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 2

September 2018

CDM Smith

GWP consultants
earth & water resources

Document Control Sheet

Client		Department of Communications, Climate Action and Environment		
Project		Environmental Monitoring of Former Mining Areas of Silvermines and Avoca		
Project No		118174		
Report		Monitoring Report for the Former Mining Area of Silvermines – September 2018		
Document Reference:		118174/40/DG/14		
Version	**Author**	**Checked**	**Reviewed**	**Date**
1	O McAlister	R O'Carroll	R L Olsen	November 2018
2	O McAlister	R O'Carroll	R L Olsen	February 2019
3	O McAlister	R O'Carroll	R L Olsen	May 2019

Table of Contents

Appendices

List of Tables

List of Figures

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 September 2018 (2018 Round 2). This report should be read alongside the Silvermines Data Report (Document Ref: 118174/40/DG/12, dated November 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 (GTD), Magcobar (MA) and Shallee South (ShS) /East (ShE), and cover an area of approximately 2,300 ha as shown on Map 1 in **Appendix A**. The last working mine, a barite operation at Magcobar, closed in 1993. Just over a decade previously, the final base metal mine shut down, following the cessation of underground operations by Mogul Mines Ltd. (Mogul) at Garryard. The latter operation resulted in the generation of significant volumes of fine to coarse grained sand-sized particles referred to as tailings. Approximately 8 Mt of such tailings were deposited in a specially constructed, 60 ha tailings management facility (TMF) at Gortmore (GM). Rehabilitation works have been completed at various localities including Gortmore TMF, with the site work administered by North Tipperary County Council on behalf of the Department. To date this rehabilitation work has included:

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

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

1.3 Catchment Description

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

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

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

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

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

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

1.4 Geology and Hydrogeology

1.4.1 Geology

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

1.4.2 Hydrogeology

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

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

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

Section 2

Methodology

2.1 Field Sampling Methods

2.1.1 Groundwater Sampling

Two groundwater monitoring wells were sampled on 12 September 2018 as listed in Table 1 and shown on Map 2 in Appendix A. Water levels were measured at an additional seven monitoring wells (Table 1), located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder.

Groundwater level data are contained in Appendix 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, oxidation-reduction potential (ORP), conductivity and dissolved oxygen (DO). Purging continues until the field parameters have stabilised. The results are recorded approximately every five minutes during the purging process 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 September 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

Twenty nine surface water locations were sampled between 10 and 13 September 2018, as listed in Table 2 and shown on Maps 2 to 5 in **Appendix A**. Table 2 lists thirty five locations of which six were not sampled (dry and no flow): SW18-Gort, SW19-Gort, Gort-TMF-Seep, SW5-Shal, SW15-Shal and SW1-Gar. In addition, SW14-Shal was not sampled due to health and safety concerns (not listed on Table 2 but shown on Map 3 in **Appendix A)**.

Surface water sampling was conducted in accordance with the Surface Water Sampling Procedure (SOP 1-1) as detailed in the Monitoring Plan. 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
SW18-Gort	GM	179772	172666	Site of discharge from the main pond on the TMF. No flow 10/9/18	No	No	No
SW19-Gort	GM	180097	172982	Discharge to TMF wetlands. DS of decant. No flow 10/9/18	No	No	No
SW17-Gort	GM	180539	173040	Site located on Kilmastulla River, upstream of TMF	Yes	Yes	No
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	Bucket
SW10-Gort-DS	GM	180192	172366	20m downstream of the outfall, on the Kilmastulla River	Yes	Yes	No
Gort-TMF-Seep	GM	179811	172176	Seeps at the southern edge of TMF, discharging to wetlands	No	No	No
SW12-Gort-Discharge	GM	179562	172165	Sample of wetland discharge prior to outfall	Yes	Yes	Bucket
SW12-Gort-DS	GM	179532	172138	20m downstream of the outfall, on the Kilmastulla River	Yes	Yes	No
SW14-Gort	GM	179336	172162	Site located on Kilmastulla River, downstream of TMF	Yes	Yes	No
DS-Gort	GM	178514	171877	Site located on Kilmastulla River, downstream of TMF	Yes	Yes	Float
SW6-Mag	MG	182774	171406	Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road.	Yes	Yes	No
US-Shal	ShS	180713	171795	Yellow River upstream of ShS	Yes	Yes	MarshMcB
SW4-Shal	ShS	180328	171078	Water-course west of 'Drum Dump' and Shallee South workings.	Yes	Yes	Bucket
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 flow 11/09/18	No	No	No
SW6-Shal	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Yes	Bucket
SW15-Shal	ShS	180606	171343	Stream downgradient of the drum dump and SW5-Shal in the Shallee mining area. No flow 12/09.18.	No	No	No
SW9-Shal	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Yes	MarshMcB
SW12-Shal	ShS	180676	171173	Stone lined drainage channel SSW of reservoir	Yes	Yes	Bucket
SW13-Shal	ShS	180709	171776	Stream draining the eastern section of the tailings impoundment (adjacent to SW1-Shal in northern most corner)	Yes	Yes	MarshMcB
SW1-Shal	ShS	180708	171776	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.	Yes	Yes	MarshMcB
DS-Shal	ShS	180609	171845	Yellow River downstream of ShS and BG	Yes	Yes	MarshMcB
DS-Gorteenadiha	GTD	180749	171785	Stream downgradient of Gorteenadiha	Yes	Yes	MarshMcB

Site Name	Area	Easting	Northing	Sample Site Notes	Chemical Analysis	Field Parameters	Flow
SW1-Gar	GA	182116	171322	Stream sampled south of R499 road (south of old Mogul Yard). No flow 12/09/18.	No	No	No
SW5-Gar	GA	181950	171418	Discharge from Knight Shaft	Yes	Yes	No
SW12-Gar	GA	181784	171573	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Yes	Flume
SW10-Gar	GA	181615	171736	Discharge from Garryard tailings lagoon	Yes	Yes	Flume
SW7-Gar	GA	181523	171493	Discharge from smaller settlement pond	Yes	Yes	Bucket
SW3-Gar	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Yes	MarshMcB
SW1-SM	BG	184066	170706	Site on Silvermines Stream (upstream of Ballygown mine workings).	Yes	Yes	MarshMcB
SW3-SM	BG	184253	171426	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)	Yes	Yes	MarshMcB
SW2-SM-South	BG	184251	171589	Discharge from 'Southern' adit.	Yes	Yes	Bucket
SW5-SM	BG	184301	171690	Site on Silvermines Stream (downstream of main Ballygown workings and of North adit)	Yes	Yes	MarshMcB
SW6-SM	BG	184121	172051	Site on Silvermines Stream (downstream of main Ballygown workings and of North adit)	Yes	Yes	MarshMcB
SW4-SM-GA	BG	183953	172486	Site on Silvermines Stream (downstream of all mine workings)	Yes	Yes	MarshMcB

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

Flow Measurements

Flow was measured at 22 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.

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 Marsh McBirney meter was also used at some lower flow locations where conditions were appropriate to use the meter.

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

2.1.3 Vegetation Sampling

Vegetation and soil sampling were undertaken at Gortmore TMF during Round 2. Vegetation samples from twenty locations were collected on 29th August 2018 from the remediated Areas A and B at Gortmore TMF, as listed in Table 3 and shown on Map 6 in Appendix A.

Vegetation sampling conducted was consistent with the procedure detailed in the Monitoring Plan. The predetermined vegetation sampling locations were located in the field using a GPS and a one metre square template was placed on the ground. Within the one meter square area, all obvious weed species were removed. Vegetation samples were collected from the above ground plant material using shears.

Representative samples were collected within each metre squared area consisting of mostly live vegetation. Photographs of the one meter square area before sample collection and of the vegetation sample after collection are contained in Appendix D of the Data Report.

Table 3 Location Vegetation and Soil Sampling Sites at Gortmore TMF

Site Name	Easting	Northing	Sample Area
SM01	179853	173080	A
SM04	179799	172980	A
SM05	179869	172983	A
SM06	179922	172988	A
SM08	179851	172929	A
SM13	179903	172882	A
SM14	179748	172832	A
SM15	179815	172829	A
SM17	179694	172775	A
SM19	179802	172780	A
SM21	179603	172781	B

Site Name	Easting	Northing	Sample Area
SM22	179502	172730	B
SM27	179629	172679	B
SM28	179706	172674	B
SM30	179511	172636	B
SM31	179587	172630	B
SM33	179448	172581	B
SM34	179532	172578	B
SM38	179551	172528	B
SM40	179502	172432	B

2.1.4 Soil Sampling

Soil samples were collected from twenty locations on 29th August 2018 from the remediated Areas A and B at Gortmore TMF, at the same locations as the vegetation samples as listed in Table 3 and shown on Map 6 in Appendix A.

