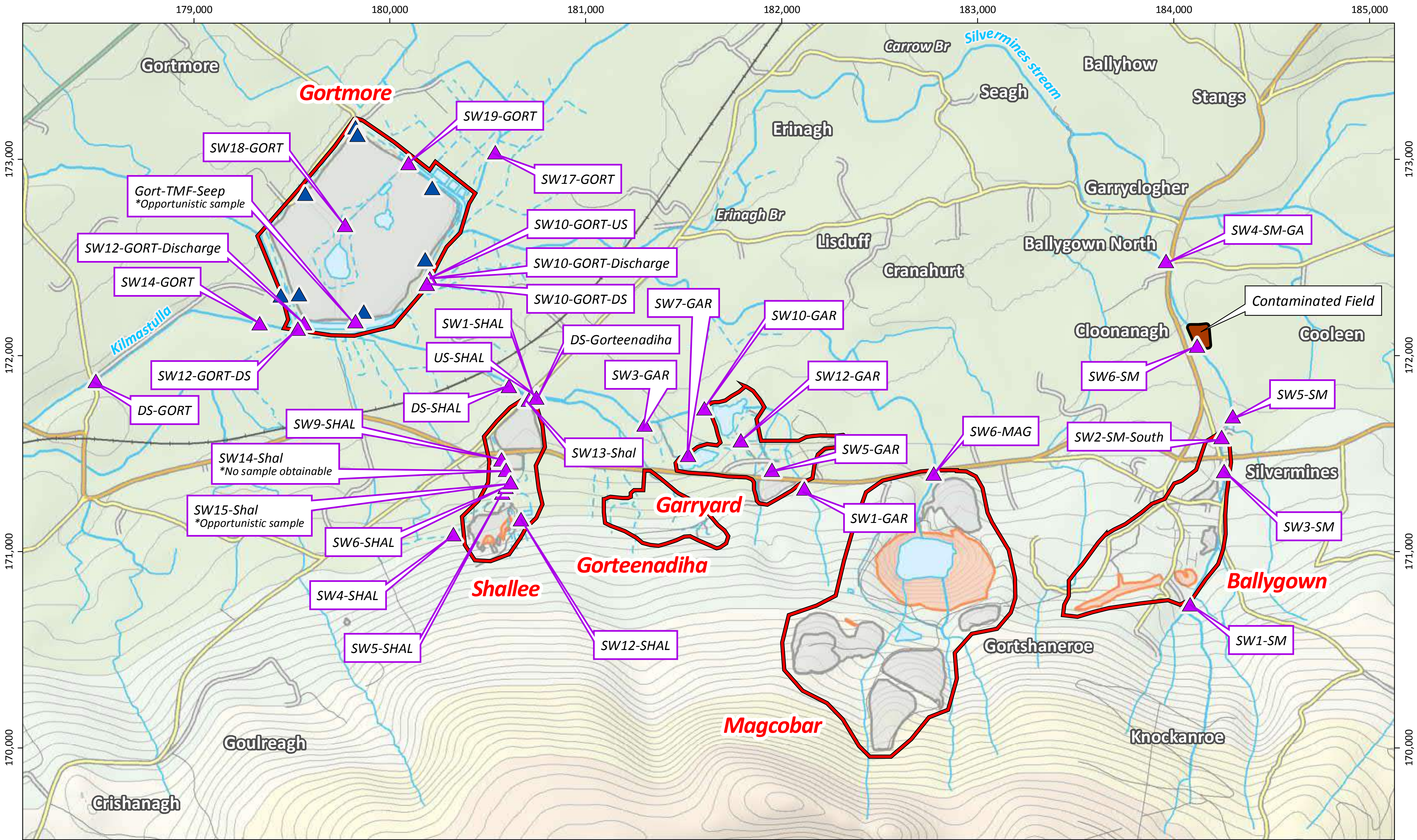
Appendix A

Figures



Map 1 - Silvermines - Overview

Drawn by: OC Date: 30/04/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\04_MonReport_R1\MXD\01_SilverMon1.mxd

CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater

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

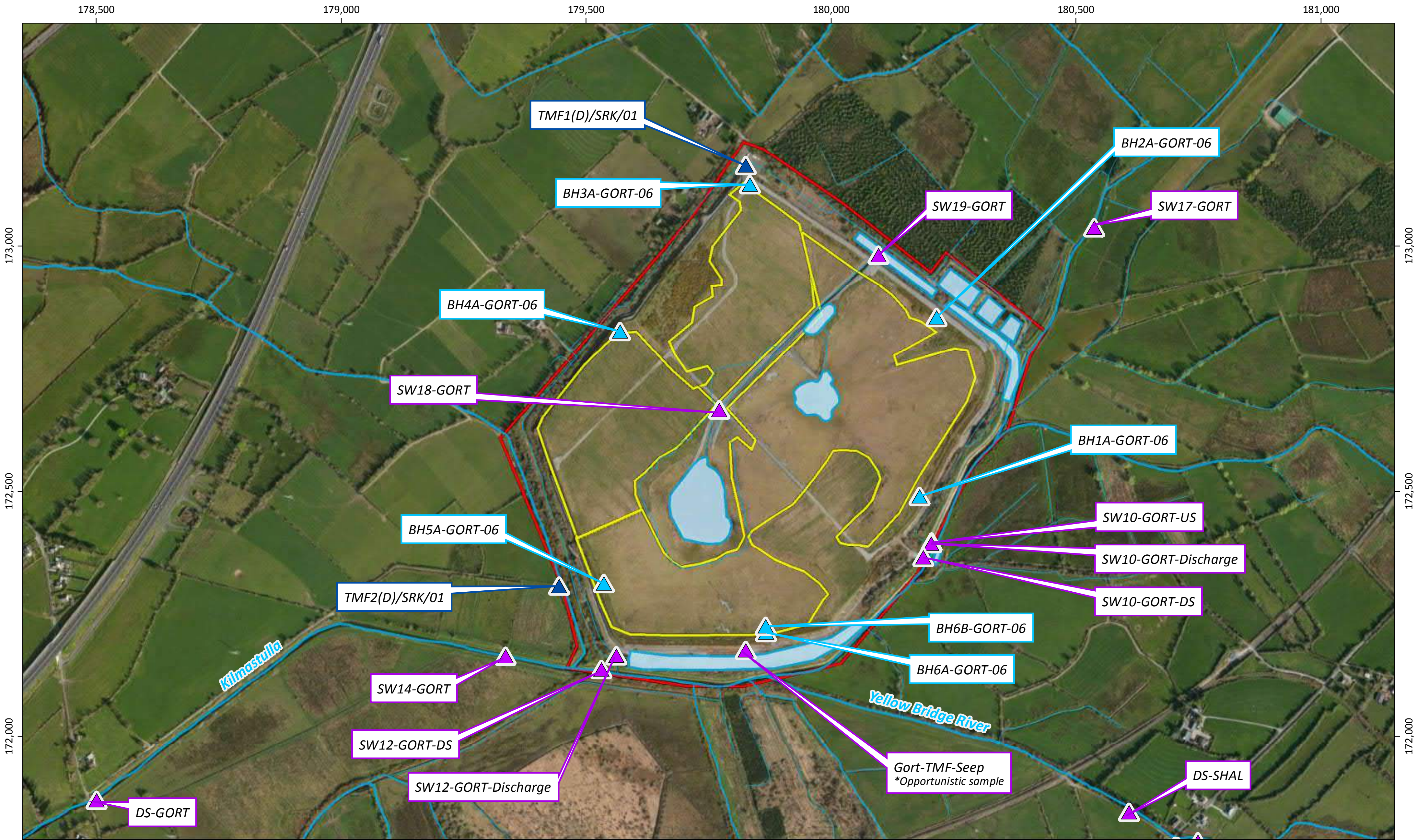
Mines

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

N W E S

Scale is 1:25,000

0 125 250 500 m



Map 2 - Silvermines - Gortmore TMF