Soil sampling was conducted with the procedure detailed in the Monitoring Plan. The predetermined soil sampling locations were located in the field using a GPS. A surface soil sample was collected to a depth of 10cm (approximately 200g) using a decontaminated stainless steel trowel. Any obvious vegetation and large rocks were removed from the soil sample and the sample was mixed to homogenize it.

2.1.5 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.
- Vegetation:

  - Two duplicate vegetation samples were collected.
- Soil:
  - Two duplicate soil samples were collected; and
- Soil Standard Reference Material:
  - One certified standard reference material soil sample containing known concentrations of metals was shipped blind to the ALS laboratory (the SRM certificate is contained in Appendix G of the Data Report).

Sample IDs for the field QA/QC samples are listed in Table 4. 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 4 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
Groundwater and Surface water		
SM GD01.11	GW Duplicate	Duplicate of TMF1(D)
SM DB01.11	GW Decontamination blank	DI water (Lennox Lab Supplies: Batch No. 804-6252) pumped through groundwater pump after final decon at site TMF2
SM SD01.11	SW Duplicate	Duplicate of SW1-Shal
SM SD02.11	SW Duplicate	Duplicate of SW3-Gar
SM SD03.11	SW Duplicate	Duplicate of SW1-SM
SM DB02.11	SW Decontamination blank	DI water (Lennox Lab Supplies: Batch No: 804-6252) poured over SW composite sample bottle after final decon at SW1-SM
SM SR01.11	Standard Reference Material	Water ERA “Trace Metals” Lot #P273-740B
SM SR02.11	Standard Reference Material	Water ERA “Trace Metals” Lot #P273-740B
WB 01.11	Filtration blank	Deionised water filtered onsite (Lennox Lab Suppliers. Batch No: 804-6252)
WB 02.11	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: 804-6252)
SM SVD01.11	Vegetation Duplicate	Duplicate of SM17-V
SM SVD02.11	Vegetation Duplicate	Duplicate of SM38-V
SM SOD01.11	Soil Duplicate	Duplicate of SM17-S
SM SOD02.11	Soil Duplicate	Duplicate of SM38-S
SM SR03.11	Standard Reference Material	ERA “Trace Metals in Soil” Lot #D099-540

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 North Wales (Water Samples)

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

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

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

2.3.2 ALS Laboratory Vancouver (Vegetation Samples)

Vegetation samples were received and processed at ALS Minerals (formerly OMAC Laboratories), Loughrea, Co. Galway (received, logged, dried to 60 degrees, processed to constant weight and weighed) for dispatch to ALS Vancouver, Canada for analysis. At ALS Vancouver, samples were ground/macerated and a representative split sample was digested using HNO_3/HCl at elevated temperature and pressure. Vegetation samples were analysed for Zinc, Arsenic, Cadmium and Lead by ICP-AES or ICP-MS (Method ME VEG 41). All the laboratory reports and analytical data are contained in Appendix F of the Data Report and discussed fully in Section 4 of this report.

2.3.3 ALS Minerals Laboratory Loughrea (Soil Samples)

ALS Minerals (formerly OMAC Laboratories), Loughrea, Co. Galway analysed the soil samples and they are accredited to ISO 17025 by the Irish National Accreditation Board (INAB). ALS Minerals prepared the soil samples by pulverizing to <75 micron (OMAC code Pul-31). This ensures that representative subsamples will be used for analyses. Representative split samples were digested using aqua regia and analysed using ICP-AES (code ME-ICP41). In total 35 elements were reported including the following 12 elements: Pb, Zn, Cd, As, Cr, Cu, Hg, Fe, Mn, Ni, Al and Ba. All the laboratory reports and analytical data are contained in Appendix F of the Data Report and discussed fully in Section 4 of this report.

Section 3

Data Quality and Usability Evaluation

3.1 Introduction

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

3.1.1 Accuracy

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

%R is calculated as follows:

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

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

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

3.1.2 Precision

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

RPD is calculated as follows:

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

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

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

3.1.3 Blanks

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

3.1.4 Field QA/QC Samples

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

- Duplicate Samples: Duplicate surface water, groundwater, soil and vegetation samples were created in the field and submitted blind to the laboratories (see Table 4 for sample IDs). The results are used to evaluate the combined reproducibility of both the laboratory analyses and field sampling.

- Decontamination Blanks: After the surface and ground water sampling equipment was cleaned, DI water was poured over or pumped through the sampling equipment and collected for laboratory analysis (see Table 4 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 #P273-740B (Metals). One certified standard reference material soil sample containing known concentrations of metals was shipped blind to the ALS laboratory. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #D099-540 (Metals). The Certificates 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 5 provides the results of the 15 dissolved metals for the four duplicate samples and the calculated RPD between each pair of samples. When a reported value was below the limit of detection (LOD), in calculating the RPD, the LOD value was then substituted with a value of half the LOD; e.g. with a reported value of <1 µg/L, the RPD formula uses a value of 0.5 µg/L for calculating the RPD. Note if both the original and duplicate results were less than the limit of detection then the RPD was zero.

The RPD values are typically very low (less than 10 %). The exceptions are one Zinc RPD of -144 % and two Arsenic RPDs of 95.8 % and 16.9 %. These RPD values are still within the accepted range of up to 150%. For the groundwater duplicate for Zinc with an RPD of -144 %, the result for the original sample is less than the limit of detection of <1 µg/L, and the RPD formula uses half the LOD for calculation purposes (0.5 µg/L). As noted in Table 5, the Zinc result tested for TMF1 (<1 µg/L) has been used for interpretation.

The RPD values shown in Table 5 are below 150 %, with the RPDs values for the remaining key parameters calculated as follows: Aluminium (0%), Cadmium (0% to 5.1%), Copper (-7.5% to 8.6%), Iron (-1% to 0%), Lead (-2.6% to 8.3%), Nickel (-3.2% to 10%) and Arsenic 2.2% to 95.8% (note that the result for the duplicate sample is less than limit of detection of <0.5 µg/L, and the RPD formula uses half the LOD for calculation purposes (0.25 µg/L)).

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

Overall acceptable precision was observed and the original values can be used for the intended purposes (see Table 5).

Table 5 Water Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Dissolved Metal	LOD µg/l	TMF 1	SMGD 01.11	% RPD	SW1 Shal	SMSD 01.11	% RPD	SW3 Gar	SMSD 02.11	% RPD	SW1 SM	SMSD 03.11	% RPD
Aluminium	<10	<10	<10	0	<10	<10	0	<10	<10	0	<10	<10	0
Antimony	<1	<1	<1	0	1.03	1.11	-7.5	<1	<1	0	<1	<1	0
Arsenic	<0.5	3.75	3.67	2.2	0.829	0.747	10.4	1.73	1.46	16.9	0.71	<0.5	95.8
Barium	<0.2	160	159	0	256	259	-1.2	52.8	52.1	1.3	37.5	37.8	-0.8
Cadmium	<0.08	<0.08	<0.08	0	1.35	1.42	-5.1	3.25	3.29	-1.2	<0.08	<0.08	0
Chromium	<1	<1	<1	1.2	<1	<1	0	<1	1	0	<1	<1	0
Cobalt	<0.5	<0.5	<0.5	0	1.01	1.06	-4.8	0.512	0.501	0	<0.5	<0.5	0
Copper	<0.3	<0.3	<0.3	0	4.45	4.85	-8.6	1.67	1.55	2.2	<0.3	<0.3	0
Iron	<19	69	68	0	37	37	0	<19	<19	7.5	<19	<19	0
Lead	0.2	<0.2	<0.2	1	116	119	-2.6	3.64	3.35	0	<0.2	<0.2	0
Manganese	<3	94	92.7	0	49	49.8	-1.6	75.5	75.2	8.3	<3	<3	0
Molybdenum	<3	<3	<3	1.4	<3	<3	0	<3	<3	0.4	<3	<3	0
Nickel	<0.04	<0.4	<0.4	0	8.44	8.35	1.1	7.84	7.59	0	<0.4	<0.4	0
Vanadium	<1	<1	<1	0	<1	<1	0	<1	<1	3.2	<1	<1	0
Zinc	<1	<1	3.07	-144	294	298	-1.4	1270	1270	0	<1	<1	0

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

[1] The test result from the Zinc duplicate at TMF1 is almost exactly that result received from the lab for neighbouring borehole TMF2. A repeat test was requested on the duplicate for TMF1, but was not possible due to sample disposal. Due to the excellent RPD of all remaining parameters for the duplicate sample of TMF1 and the Zinc result for the duplicate of TMF1 being almost identical to that of TMF 2, the duplicate Zinc result for TMF1 is not being interpreted for assessment purposes. The Zinc result for TMF1 (<1 µg/L) has been assessed for interpretive purposes, and not the duplicate for TMF1.