Drawn by: OC Date: 30/04/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\04_MonReport_R1\MXD\02_SilverMonGM.mxd

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

CDM Smith

Legend

Sampling Locations
- Surface water
- Groundwater
- Groundwater *(Levels only)*

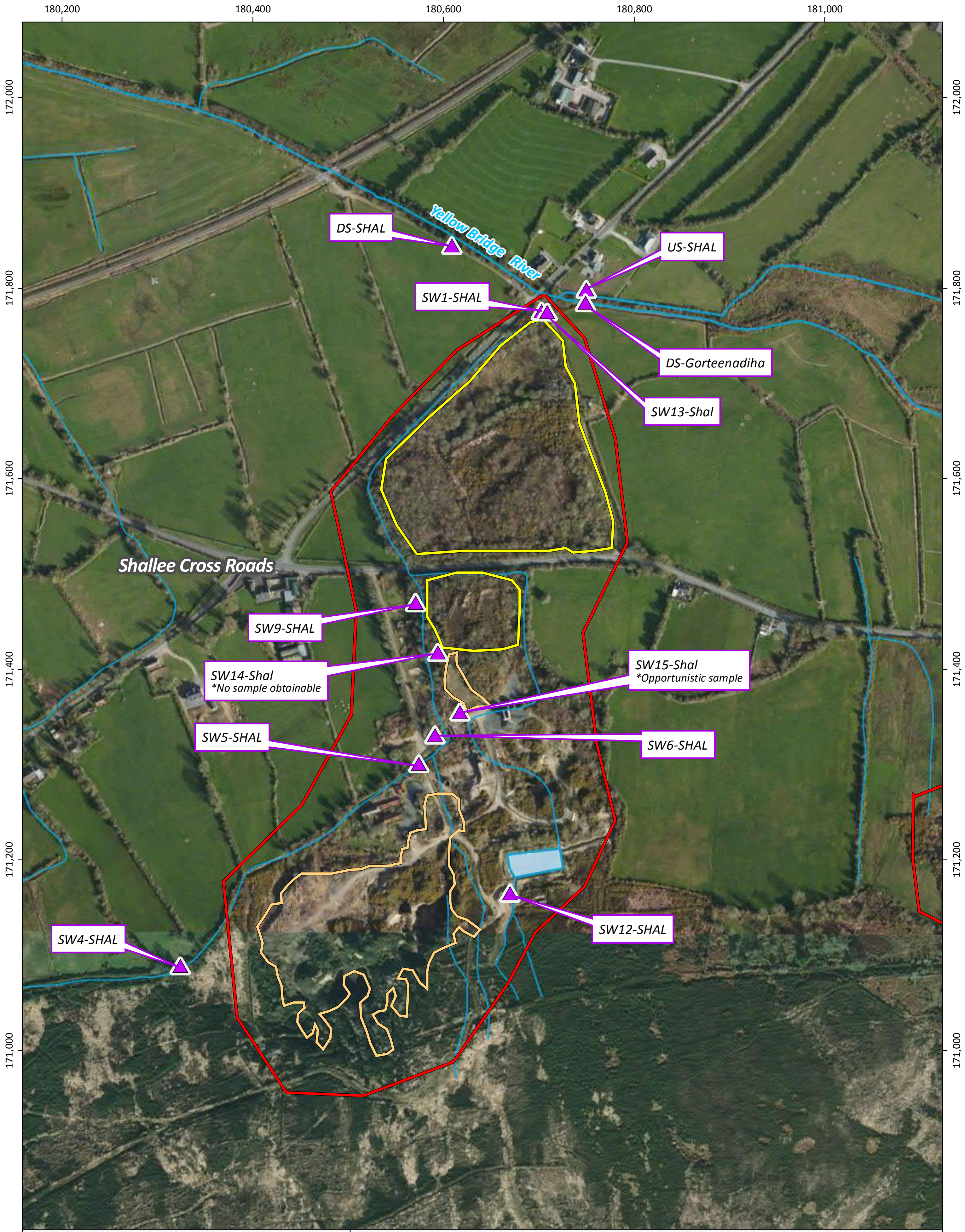
- Rivers
- Streams
- Pond / Wetland / Pit Lake