Soil and Vegetation Duplicates

Duplicates values are provided for vegetation samples in Table 6 and for soil samples in Table 7. The sampling for vegetation included a duplicate vegetation sample for SM17-V and SM38-V. The RPDs are both within expected ranges and of relatively comparable percentage values, with one RPD slightly higher than others; the vegetation duplicate for SM38-V, had an RPD value of 102% for Arsenic, with a sample value of 0.1 mg/kg and a duplicate of 0.31 mg/kg (LOD <0.01 mg/kg). As noted above, the acceptable RPD values for field duplicates are usually 50 % to 150 %.

The soil sampling at the site, included a duplicate soil sample at the same locations for the vegetation, with samples SM17-S and SM38-S. The RPD results are below 50% in each case, and with two exceptions, the majority of the RPS values are below 20%. Overall, acceptable precision was observed and the original values can be used for the intended purposes.

Table 6 Vegetation Duplicate Pairs Reported Values (mg/kg) and Calculated % RPD

Sample	As	Cd	Pb	Zn
LOD	<0.01	<0.001	<0.01	<0.01
SM17-V	0.10	0.105	1.12	29.1
SM V001.11	0.08	0.101	1.12	29.1
% RPD	22	4	0	0
SM38-V	0.10	0.036	0.65	29.3
SM V002.11	0.31	0.040	0.94	30.4
% RPD	-102	-11	-36	4

Table 7 Soil Duplicate Pairs Reported Values (mg/kg) and Calculated % RPD

Sample	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
LOD	<100	<2	<10	<0.5	<1	<1	<100	<1	<5	<1	<2	<2
SM17-S	7200	6	80	1	15	10	9500	<1	1110	17	31	61
SM S0D01.11	6800	6	80	1	14	10	9000	<1	1070	16	28	57
% RPD	-5.7	0.0	0.0	28.6	6.9	0.0	5.4	0.0	3.7	6.1	10.2	6.8
SM38-S	6200	6	40	1	13	10	10100	<1	646	16	21	54
SM S0D02.11	6300	8	40	1	13	11	10400	<1	678	16	25	56
% RPD	1.6	-28.6	0.0	-15.4	0.0	-9.5	-2.9	0.0	-4.8	0.0	-17.4	-3.6

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 8 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 10 µg/l except for Iron with a detection limit of 19 µg/l.

In the filtered deionised blank water sample (WB 01.10), dissolved Iron was detected at a concentration of 30.9 µg/L (limit of detection <19 µg/L). In the unfiltered blank water sample (WB

02.10), Molybdenum was detected at a concentration of 9.35 µg/L (LOD <3 µg/L); and dissolved metals were detected at close to the LOD for two parameters, with Iron detected at a concentration of 19.4 µg/L (limit of detection <19 µg/L) and Zinc at a concentration of 1.03 µg/L (LOD <1 µg/L).

Decontamination blank samples were collected after field equipment decontamination, a groundwater decon blank sample (SM DB01.11) and a surface water decon blank sample (SM DB02.11). In the groundwater blank sample, the Barium concentration was 0.442 µg/L (LOD <0.2 µg/L), the Zinc concentration was 2.84 µg/L (LOD 1 µg/L) and the Chromium concentration was 1.03 µg/L (LOD <1 µg/L). In the surface water blank sample, the Barium concentration was 0.224 µg/L (LOD <0.2 µg/L), the Zinc concentration was 2.17 µg/L (LOD <1 µg/L) and the Lead concentration was 0.298 µg/L (LOD <0.2 µg/L).

The results from the laboratory method blank were obtained from ALS to determine if any contamination occurred within the laboratory (Table 8). There were no detections in the laboratory method blank. The blank sampling procedures show limited detection of a small number of metal parameters in the deionised water blank samples and decontamination blank samples within the larger suite of results from the quality control testing. The magnitude of the concentrations detected in the blank samples were close to the limit of detection and small relative to the concentrations detected in positive results which were reviewed across the site monitoring network, and therefore, do not affect the interpretation of results. Overall, the quality check procedures indicate that the results are considered acceptable for their intended use.

Table 8 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l)

Sample Description Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.11 (µg/l)	Water Blank WB02.11 (µg/l)	Labor-atory Method Blank (µg/l)	Decon blank SMDB01.11 (µg/l)	Labor-atory Method Blank (µg/l)	Decon blank SMDB02.11 (µg/l)	Labor-atory Method Blank (µg/l)
	Sample batch:	*180906-116*	*180906-116*		*180918-57*		180918-53	
Aluminium	<10	<10	<10	<10	<10	<10	<10	<10
Antimony	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Barium	<0.2	<0.2	<0.2	<0.2	**0.442**	<0.2	**0.224**	<0.2
Cadmium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.03	<0.08	<0.08
Chromium	<1	<1	<1	<1	**1.04**	<1	<1	<1
Cobalt	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Iron	<19	**30.9**	**19.4**	<0.2	<19	<19	<19	<19
Lead	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.298**	<0.2
Manganese	<3	<3	<3	<1	<3	<1	<3	<1
Molybdenum	<3	<3	**9.35**	<3	<3	<3	<3	<3
Nickel	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Vanadium	<1	<1	<1	<1	<1	<1	<1	<1
Zinc	<1	<1	**1.03**	<1	**2.84**	<1	**2.17**	<1

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. NB No such exceedance was detected.

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 9 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, Iron, Lead, Manganese, Molybdenum, Nickel and Zinc are in good agreement with the certified value (%R ranged from 85 to 107%). One of the reported values for dissolved Arsenic (85%) and Vanadium (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.

Table 9 Water SRM Reported Values (µg/l) and Calculated % R

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits		18349956 SMSR01.10 (µg/l)	% R	18329587 SMSR02.10 (µg/l)	% R
		Lower (%)	Upper (%)				
Aluminium	1,540	88	113	1,520	99	1,520	99
Antimony	314	87	110	287	91	304	97
Arsenic	644	87	110	549	**85**	586	91
Barium	2,140	91	108	1,950	91	2,280	107
Cadmium	738	89	107	693	94	716	97
Chromium	436	91	109	416	95	401	92
Cobalt	493	93	111	482	98	477	97
Copper	423	91	109	421	100	401	95
Iron	2,490	91	111	2,410	97	2,440	98
Lead	592	91	110	586	99	615	104
Manganese	210	93	110	195	93	200	95
Molybdenum	104	90	108	99	95	94	91
Nickel	449	91	109	432	96	412	92
Vanadium	1,440	91	107	1,280	**89**	1,320	92
Zinc	1,780	90	110	1,730	97	1,800	101

Notes:
Bold indicates an exceedance in acceptance limits

SRM Soil

One certified soil SRM was sent blind to the laboratory (Sample IDs SM SR03.10) to evaluate laboratory accuracy. The laboratory reports are provided in Appendix F of the Data Report. Table 10 summarises the SRM results. The certificate for the standard reference sample give the QC range of values within which a reported laboratory result will be acceptable. All the values are within the QC range noted.

Table 10 Soil SRM Reported Values (mg/kg) and Calculated % R

Sample Ref / Cert Ref	D099-540 (Issued 25Sep17) mg/kg	QC Lower limit mg/kg	QC Upper limit mg/kg	SM SR03-6 mg/kg
Aluminium	8360	4150	12600	7800
Arsenic	161	134	188	155
Barium	260	215	305	250
Cadmium	211	176	246	191
Chromium	136	112	160	130
Copper	166	139	192	151
Iron	14100	8470	19700	15700
Mercury	12	8	15	8
Manganese	228	188	268	206
Nickel	92	76	108	83
Lead	111	92	130	98
Zinc	199	162	237	194

Notes:
Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALS Laboratories

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

- Analytical Quality Control Samples (AQC) including, Certified Reference Material (CRM), Internal Reference Material (IRM) and Matrix spiked material. For batch sizes of 20 samples or less, a minimum of one AQC and for batches of greater than 20 samples, one AQC every additional twenty samples or part thereof. They are introduced into the sample batch on a random basis where possible. They are prepared at the same time as the rest of the batch and by the same person who prepares the batch;

- Process Blanks: A process blank was included with each batch of samples. The blanks are matrix matched where possible and were taken through the entire analytical system;

- Instrument Blanks: An instrument blank was run to check for any contamination within the instrument;

- Independent Check Standard: An independent check standard was included with every instrumental run of samples. This standard is prepared from a different standard than the calibration standards and is used as a check on the validity of the calibration standards. The acceptance criteria for this standard was method specific; and

- Replicate samples (samples tested more than once using the same method) were included at the same frequency as the AQCs.

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

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

3.4 Summary of Data Checks

3.4.1 Field Physico-chemical Versus Laboratory Data

Table 11 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 good. 90% of the samples had calculated %RPD values of less than 10%. 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 11 Field Physico-chemical Data and Laboratory Reported Values and Calculated % RPD

Sample Description	pH Lab (pH Units)	pH Field (pH Units)	% RPD
SW17-GORT	7.78	6.84	-12.9
SW18-GORT	no flow	no flow	no flow
SW19-GORT	no flow	no flow	no flow
SW10-GORT US	7.98	7.77	-2.7
SW10-GORT DISCHARGE	7.87	7.61	-3.4
SW10-GORT DS	8.13	7.92	-2.6
SW12-GORT DISCHARGE	7.65	7.3	-4.7
SW12-GORT DS	8.15	7.97	-2.2
SW14-GORT	8.15	8.22	0.9
DS-GORT	8.16	8.39	2.8
SW6-MAG	7.65	7.93	3.6
US-SHAL	8.27	8.05	-2.7
SW4-SHAL	7.24	6.57	-9.7
SW5-SHAL	no flow	no flow	no flow
SW6-SHAL	7.42	6.52	-12.9
SW15-SHAL	no flow	no flow	no flow
SW9-SHAL	7.71	7.20	-6.8
SW12-SHAL	4.82	4.23	-13.0
SW13-SHAL	7.13	6.90	-3.3
SW1-SHAL	7.47	7.38	-1.2
DS-SHAL	7.46	6.90	-7.8
DS-GORTEENADHIA	6.99	7.69	9.5
SW10-GAR	7.84	8.16	4.0
SW12-GAR	7.57	7.52	-0.7
SW1-GAR	dry	dry	dry
SW3-GAR	8.18	8.08	-1.2
SW5-GAR	7.12	7.09	-0.4
SW7-GAR	8.08	7.90	-2.3
SW1-SM	7.60	7.64	0.5
SW3-SM	7.72	7.12	-8.1
SW2-SM-SOUTH	7.72	7.78	0.8
SW5-SM	7.90	7.37	-6.9
SW6-SM	7.82	7.30	-6.9
SW4-SM-GA	7.94	7.48	-6.0
TMF1	7.90	7.35	-7.2
TMF2	7.44	7.05	-5.4

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 12 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 12 Summary of Dissolved Metal Concentrations in Groundwater

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Aluminium	<10	2	0	<10	<10	<10
Antimony	<1	2	0	<1	<1	<1
Arsenic	<0.5	2	2	3.75	4.31	4.03
Barium	<0.2	2	2	160	597	379
Cadmium	<0.08	2	0	<0.08	<0.08	<0.08
Chromium	<1	2	0	<1	<1	<1
Cobalt	<0.5	2	1	<0.5*	0.58	0.41
Copper	<0.3	2	0	<0.3	<0.3	<0.3
Iron	<19	2	2	69	77.4	73.2
Lead	<0.2	2	1	<0.2*	0.78	0.44
Manganese	<3	2	2	94	1020	557
Molybdenum	<3	2	0	<3	<3	<3
Nickel	<0.4	2	1	<0.4*	0.44	0.32
Vanadium	<1	2	0	<1	<1	<1
Zinc	<1	2	1	<1*	3.18	1.8

Notes: * If less than LOD minimum value taken to be half LOD for calculations.
Where 1 or 2 detections, No calculation of standard deviation

Elevated concentrations of dissolved Barium (597 µg/l) and Manganese (1020 µg/l) were recorded at TMF2 (downgradient of the TMF) and were significantly higher than the concentrations at TMF1 (upgradient of the TMF). The concentrations of dissolved Arsenic, Lead, Nickel and Zinc were higher in TMF2 compared to TMF1.

4.1.2 Surface Water Sample Results

Samples were collected for two major categories. The first comprised of mine adit discharges and discharges from wetlands as well as some drainage ditches for which Table 13 provides a summary of the results of the 11 discharge/ drainage samples), and the second comprised of rivers and streams, for which Table 14 provides a summary of the results of the 18 river and stream samples.

Discharges and Drainage

Table 13 Summary of Dissolved Metal Concentrations in Discharges and Drainage

Dissolved Metal	LOD (µg/l)	Number	Number of Detect-ions	Minimum (µg/l)	Maxi-mum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<10	11	1	<10*	153	18	-
Antimony	<1	11	1	<1*	1.46	1.38	-
Arsenic	<0.5	11	10	<0.5*	3.86	1.8	1.3
Barium	<0.2	11	11	20.5	572	164	160
Cadmium	<0.08	11	9	<0.08*	32.8	4.5	9.6
Chromium	<1	11	1	<1*	1.01	0.55	-
Cobalt	<0.5	11	7	<0.5*	7.14	1.6	2.1
Copper	<0.3	11	7	<0.3*	9.14	2.4	3.3
Iron	<19	11	5	<19*	1,500	194	445
Lead	<0.2	11	9	<0.2*	248	46.9	96.8
Manganese	<3	11	9	<3*	5,830	780	1,713
Molybdenum	<3	11	1	<3*	6.22	1.93	-
Nickel	<0.4	11	11	1.66	61.3	14.3	18.6
Vanadium	<1	11	0	<1*	<1	<1	0
Zinc	<1	11	11	35.4	11,900	2,349	4,116

Notes: * If less than LOD, min value taken to be half LOD for calculations. Where 1 or 2 detections, No calculation of standard deviation.

Rivers and Streams

Table 14 Summary of Dissolved Metal Concentrations in Rivers and Streams

Dissolved Metal	LOD (µg/l)	Number	Number of Detect-ions	Minimum (µg/l)	Maxi-mum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<10	18	2	<10*	115	60	-
Antimony	<1	18	1	<1*	1.03	0.77	-
Arsenic	<0.5	18	16	<0.5*	1.73	0.9	0.4
Barium	<0.2	18	18	34	282	136	86
Cadmium	<0.08	18	17	<0.08*	3.3	0.7	1.0
Chromium	<1	18	0	<1*	<1	<1	-
Cobalt	<0.5	18	5	<0.5*	2.1	0.5	0.5
Copper	<0.3	18	11	<0.3*	18.2	2.9	5.0
Iron	<19	18	12	<19*	257	52.7	73.7
Lead	<0.2	18	15	< 0.2*	151	25.1	47.2
Manganese	<3	18	14	< 3*	355	57.2	84.6
Molybdenum	<3	18	1	< 3*	6.0	3.8	-
Nickel	<0.4	18	16	< 0.4*	10.7	3.0	3.5
Vanadium	<1	18	0	<1*	<1	<1	-
Zinc	<1	18	17	<1*	1860	275	491

Notes: * If less than LOD, minimum value taken to be half LOD for calculations. Where 1 or 2 detections, No standard deviation.

Included in Table 13 and Table 14 are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metal concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection for calculation of mean values and standard deviations. The highest reported value of the field duplicate pair was used where applicable. Where the set of results for a parameter had only 1 or 2 positive results detected, the standard deviation was not calculated.

Within the drainage / discharges monitoring locations, the highest concentrations of Zinc (11,900 µg/L) and Cadmium (32.8 µg/L) were found at SW12-Gar, while the highest concentrations of Lead (248 µg/L) and Barium (572 µg/L) were found at SW12-Shal. The sample from SW6-Shal had the highest concentration of Copper (9.14 µg/L) within the drainage network.

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 3.11 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 37.5 µg/l and 282 µg/l, respectively.