Mines
- Mining Areas

Scale is 1:10,000

0 100 200 m

N E S W



Map 3 - Silvermines - Shallee South

Drawn by: OC Date: 30/04/2018

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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

Scale is 1:5,000

0 50 100 m

Map 4 - Silvermines - Garryard

Drawn by: OC   Date: 30/04/2018

Internal Project Reference: Q:\118000-118499\118174
40 Documents Generated\GIS\02_GIS_Tasks\04_MonReport_R1\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

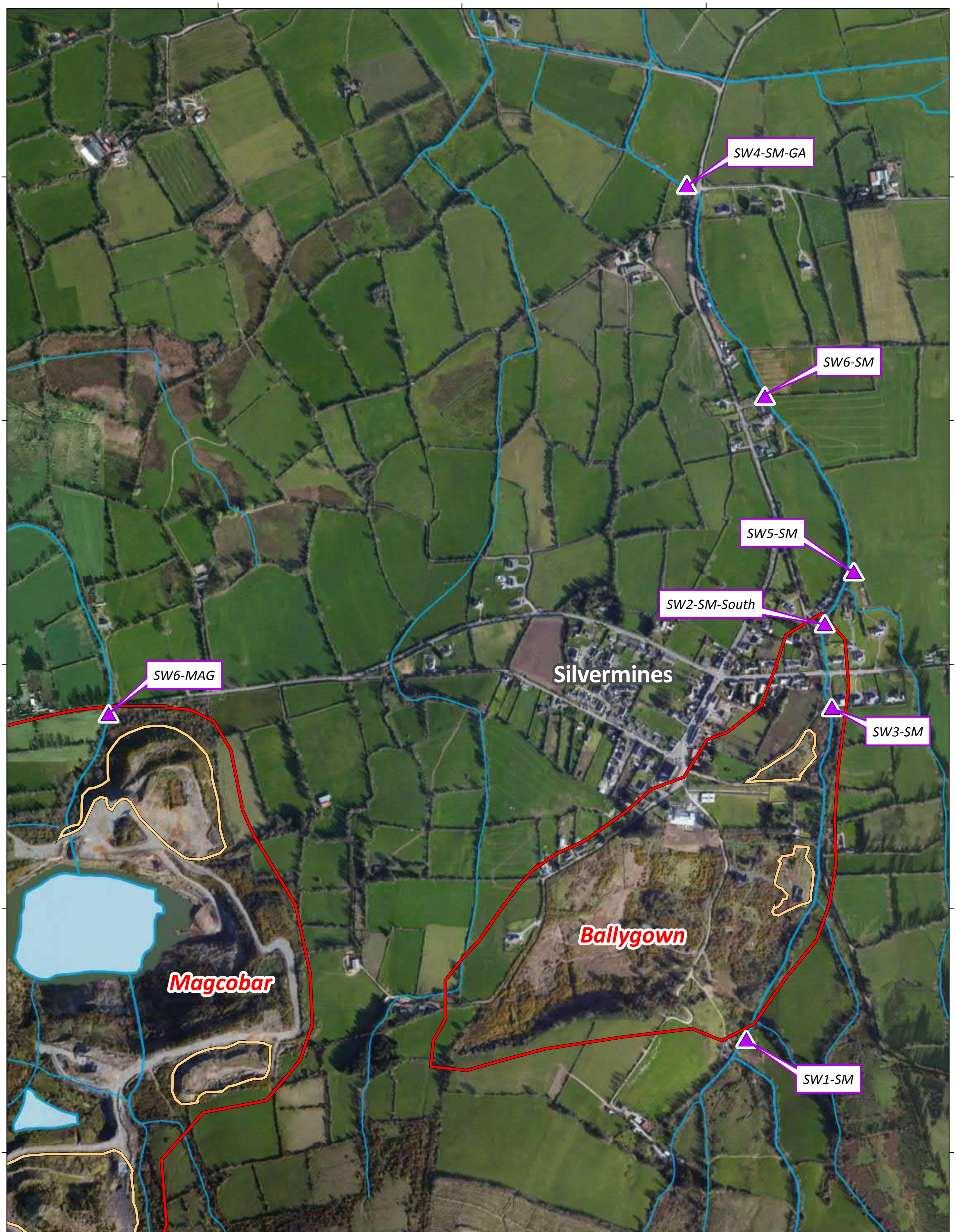
Mining Areas

Stockpile Dump

Scale is 1:5,000

0 50 100 m

N W E S



Map 5 - Silvermines - Magcobar and Ballygown

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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
- Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:10,000

0 100 200 m

Appendix B

Analytical Data Tables and Assessment Criteria

CDM Smith

Table B-1 Comparison of Groundwater and
Surface Water Results to Assessment Criteria R1 (2018)

Sample Description	Type	Area	Date Sampled	Total Organic Carbon	Ammoniacal Nitrogen as N	Oxygen, dissolved (field)	pH (field)	Specific Conductance @ deg.C (field)	Sulphate	Aluminium (diss.filt)	Antimony (diss.filt)	Arsenic (diss.filt)	Barium (diss.filt)	Cadmium (diss.filt)	Calcium (diss.filt)
			Units	mg/l	mg/l	% Sat	pH Units	mS/cm	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				-	**0.14**	**80 to 120***	**4.5 to 9**	-	-	**1,900**	-	**25**	**4**	**0.9**	-
Human Health Criteria				-	**0.3**	-	**6.5 to 9.5**	**2.5**	**250**	**200**	**5**	**10**	-	**5**	-
TMF1	Groundwater	GM	21/02/2018	*1.5*	*0.1*	11.1	7.48	0.421	12.7	*1*	*0.05*	2.17	154	*0.04*	63
TMF2	Groundwater	GM	21/02/2018	*1.5*	*0.1*	0.5	7.11	0.5	3.3	*1*	*0.05*	4.45	619	*0.04*	88.4
DS-GORT	River/Stream	GM	19/02/2018	3.8	*0.1*	99	7.82	0.454	34	10.4	0.147	*0.25*	149	0.476	70.6
GORT-TMF-SEEP	Seep	GM	19/02/2018	-	-	-	-	-	-	3.24	0.466	2.76	6.47	2.84	-
SW10-GORT DISCHARGE	Discharge	GM	19/02/2018	-	*0.1*	87	7.64	0.805	311	3.66	0.927	*0.25*	20.4	0.122	-
SW10-GORT DS	River/Stream	GM	19/02/2018	3.95	*0.1*	95.6	7.79	0.462	33.4	11.7	0.125	*0.25*	146	0.107	77.8
SW10-GORT US	River/Stream	GM	19/02/2018	3.94	*0.1*	95.6	7.79	0.462	25.6	8.32	0.134	*0.25*	145	0.105	75.3
SW12-GORT DISCHARGE	Discharge	GM	19/02/2018	-	0.213	46.5	7.17	1.035	351	10.4	0.105	*0.25*	207	0.519	-
SW12-GORT DS	River/Stream	GM	19/02/2018	3.84	*0.1*	96	7.8	0.514	50.4	9.36	0.254	*0.25*	154	0.456	79.5
SW14-GORT	River/Stream	GM	19/02/2018	3.67	*0.1*	97.9	7.83	0.404	33.7	8.87	*0.05*	*0.25*	147	0.414	68