Within the rivers and streams, the highest concentration of Lead (151 µg/l) was found at SW9-Shal, located downstream of the field shaft. DS-Gorteenadiha had the highest concentration of dissolved Copper (18.2 µg/l). The upstream US-Shallee monitoring sample had the highest concentration of Zinc (1,860 µg/L), Cadmium (3.32 µg/L) and Nickel (10.7 µg/L).

4.1.3 Vegetation Sample Results

Table 15 provides a summary of the results of the 20 vegetation samples from the remediated Areas A and B at Gortmore TMF. Included in this table are the mean, minimum, maximum, and standard deviation (SDEV).

Table 15 Summary of Vegetation Concentrations (mg/kg) at Gortmore TMF

	LOD	Number	Detections	Minimum	Maximum	Mean	SDEV	Median
Arsenic	<0.01	20	20	0.04	0.31	0.14	0.07	0.12
Cadmium	<0.001	20	20	0.03	0.22	0.11	0.06	0.09
Lead	<0.01	20	20	0.23	1.37	0.80	0.31	0.81
Zinc	<0.01	20	20	24.40	43.40	34.33	4.99	33.40

There were 20 detections of Cadmium, Arsenic, Lead and Zinc. The highest Arsenic concentration of 0.31 mg/kg tested was from vegetation sample SM 30-V (located towards the southern part of sample area B) and vegetation sample SM 17-V (located in sample area A, close to the boundary of area B). The highest concentration of Zinc was found in vegetation sample SM 27-V (sample area B) while the highest concentration of Cadmium and Lead were found in the sample SM 19-V (located towards the southern part of sample area A) area (see Map 6 in Appendix A).

4.1.4 Soil Sample Results

Table 16 provides a summary of the results of the 20 soil samples from the remediated Areas A and B at Gortmore TMF. Included in this table are the minimum, maximum, mean, median, and standard deviation (SDEV). Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection for the calculation of the mean and standard deviations.

Table 16 Summary of Soil Concentrations (mg/kg) at Gortmore TMF

Metal	LOD	Count	Detect-ions	Min	Max	Mean	SDEV	Median	Median in Irish soil
Aluminium	<100	20	20	5500	7900	6475	587	6350	34800
Arsenic	<2	20	20	6	11	7	1	8	7.3
Barium	<10	20	20	40	120	70	21	70	230
Cadmium	<0.5	20	18	<0.5	1.00	0.59	0.17	0.60	0.50
Chromium	<1	20	20	12	15	13	1	13	43
Copper	<1	20	20	8	49	12	9	10	16.2
Iron	<100	20	20	9500	14100	10980	1146	10800	18700
Mercury	<1	20	0	<1	<1	<1	0	<1	0.09
Manganese	<5	20	20	577	1110	741	157	690	462
Nickel	<1	20	20	12	21	16	2	16	17.5
Lead	<2	20	20	22	53	31	8	30	24.8
Zinc	<2	20	20	45	107	59	13	55	62.6

Notes: * If less than LOD minimum value taken to be half LOD for calculations
Notes: Irish Soil Median value from 1310 Irish soil samples (EPA, 2007)

Mercury was not detected in the soil samples during this round. Compared to Irish soils, the median concentrations of the samples are higher for arsenic, cadmium, manganese and lead. The median concentrations are lower than Irish soils, but in the same order of magnitude, for copper, nickel and zinc and the median concentrations are significantly lower for aluminium, barium, iron and chromium compared to the median concentration in Irish soils.

The highest arsenic concentration (11 mg/kg) was found in sample SM13-S which is located towards the centre of sampling area A; the sample from this location also had the highest lead concentration (53 mg/kg). The soil sample from location SM27-S had the highest concentration of cadmium (1 mg/kg) and zinc (107 mg/kg); SM27-S is located in the northern part of sample area B (see Map 6 in Appendix A). Overall, the median values for the samples are broadly similar to the values when last tested in 2015.

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 17. 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, and Manganese (Table 17).

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 17. The appropriate ecological assessment criteria are highlighted in bold in Table 17.

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 18. These values are the maximum permissible values for a drinking water source. In the case of metals, the standards are for total metals, however they apply post-treatment (including filtration) and therefore the dissolved portion is used in the assessment in Section 4.

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

The two main receptors of groundwater at Gortmore TMF are surface water bodies and the groundwater resource as a drinking water supply. Therefore, to assess the potential impact of the groundwater quality on relevant groundwater receptors, the same standards and guidelines as mentioned for surface water were utilised for screening purposes (Table 17).

Table 17 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

Parameter	Unit	AA	MAC (or 95%-ile)	Source	Description
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
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 18 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 19 summarises the recommended levels for metals where limits have been established, and for total dissolved solids and sulphate.

Table 19 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	

Parameter	Unit	Parametric Value	Source	Comment
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

4.2.3 Vegetation Assessment Criteria

The European Communities (Undesirable Substances in Feedingstuffs) Regulations 2003 (S.I. 317 of 2003) transpose the Directive 2002/32/EC on Undesirable Substances in Animal Feed into Irish law and are in place to control the metal content in animal feed. The EU Directive was last updated on 29 September 2006. Table 20 summarises the maximum content in feedingstuff for Arsenic, Cadmium and Lead applicable to the vegetation samples collected. No values are available for Zinc.

Table 20 Assessment Criteria for Vegetation (mg/kg)

Undesirable Substance	Directive 2002/32/EC		Oak Ridge National Laboratory	
	Product Intended for Animal Feed	Maximum Content in Animal Feed (mg/kg)	Plants	Wildlife No Effect / Low Effect Level (mg/kg)
Arsenic	Feed materials	2	Concentrations for adverse effects in whitetail deer (dietary exposure)	0.621 / 6.211
Cadmium	Feed materials of Vegetable Origin	1		8.787 / 87.871
Lead	Green Fodder	30		72.88 / 728.78
Zinc	n/a	None		1457.6 / 2915.1

For Arsenic in animal feed, the value given in the above table is the lowest provided. For Cadmium, feeding stuffs for calves, lambs and kids should have a maximum concentration of 0.5 mg/kg. Exceptions are provided for other products such as meal made from grass, minerals, etc. For Lead, green fodder is defined as "products intended for animal feed such as hay, silage, fresh grass, etc."

The maximum content is actually the "Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12 %". For Cadmium and Lead, the Directive states that the extraction be "performed with nitric acid (5 % w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency." The ALS drying and digestion methods for the vegetations samples probably yield slightly higher values than those reported to a moisture content of 12 % and using 5 % nitric acid. Therefore any comparisons of the measured values to the standards in Table 20 will be conservative and provide adequate protection.

Additional comparisons of the measured vegetation concentrations to published criteria and screening levels were also performed. The criterion for plants shown on Table 20 is for digestion by wildlife (whitetail deer) taken from the Oak Ridge National Laboratory (Sample *et al.*, 1996).

4.2.4 Soil Assessment Criteria

The Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 (S.I. No. 148 of 1998) sets maximum values for concentrations of heavy metals in soil designed to set specifications for soils that may receive sewage sludge. These maximum values have been widely used as threshold or indicator values of soil quality. Table 21 summarises the maximum values for concentrations of heavy metals in soil.

Additional comparisons are made to screening levels or thresholds to indicate the concentrations at which metals in soils may have adverse effects (phytotoxicity) on the vegetation, wildlife or grazing cattle and sheep. Table 21 summarises the screening level and threshold values and the information sources.

Table 21 Assessment Criteria for Soil (mg/kg)

Metal	Maximum values for concentrations of heavy metals [1]	Eco-SSL (phytotoxicity) (mg/kg) [2]	Eco-SSL (mammalian) (mg/kg) [2]	ORNL Phytotoxicity Benchmark (mg/kg) [3]	Toxicity Reference Value (TRV) for Cattle (mg/kg) [4]	TRV for Sheep (mg/kg) [4]
	Threshold for soil where sewage sludge might be applied	*Threshold for plant toxicity via direct contact/ uptake*	*Threshold for toxicity to mammals via dietary transfer (considers bioaccumulation)*	*Threshold for adverse effects in terrestrial plants*	*TRV for protection of cattle via diet*	*TRV for protection of sheep via diet*
Arsenic	none	18	46	10	419	352
Cad-mium	1	32	0.36	4	15	12
Copper	50	70	49	100	413	86
Nickel	30	38	130	30	none	none
Lead	50	120	56	50	244[3]	203
Zinc	150	160	79	50	1082	545

Notes:
1. Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 (S.I. No. 148 of 1998);
2. USEPA (2005); 3. Oak Ridge National Laboratory (ORNL) Efroymson *et al.* (1997); 4. Ford (2004).
3. Teagasc has recently published the document “Lead and Animal Health” for areas near Silvermines; a value of 1000 mg/kg was adopted as a cautionary level.