SW17-GORT	River/Stream	GM	19/02/2018	3.48	*0.1*	90.4	7.59	0.397	11.5	9.5	*0.05*	*0.25*	185	*0.04*	53.6
SW18-GORT	Drainage	GM	19/02/2018	-	*0.1*	105	8.04	0.512	151	*1*	2.29	0.559	22.9	0.472	-
SW19-GORT	Drainage	GM	19/02/2018	-	*0.1*	104	8.04	0.611	203	*1*	1.56	*0.25*	26.5	0.591	-
SW6-MAG	River/Stream	Mag	19/02/2018	*1.5*	*0.1*	102.2	7.76	0.486	184	7.4	0.196	*0.25*	43.1	1.78	54.1
DS-SHAL	River/Stream	Shal	20/02/2018	*1.5*	*0.1*	99.7	7.53	0.487	128	11.8	0.73	*0.25*	168	6.81	65.5
SW12-SHAL	Drainage	Shal	20/02/2018	-	*0.1*	94.4	5.5	0.457	*1*	50.4	0.358	*0.25*	213	0.0826	-
SW13-SHAL	Drainage	Shal	20/02/2018	-	*0.1*	90.1	7.55	0.377	38.4	*1*	0.746	*0.25*	212	0.265	-
SW15-SHAL	Drainage	Shal	20/02/2018	-	*0.1*	94.8	6.83	0.285	92.2	20.1	0.372	*0.25*	263	23.3	-
SW1-SHAL	River/Stream	Shal	20/02/2018	*1.5*	*0.1*	99.5	7.65	0.185	28.3	33.6	1.16	*0.25*	216	3.41	20.6
SW4-SHAL	Drainage	Shal	20/02/2018	-	*0.1*	54.6	7.11	0.139	2	7.97	0.472	*0.25*	464	0.701	-
SW5-SHAL	Drainage	Shal	20/02/2018	-	*0.1*	100	7.07	0.289	92.7	32.7	0.3	*0.25*	303	24.1	-
SW6-SHAL	Discharge	Shal	20/02/2018	-	*0.1*	70.7	6.54	0.131	11.5	39.2	1.01	0.827	232	1.3	-
SW9-SHAL	River/Stream	Shal	20/02/2018	*1.5*	*0.1*	100.1	7.48	0.176	26.3	34.1	1.06	0.505	211	3.58	19.1
US-SHAL	River/Stream	Shal	20/02/2018	*1.5*	*0.1*	99.2	7.84	0.9	327	*1*	0.85	*0.25*	54.5	15.5	132
SW10-GAR	Discharge	Gar	21/02/2018	*1.5*	*0.1*	95.6	7.89	0.92	390	*1*	1.15	*0.25*	29.2	27.7	147
SW12-GAR	Drainage	Gar	21/02/2018	-	*0.1*	96.6	7.51	0.928	397	*1*	1.89	*0.25*	21.7	28.5	-
SW1-GAR	River/Stream	Gar	21/02/2018	*1.5*	*0.1*	94.5	7.64	1.343	768	4.06	*0.05*	*0.25*	33.5	7.79	171
SW3-GAR	River/Stream	Gar	21/02/2018	*1.5*	*0.1*	102.2	7.88	0.897	362	*1*	0.965	*0.25*	34.1	26.2	145
SW5-GAR	Discharge	Gar	21/02/2018	-	*0.1*	59.3	6.97	0.855	332	*1*	2.19	0.656	23.6	32.3	-
SW7-GAR	Drainage	Gar	21/02/2018	-	*0.1*	96	7.59	0.791	353	*1*	*0.05*	*0.25*	75.9	5.95	-
SW1-SM	River/Stream	Bg	22/02/2018	*1.5*	*0.1*	99.5	7.69	0.151	4.1	2.01	*0.05*	*0.25*	59.5	*0.04*	16.5
SW2-SM-SOUTH	Discharge	Bg	22/02/2018	-	*0.1*	58.5	7.5	0.531	33.2	6.05	0.127	*0.25*	163	5.56	-
SW3-SM	River/Stream	Bg	22/02/2018	*1.5*	*0.1*	101.4	7.83	0.189	5.2	7.01	0.106	*0.25*	66.1	0.27	23.9
SW4-SM-GA	River/Stream	Bg	22/02/2018	*1.5*	*0.1*	99.3	7.99	0.296	10	4.82	0.13	*0.25*	125	0.301	42.2
SW5-SM	River/Stream	Bg	22/02/2018	*1.5*	0.413	95.9	7.8	0.296	9.7	3.65	*0.05*	*0.25*	110	0.358	38.5
SW6-SM	River/Stream	Bg	22/02/2018	*1.5*	*0.1*	97.9	7.86	0.292	10.1	3.82	0.121	*0.25*	122	0.294	40.9
DS-GORTEENADIHA	River/Stream	Gtd	20/02/2018	*1.5*	*0.1*	100	7.67	0.156	8.6	20.7	0.353	*0.25*	281	0.901	17