4.3 Comparison to Assessment Criteria

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

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

4.3.1 Groundwater Assessment

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

Sulphate was within normal ranges, with values ranging from 3.3 to 19.7 mg/l, which was well below the criteria for drinking water of 250 mg/l. Ammonia was below the limit of detection in both monitoring wells. For Barium and Manganese, concentrations were significantly higher in TMF2 with a value of 597 µg/l for Barium and 1,020 µg/l for Manganese. Dissolved Zinc was below the limit of detection in TMF1 and 3.18 µg/l in TMF2.

4.3.2 Surface Water Assessment

A total of twenty nine locations were sampled for chemical analyses, including discharges / drainage locations (11 samples) and river / stream locations (18 samples). Full details of the results are given in **Appendix B,** with locations identified in the table as being either drainage or river / stream.

In addition to detailed results given in **Appendix B,** Table 22 provides a summary for a number of key parameters and dissolved metals, for the river/stream locations only, of the upstream and downstream locations at the different mining areas which exceeded the relevant ecological and drinking water assessment criteria. Footnotes in both tables (Tables B-1 and 22) describe which assessment criterion is colour highlighted within the table in each case. For the sampling locations refer to the maps in **Appendix A**.

The field pH from these sampling locations in the Silvermines mining area ranged from 4.23 to 8.39 with a median of 7.48. Two of the field pH values were outside the pH range (pH 6.5 to 9.5) given in the Drinking Water assessment criteria (SI 106 of 2017), the field pH at SW12-Shal (pH 4.2) and pH at SW4-Shal (pH 6.37).

The conductivity at all locations, including discharges, ranged from 0.075 mS/cm to 2.849 mS/cm with an average of 0.599 mS/cm and a median of 0.495 mS/cm; the highest conductivity was at the discharge location SW10-Gort-Discharge (2.849 mS/cm) and the highest conductivity in the drainage channels/ streams was at location SW12-Gar (1.357 mS/cm), (Table B-1 in **Appendix B**). With the exception of the measured value at DS_GORT (133 % Saturation DO), the dissolved oxygen values in river and stream sampling locations (marked River/ Stream in Table B-1 in **Appendix B**) were within the range (80-120%) cited in S.I. No. 272 of 2009 Environmental Objectives Surface Water Regulations for ecological health with an average dissolved oxygen value at the river and stream locations of 99%.

Table 22 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

Area	Sample Description	Sample Location	Date Sampled Units	Ammoniacal Nitrogen as N mg/l	Sulphate mg/l	Cadmium (diss.filt) µg/l	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Nickel (diss.filt) µg/l	Zinc (diss.filt) µg/l
			Ecological Criteria	0.14	-	0.9	1.2	1100	4	100
			Human Health Criteria	0.3	250	5	10	50	20	-
Gortmore	SW17-GORT	Upstream		0.1	16.5	0.04	0.1	28.8	0.577	3.11
	SW12-GORT-DS	Downstream (TMF)		0.1	89	0.314	2.93	160	1.47	53.7
	SW14-GORT	Downstream (TMF and Yellow River)		0.1	62	0.099	2.53	80.1	1.37	43.3
	DS-Gort	Downstream (TMF and Yellow River)		0.1	61.7	0.04	2.0	55.7	1.24	27.7
Magcobar	SW6-Mag	Downstream		0.1	184	0.497	0.1	1.5	2.56	188
Shallee	US SHAL	Downstream of SW3-GAR		0.1	293	3.32	8.94	355	10.7	1860
Shallee	SW4-SHAL	Upstream		0.1	23.9	0.681	6.08	48	4.17	92.2
	SW5-SHAL	DS (drum dump)		[1]	[1]	[1]	[1]	[1]	[1]	[1]
	SW9-SHAL	Downstream		0.1	21.1	1.52	151	60.2	8.95	318
	SW1-SHAL	Downstream (all)		0.1	21.7	1.35	116	49	8.44	294
Garryard/ Shallee	DS SHAL	Downstream of SW3-GAR and SW1-SHAL		0.211	39.9	0.913	77.9	62.7	3.9	299
GTD	DS-Gorteenadiha	Downstream of GTD		0.1	10.6	0.563	82	20	2.21	66.4
Garryard	SW1-GAR	Upstream		[1]	[1]	[1]	[1]	[1]	[1]	[1]
	SW3-GAR	Downstream (all)		0.1	298	3.25	3.64	75.5	7.84	1270
Ballygown	SW1-SM	Upstream		0.1	11.7	0.04	0.1	1.5	0.2	0.5
	SW3-SM	DS (workings & Adits)		0.1	9.6	0.04	0.421	1.5	0.2	30.8
	SW5-SM	DS (workings & Adits)		0.1	10.4	0.298	0.724	3.78	0.515	150
	SW6-SM	DS (workings & Adits)		0.1	10.5	0.234	1.44	3.73	0.549	148
	SW4-SM-GA	Downstream (all incl. tailings deposit)		0.1	11.4	0.187	1.63	1.5	0.578	149

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

xx Exceeds Ecological Assessment Criteria

xx Exceeds Drinking Water Assessment /Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

Metals are dissolved

Ammonia was detected in three of the discharges; SW12-Gort-Discharge (1.04 mg/l N), SW5-Gar (1.85 mg/l N) and SW10-Gar (0.82 mg/l N) (Table B-1 in **Appendix B**) and in two of the stream samples DS-Gort (0.388 mg/l N) and DS-Shal (0.211 mg/l N). The ecological assessment criteria for Ammonia is 0.14 mg/l as N and each of the samples with Ammonia detected exceeded the threshold. Ammonia was below the limit of detection in samples from the remaining fourteen river and stream locations and the remaining discharges/ drainage locations.

Sulphate exceeded the criteria for drinking water (250 mg/l) at the wetland discharges in the Gortmore area, SW12-Gort-Discharge (1,110 mg/l), with the highest measured value at SW10-Gort-Discharge (1,780 mg/l) (Table B-1 in **Appendix B**). The Sulphate threshold was exceeded at four of the five locations within the Garryard area with values ranging from 150 to 683 mg/l. In Table 22, within the set of stream/ river locations, two locations exceeded the criteria; SW3-GAR, a downstream location, exceeded the threshold with a Sulphate concentration of 298 mg/l, and in the Shallee area, location US-Shal, located downstream of the Garryard area, also exceeded (293 mg/l).

Dissolved Metals Assessment

As noted above, Table 22 provides a summary for a number of key parameters and dissolved metals, for the river/stream locations only, see the Table B-1 in **Appendix B** for the full listing of all parameters.

Dissolved Arsenic (Table B-1 in **Appendix B**) was detected at twenty six of the sampling locations, with a median value of 1.06 µg/L, and there were no exceedances of either the human health (10 µg/L) or the ecological assessment criteria (25 µg/L).

There were exceedances of dissolved barium, cadmium, cobalt, iron, lead, manganese, nickel and zinc, as discussed below. Results for barium testing are given in the Table B-1 in **Appendix B**. The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with a median value of 148 µg/L, with elevated values at upstream locations SW10-Gort Upstream (145 µg/L) and US-Shal (75 µg/L). These barium concentrations are similar to those recorded in previous monitoring rounds. Exceedances of dissolved barium are not discussed further.

With the exception of the discharge location sample at Gortmore, the highest concentrations of lead, manganese, nickel and zinc (Table 22) were in the Garryard and Shallee areas as described below.

In the Ballygown area (Map 5 of **Appendix A**) where the Silvermines stream is located, there were exceedances of dissolved lead, nickel and zinc. There were no exceedances at the upstream site, SW1-SM, other than for barium as noted. At the southern Adit (SW2-SM-South) (Table B-1 in **Appendix B)**, concentrations of dissolved lead (1.25 µg/l), nickel (4.86 µg/l) and zinc (1,660 µg/l) exceeded the ecological assessment criteria, respectively. Dissolved zinc concentrations exceeded the ecological assessment criteria of 100 µg/l at the three sites downstream of the discharge (SW5-SM, SW6-SM and SW4-SM-GA) (Table 22), and values ranged from 148 µg/l to 150 µg/l. Dissolved lead concentrations were measured at the downstream locations (SW5-SM, SW6-SM and SW4-SM-GA) ranging from 0.72 µg/L to 1.63 µg/L, relative to the ecological assessment criteria of 1.2 µg/l.