xx Exceeds Ecological Assessment Criteria
xx Exceeds Human Health Assessment Criteria
xx Exceeds both Ecological and Human Health Criteria
xx Less than the Limit of Detection (LOD) - Value taken to l
- Not analysed or no assessment criteria
* Only applies to rivers or streams (i.e. not discharges)

Table B-1 Comparison of Groundwater and
Surface Water Results to Assessment Criteria R1 (2018)

Sample Description	Type	Area	Date Sampled	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Iron (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Molybdenum (diss.filt)	Nickel (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				3.4	5.1	30	-	1.2	1100	-	4	-	100
Human Health Criteria				50	-	2000	200	10	50	-	20	-	-
TMF1	Groundwater	GM	21/02/2018	*0.5*	0.159	*0.15*	99	*0.1*	80.5	*0.25*	*0.2*	*0.5*	*0.5*
TMF2	Groundwater	GM	21/02/2018	1.15	0.599	*0.15*	183	1.17	929	0.536	1.4	*0.5*	5.45
DS-GORT	River/Stream	GM	19/02/2018	*0.5*	*0.075*	1.21	57.3	1.82	40.7	*0.25*	1.76	*0.5*	190
GORT-TMF-SEEP	Seep	GM	19/02/2018	*0.5*	1.71	*0.15*	*9.5*	*0.1*	641	*0.25*	31.3	1.25	2600
SW10-GORT DISCHARGE	Discharge	GM	19/02/2018	*0.5*	*0.075*	0.95	*9.5*	0.425	35.7	*0.25*	5.44	*0.5*	794
SW10-GORT DS	River/Stream	GM	19/02/2018	*0.5*	*0.075*	0.876	40.8	0.442	43.3	*0.25*	1.28	*0.5*	75.1
SW10-GORT US	River/Stream	GM	19/02/2018	*0.5*	*0.075*	0.857	41.3	0.38	43.3	*0.25*	1.13	*0.5*	51.2
SW12-GORT DISCHARGE	Discharge	GM	19/02/2018	*0.5*	0.662	0.844	35.6	*0.1*	346	*0.25*	7.38	*0.5*	701
SW12-GORT DS	River/Stream	GM	19/02/2018	*0.5*	0.164	1.25	37	1.98	54.3	*0.25*	2.08	*0.5*	225
SW14-GORT	River/Stream	GM	19/02/2018	*0.5*	*0.075*	1.1	33.1	1.96	39.9	*0.25*	1.77	*0.5*	186
SW17-GORT	River/Stream	GM	19/02/2018	*0.5*	*0.075*	1.08	36.1	*0.1*	1.95	*0.25*	0.643	*0.5*	3.59
SW18-GORT	Drainage	GM	19/02/2018	*0.5*	*0.075*	2.82	*9.5*	27	26.7	*0.25*	2.96	*0.5*	196
SW19-GORT	Drainage	GM	19/02/2018	*0.5*	*0.075*	2.11	*9.5*	4.21	5.58	*0.25*	3.01	*0.5*	293
SW6-MAG	River/Stream	Mag	19/02/2018	*0.5*	0.637	6.13	*9.5*	*0.1*	51.9	1.09	8.51	*0.5*	795
DS-SHAL	River/Stream	Shal	20/02/2018	*0.5*	0.738	5.54	31.7	41.3	61.2	0.811	13.7	*0.5*	3240
SW12-SHAL	Drainage	Shal	20/02/2018	*0.5*	0.243	*0.15*	50.2	23	44.7	*0.25*	1.11	*0.5*	16.5
SW13-SHAL	Drainage	Shal	20/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	0.611	14.9	*0.25*	1.09	*0.5*	16.5
SW15-SHAL	Drainage	Shal	20/02/2018	*0.5*	5.08	15.2	*9.5*	11.1	681	*0.25*	52.8	*0.5*	8100
SW1-SHAL	River/Stream	Shal	20/02/2018	*0.5*	1.7	9.21	57	198	101	*0.25*	12.3	*0.5*	969
SW4-SHAL	Drainage	Shal	20/02/2018	*0.5*	0.484	1.32	50.6	6.39	73.2	0.743	5.51	*0.5*	87.1
SW5-SHAL	Drainage	Shal	20/02/2018	*0.5*	6.23	24.5	*9.5*	22.4	768	*0.25*	56.6	*0.5*	8710
SW6-SHAL	Discharge	Shal	20/02/2018	*0.5*	1.94	16.9	66.7	417	82.5	*0.25*	8.97	*0.5*	250
SW9-SHAL	River/Stream	Shal	20/02/2018	*0.5*	1.89	12	43	260	110	*0.25*	13	*0.5*	1060
US-SHAL	River/Stream	Shal	20/02/2018	*0.5*	0.748	*0.15*	*9.5*	2.05	92.2	*0.25*	29.4	*0.5*	7910
SW10-GAR	Discharge	Gar	21/02/2018	*0.5*	2.32	0.663	*9.5*	2.41	197	*0.25*	42.5	*0.5*	10600
SW12-GAR	Drainage	Gar	21/02/2018	*0.5*	5.02	2.32	*9.5*	0.391	405	*0.25*	59.2	*0.5*	14400
SW1-GAR	River/Stream	Gar	21/02/2018	*0.5*	0.401	2.55	*9.5*	4.43	28.9	0.599	32.1	1.15	4400
SW3-GAR	River/Stream	Gar	21/02/2018	*0.5*	2.2	0.966	26.3	2.98	220	*0.25*	37.2	*0.5*	9860
SW5-GAR	Discharge	Gar	21/02/2018	*0.5*	6.46	4.49	*9.5*	*0.1*	444	1.07	73.6	*0.5*	17400
SW7-GAR	Drainage	Gar	21/02/2018	*0.5*	*0.075*	0.317	*9.5*	0.399	23.7	*0.25*	16	*0.5*	4590
SW1-SM	River/Stream	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	*0.1*	4.92	*0.25*	*0.2*	*0.5*	*0.5*
SW2-SM-SOUTH	Discharge	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	1.69	*0.5*	*0.25*	6.74	*0.5*	2040
SW3-SM	River/Stream	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	1.68	3.08	*0.25*	0.615	*0.5*	90.6
SW4-SM-GA	River/Stream	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	1.23	3.71	*0.25*	1.06	*0.5*	203
SW5-SM	River/Stream	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	0.823	2.93	*0.25*	1.11	*0.5*	217
SW6-SM	River/Stream	Bg	22/02/2018	*0.5*	*0.075*	*0.15*	*9.5*	1.5	3.96	*0.25*	1.08	*0.5*	213
DS-GORTEENADIHA	River/Stream	Gtd	20/02/2018	*0.5*	0.257	15.9	44.5	28.7	28	*0.25*	2.21	*0.5*	134