The concentration of dissolved zinc at SW6-Mag (188 µg/l), which is downstream of the Magcobar mining area, exceeded the ecological assessment criteria of 100 µg/l. With the exception of barium, previously discussed above, the remaining dissolved metal concentrations at SW6-MAG, did not exceed the Drinking Water or ecological criteria.

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

At Gortmore TMF, dissolved Manganese exceeded the drinking water criteria (50 µg/l) at SW12-Gort-Discharge (5,830 µg/L Mn) and four other locations with values ranging from 55 µg/L to 160 µg/L (Table B-1 in **Appendix B**). Manganese exceeded the drinking water criteria at seven of the river/ stream locations within the Gortmore, Shallee and Garryard mining areas with concentrations ranging from 55.7 µg/L to 355 µg/L (US-Shal). Dissolved Nickel values in the Shallee mining area exceeded the Nickel ecological assessment criteria (4 µg/L) at each of the sampling locations as well as at SW3-GAR. Dissolved Lead exceeded the ecological (1.2 µg/l) assessment criteria at locations SW12-Gort (2.93 µg/L), SW14-Gort (2.53 µg/L) and Downstream at DS-Gort (2 µg/L) (Table 22).

The dissolved Iron concentration at SW12-Gort-Discharge (332 µg/L) also exceeded the drinking water criteria of 200 µg/L (Table B-1 in **Appendix B**).

The concentration of dissolved Zinc increased on the Kilmastulla River from 3.11 µg/l at the upstream location, SW17-Gort, to 53.7 µg/l at the downstream location, SW12-Gort-DS (Table 22). SW12-Gort-DS is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The loadings from these areas are discussed in Section 5.

At Garryard, the highest concentrations of dissolved Nickel were in drainage / discharge samples from SW5-Gar (61.3 µg/L) and SW12-Gar (38.9 µg/L) (Table B-1 in **Appendix B**) and exceed the human health criteria of 20 µg/L, and concentrations at SW10-Gar (9.45 µg/L) and SW3-Gar (7.84 µg/L) exceed the ecological criteria (4 µg/L).

Within Garryard, dissolved Zinc concentrations ranged from 35 µg/L to 11,900 µg/L with a median value of 2,190 µg/L relative to the ecological criteria of 100 µg/L. Lead concentrations at Garryard ranged from 3.6 µg/L to 6.1 µg/L, exceeding the ecological assessment criteria (1.2 µg/L).

At Shallee (Map 3 of **Appendix A**), there were exceedances of the ecological assessment criteria for Lead, Manganese, Nickel and Zinc for almost all locations, and drinking water criteria were exceeded for Lead and for Manganese for five of the seven samples. Dissolved Manganese values ranged from 60 µg/L to 863 µg/L (SW12-Shal), with a median of 63 µg/L, relative to the drinking water criteria of 50 µg/L. Dissolved Nickel concentrations exceeded the ecological assessment criteria at six of the seven Shallee locations, ranging from 4.17 µg/L to 10.3 µg/L.

Dissolved Lead concentrations in the Shallee area ranged from 6 µg/L to 237 µg/L, relative to the drinking water criteria of 10 µg/L. The highest concentrations of Lead were at 12-Shal (248 µg/L) and at SW6-Shal (237 µg/L) with a median Lead concentration in the Shallee samples of 116 µg/L. Dissolved Zinc concentrations ranged from 161 µg/L to 478 µg/L with a median value of 294 µg/L relative to the ecological criteria of 100 µg/L.

Downstream-Shal is located on the Yellow River, downstream of all the discharges from the Shallee and Garryard mining areas and located upstream of the confluence with the Kilmastulla River in the Gortmore area. The Dissolved Iron concentration exceeded the drinking water criteria (200 µg/L) at Downstream-Shal (243 µg/L). The dissolved Lead concentration (77.9 µg/L) exceeded both the ecological and drinking water (10 µg/l) assessment criteria. The dissolved Zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 299 µg/l.

4.3.3 Livestock Water Quality Assessment

Recommendations on the levels of toxic substances in drinking water for livestock are provided in Table 19. 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 237 µg/l, relative to the livestock criteria (100 µg/L). The sampling location on the stream SW9-Shal, which is just downstream of the Field Shaft, had concentration of 151 µg/l, while the concentration at SW12-Shal was 248 µg/L. Further downstream at SW1-Shal, which is located downgradient of the Shallee tailings impoundment, the concentration of dissolved Lead was 116 µg/l. Therefore, livestock should be prevented from drinking water in the stream in the Shallee mining area.

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

At four sample locations, Sulphate concentrations exceeded the criteria for calves (500 mg/l), at SW12-Gar (683 mg/l) and at three of the discharges; discharge location SW5-Gar (533 mg/l), and a further two locations which also exceed the Sulphate levels for adult livestock (1000 mg/l), SW10-Gort-Discharge (1,780 mg/l) and SW12-Gort-Discharge (1,110 mg/l).

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.

In relation to the two surface water ponds, it is also noted 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 while horses were disturbing the sediments.

4.3.4 Vegetation Assessment

Table B-3 in Appendix B highlights the assessment criteria for vegetation. No measured vegetation concentrations for Arsenic, Cadmium or Lead exceeded the Maximum Content standards in Table 20. The measured concentrations in the vegetation were all below both the no effect and low effect levels provided in Table 20.

4.3.5 Soil Assessment

Table B-4 in Appendix B highlights the exceedances of the assessment criteria for soil. In general, the measured soil concentrations are below the screening levels for Arsenic, Cadmium, Copper, Nickel, Lead and Zinc shown in Table 21 that may have adverse effects on the vegetation or mammals. The measured soil concentrations are all below the threshold reference values (TRVs) for grazing sheep and cattle provided in Table 21. These values consider that in many cases the grazing animals consume the plant leaves and roots containing soil.

The reported value for Arsenic in SM13-S was 11 mg/kg, which is slightly above the Oak Ridge National Laboratory (ORNL) threshold of 10 mg/kg for adverse effects in terrestrial plants. The reported values for Zinc concentrations were at or above the ORNL threshold (50 mg/kg) in 17 of the 20 samples, with a median value of 55 mg/kg. SM27-S had a reported Zinc value of 107 mg/kg which exceeds the recommended value of 79 mg/kg threshold for toxicity to mammals via dietary transfer. All reported values were lower than the maximum Zinc concentrations of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998.

The reported value for Lead in SM13-S (53 mg/kg) exceeded maximum values for concentrations of Lead of 50 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998.

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

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

- **Tier 1:** The annual average 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, respectively, as discussed above (fixed by the WFD). In addition, generic $EQS_{bioavailable}$ values for Cu (1 µg/L) and Zn (10.9 µg/L) are 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 23

As shown in Table 23 the bioavailable Pb, Ni and Zn concentrations are significantly less than the measured Pb, Ni and Zn concentrations. For Pb and Ni, the HC5 are in all cases, higher (less stringent) than the current EQS of 1.2 µg/L for Pb and EQS of 4 µg/L for Ni. For Zn, the HC5 are significantly lower (more stringent) than the current EQS of 100 µg/L at all locations.