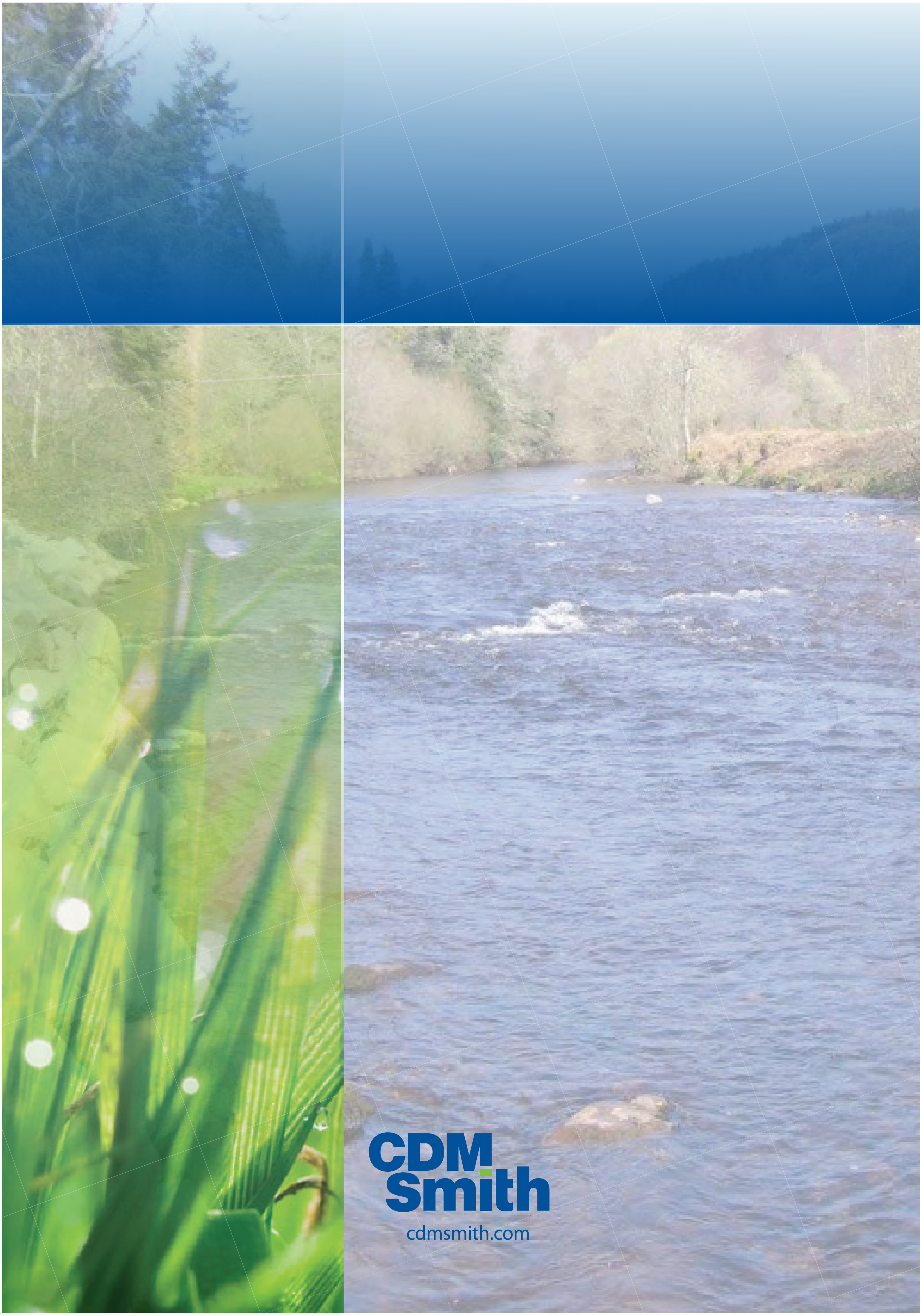
xx Exceeds Ecological Assessment Criteria
xx Exceeds Human Health Assessment Criteria
xx Exceeds both Ecological and Human Health Criteria
xx Less than the Limit of Detection (LOD) - Value taken to t
- Not analysed or no assessment criteria
* Only applies to rivers or streams (i.e. not discharges)

Table B-2 Comparison of Surface Water Results to Assessment Criteria for Livestock Drinking Water R1 (2018)

Sample Description	Area	Type	Date Sampled	Sulphate	Aluminium (diss.filt)	Arsenic (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Lead (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
		Livestock Criteria		500	5000	200	50	1000	1000	500	100	100	24000
DS-GORT	River/Stream	GM	19/02/2018	34	10.4	*0.25*	0.476	*0.5*	*0.075*	1.21	1.82	*0.5*	190
GORT-TMF-SEEP	Seep	GM	19/02/2018	-	3.24	2.76	2.84	*0.5*	1.71	*0.15*	*0.1*	1.25	2600
SW10-GORT DISCHARGE	Discharge	GM	19/02/2018	311	3.66	*0.25*	0.122	*0.5*	*0.075*	0.95	0.425	*0.5*	794
SW10-GORT DS	River/Stream	GM	19/02/2018	33.4	11.7	*0.25*	0.107	*0.5*	*0.075*	0.876	0.442	*0.5*	75.1
SW10-GORT US	River/Stream	GM	19/02/2018	25.6	8.32	*0.25*	0.105	*0.5*	*0.075*	0.857	0.38	*0.5*	51.2
SW12-GORT DISCHARGE	Discharge	GM	19/02/2018	351	10.4	*0.25*	0.519	*0.5*	0.662	0.844	*0.1*	*0.5*	701
SW12-GORT DS	River/Stream	GM	19/02/2018	50.4	9.36	*0.25*	0.456	*0.5*	0.164	1.25	1.98	*0.5*	225
SW14-GORT	River/Stream	GM	19/02/2018	33.7	8.87	*0.25*	0.414	*0.5*	*0.075*	1.1	1.96	*0.5*	186
SW17-GORT	River/Stream	GM	19/02/2018	11.5	9.5	*0.25*	0.04	*0.5*	*0.075*	1.08	*0.1*	*0.5*	3.59
SW18-GORT	Drainage	GM	19/02/2018	151	*1*	0.559	0.472	*0.5*	*0.075*	2.82	27	*0.5*	196
SW19-GORT	Drainage	GM	19/02/2018	203	*1*	*0.25*	0.591	*0.5*	*0.075*	2.11	4.21	*0.5*	293
SW6-MAG	River/Stream	Mag	19/02/2018	184	7.4	*0.25*	1.78	*0.5*	0.637	6.13	*0.1*	*0.5*	795
DS-SHAL	River/Stream	Shal	20/02/2018	128	11.8	*0.25*	6.81	*0.5*	0.738	5.54	41.3	*0.5*	3240
SW12-SHAL	Drainage	Shal	20/02/2018	*1*	50.4	*0.25*	0.0826	*0.5*	0.243	*0.15*	23	*0.5*	16.5
SW13-SHAL	Drainage	Shal	20/02/2018	38.4	1	*0.25*	0.265	*0.5*	*0.075*	*0.15*	0.611	*0.5*	16.5
SW15-SHAL	Drainage	Shal	20/02/2018	92.2	20.1	*0.25*	23.3	*0.5*	5.08	15.2	11.1	*0.5*	8100
SW1-SHAL	River/Stream	Shal	20/02/2018	28.3	33.6	*0.25*	3.41	*0.5*	1.7	9.21	198	*0.5*	969
SW4-SHAL	Drainage	Shal	20/02/2018	2	7.97	*0.25*	0.701	*0.5*	0.484	1.32	6.39	*0.5*	87.1
SW5-SHAL	Drainage	Shal	20/02/2018	92.7	32.7	*0.25*	24.1	*0.5*	6.23	24.5	22.4	*0.5*	8710
SW6-SHAL	Discharge	Shal	20/02/2018	11.5	39.2	0.827	1.3	*0.5*	1.94	16.9	417	*0.5*	250
SW9-SHAL	River/Stream	Shal	20/02/2018	26.3	34.1	0.505	3.58	*0.5*	1.89	12	260	*0.5*	1060
US-SHAL	River/Stream	Shal	20/02/2018	327	*1*	*0.25*	15.5	*0.5*	0.748	*0.15*	2.05	*0.5*	7910
SW10-GAR	Discharge	Gar	21/02/2018	390	*1*	*0.25*	27.7	*0.5*	2.32	0.663	2.41	*0.5*	10600
SW12-GAR	Drainage	Gar	21/02/2018	397	*1*	*0.25*	28.5	*0.5*	5.02	2.32	0.391	*0.5*	14400
SW1-GAR	River/Stream	Gar	21/02/2018	768	4.06	*0.25*	7.79	*0.5*	0.401	2.55	4.43	1.15	4400
SW3-GAR	River/Stream	Gar	21/02/2018	362	*1*	*0.25*	26.2	*0.5*	2.2	0.966	2.98	*0.5*	9860
SW5-GAR	Discharge	Gar	21/02/2018	332	*1*	0.656	32.3	*0.5*	6.46	4.49	*0.1*	*0.5*	17400
SW7-GAR	Drainage	Gar	21/02/2018	353	*1*	*0.25*	5.95	*0.5*	*0.075*	0.317	0.399	*0.5*	4590
SW1-SM	River/Stream	Bg	22/02/2018	4.1	*1*	*0.25*	27.7	*0.5*	2.32	0.663	2.41	*0.5*	10600
SW2-SM-SOUTH	Discharge	Bg	22/02/2018	33.2	*1*	*0.25*	28.5	*0.5*	5.02	2.32	0.391	*0.5*	14400
SW3-SM	River/Stream	Bg	22/02/2018	5.2	4.06	*0.25*	7.79	*0.5*	0.401	2.55	4.43	1.15	4400
SW4-SM-GA	River/Stream	Bg	22/02/2018	10	*1*	*0.25*	26.2	*0.5*	2.2	0.966	2.98	*0.5*	9860
SW5-SM	River/Stream	Bg	22/02/2018	9.7	*1*	0.656	32.3	*0.5*	6.46	4.49	*0.1*	*0.5*	17400
SW6-SM	River/Stream	Bg	22/02/2018	10.1	*1*	*0.25*	5.95	*0.5*	*0.075*	0.317	0.399	*0.5*	4590
DS-GORTEENADIHA	River/Stream	Gtd	20/02/2018	8.6	20.7	*0.25*	0.901	*0.5*	0.257	15.9	28.7	*0.5*	134

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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