Table 23 Results from the Bio-Met Model at River and Stream Locations in the Silvermines Area

Site	Metal	Measured Conc.	Bioavailable Conc.	HC5	Bioavailable Conc. Exceedance of HC5	Bioavailable Conc. Exceedance of current EQS*	Measured Conc. Exceedance of current EQS*
SW17-Gort	Pb	0.10	0.02	5.6	No	No	No
	Zn	3.11	0.86	26.8	No	No	No
	Ni	0.577	0.20	11.5	No	No	No
SW10-Gort-US	Pb	0.435	0.08	6.4	No	No	No
	Zn	27.7	10.37	28.1	No	No	No
	Ni	1	0.63	6.3	No	No	No

Site	Metal	Measured Conc.	Bioavailable Conc.	HC5	Bioavailable Conc. Exceedance of HC5	Bioavailable Conc. Exceedance of current EQS*	Measured Conc. Exceedance of current EQS*
SW10-Gort-DS	Pb	0.561	0.20	3.3	No	No	No
	Zn	27.8	14.60	20.0	No	No	No
	Ni	0.981	0.98	3.7	No	No	No
SW12-Gort-DS	Pb	2.93	0.52	6.7	No	No	Yes
	Zn	53.7	20.32	28.3	No	No	No
	Ni	1.47	1.01	5.8	No	No	No
SW14-Gort	Pb	2.53	0.91	3.3	No	No	Yes
	Zn	43.3	22.96	20.1	Yes	No	No
	Ni	1.37	1.37	2.9	No	No	No
DS-Gort	Pb	2	0.72	3.3	No	No	Yes
	Zn	27.7	14.09	20.7	No	No	No
	Ni	1.24	1.24	1.8	No	No	No
SW6-Mag	Pb	0.1	0.03	3.8	No	No	No
	Zn	188	118	17.3	Yes	Yes	Yes
	Ni	2.56	2.56	3.7	No	No	No
US-Shal	Pb	8.94	3.22	3.3	No	Yes	Yes
	Zn	1860	624	32.5	Yes	Yes	Yes
	Ni	10.7	10.7	3.3	Yes	Yes	Yes
SW9-Shal	Pb	151	47.16	3.8	Yes	Yes	Yes
	Zn	318	259	13.4	Yes	Yes	Yes
	Ni	8.95	4.79	7.5	No	Yes	Yes
SW1-Shal	Pb	116	34.99	4.0	Yes	Yes	Yes
	Zn	294	231	13.8	Yes	Yes	Yes
	Ni	8.44	5.74	5.9	No	Yes	Yes
DS-Shal	Pb	77.9	4.36	21.4	No	Yes	Yes
	Zn	299	92	35.4	Yes	No	Yes
	Ni	3.9	0.83	18.8	No	No	No
DS-Gorteenadiha	Pb	82	3.93	25.0	No	Yes	Yes
	Zn	66.4	9.65	73.9	No	No	No
	Ni	2.21	0.58	15.1	No	No	No
SW1-Gar	Pb	[1]	[1]	[1]	[1]	[1]	[1]
	Zn	[1]	[1]	[1]	[1]	[1]	[1]
	Ni	[1]	[1]	[1]	[1]	[1]	[1]
SW10-Gar	Pb	3.37	1.21	3.3	No	Yes	Yes
	Zn	2190	734	32.5	Yes	Yes	Yes
	Ni	9.45	9.45	2.9	Yes	Yes	Yes
SW3-Gar	Pb	3.64	1.31	3.3	No	Yes	Yes
	Zn	1270	426	32.5	Yes	Yes	Yes

Site	Metal	Measured Conc.	Bioavailable Conc.	HC5	Bioavailable Conc. Exceedance of HC5	Bioavailable Conc. Exceedance of current EQS*	Measured Conc. Exceedance of current EQS*
	Ni	7.84	7.84	3.3	Yes	Yes	Yes
SW1-SM	Pb	<0.2	0.03	4.2	No	No	No
	Zn	<1	<1	14.4	No	No	No
	Ni	<0.4	0.17	4.7	No	No	No
SW3-SM	Pb	0.421	0.11	4.4	No	No	No
	Zn	30.8	22.03	14.7	Yes	No	No
	Ni	<0.4	0.19	4.2	No	No	No
SW5-SM	Pb	0.724	0.22	3.9	No	No	No
	Zn	150	120	13.6	Yes	Yes	Yes
	Ni	0.515	0.31	6.6	No	No	No
SW6-SM	Pb	1.44	0.42	4.1	No	No	Yes
	Zn	148	103	15.6	Yes	Yes	Yes
	Ni	0.549	0.37	5.9	No	No	No
SW4-SM-GA	Pb	1.63	0.49	4.0	No	No	Yes
	Zn	149	103	15.6	Yes	Yes	Yes
	Ni	0.578	0.35	6.6	No	No	No

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

The following summarises the data within Table 23;

- Number of exceedances when comparing the measured concentrations of the metals to the current EQS: Pb = 12; Ni = 5; Zn = 10.
- Number of exceedances when comparing the bioavailable concentrations of the metals to the HC5: Pb =2; Ni =3; Zn = 12.
- Number of exceedances when comparing the bioavailable concentrations of the metals to the current EQS: Pb = 6; Ni = 5; Zn = 9.

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

Section 5
Flows, Loads and Trend Analysis

5.1 Surface Water Flows

No river flow gauging stations exist within the Silvermines mining area. The nearest gauge is on the Kilmastulla River, approximately 10 km downstream of the Silvermines mining area, at Coole (EPA station 25044) for which the flow record for one year was downloaded. A plot showing data to December 2018 is shown in Figure 1, and maximum and minimum flows were calculated in the period from 14 December 2017 to 14 September 2018 (just after the end of sampling). The median flow in that period was approximately 1.4 m^3/s. The flow records show there was a sustained period, following a number of storm rainfall events, of approximately ten days in January 2018 of high flows, which were above the estimated 5%-ile (high flow) value of 6.85 m^3/s (note the 5%-ile (high flow) value was calculated from the dataset 1970 to September 2018). There were shorter duration flow peaks above this long term 5%-ile (high flow) value recorded in February and April 2018 also. The flow during these periods shows a flashy response to rainfall.

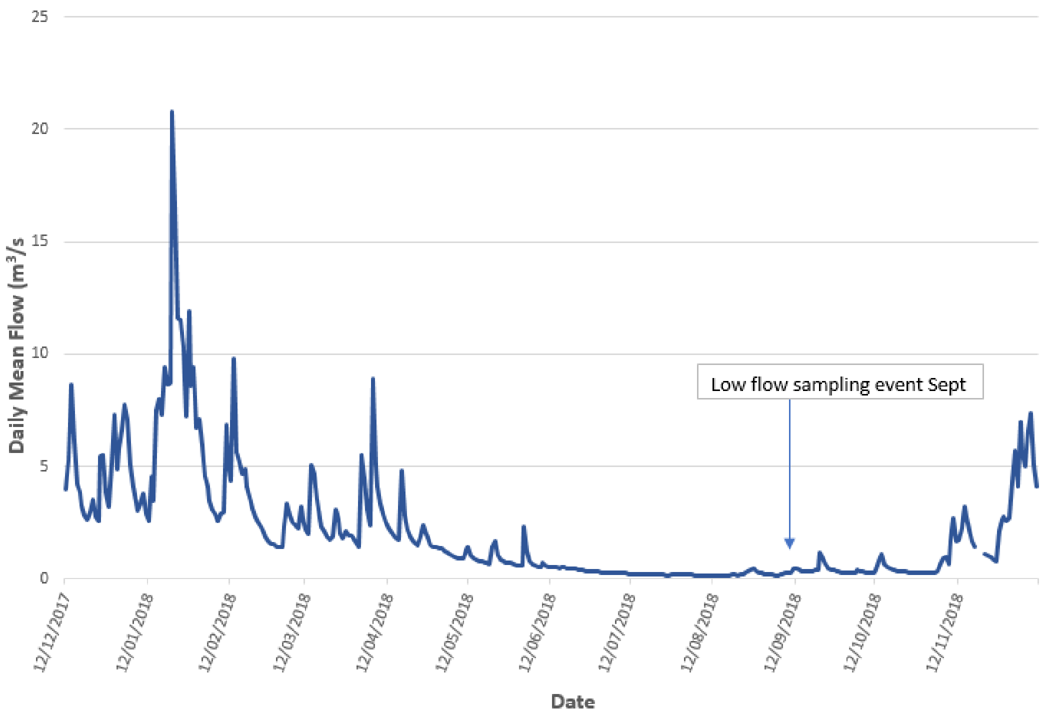


Figure 1 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 12 Dec 2017 to 12 Dec 2018

The maximum flow value recorded from December 2017 to September 2018 was on 21 Jan 2018 (20.8 m^3/s) following rainfall events. The flow records also show there was a sustained period from early July 2018 to early September 2018, coinciding with low or no rainfall and drought, when the recorded values were below the 5%-ile (low flow) value of 0.30 m^3/s (calculated from the dataset

1970 to September 2018); the minimum flow value recorded in the period December 2017 to September 2018, was on 14 August 2018 (0.16 m^3/s), approximately half the long term low flow value.

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.

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 24 presents a summary of the results from the flow measured in September 2018 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 24 Surface Water Flow Value Measured in September 2018

Site Name	Flow l/s	Date	Method
SW19-GORT	No Flow	10/09/2018	Dry - no flow
SW10-GORT Discharge	0.1	10/09/2018	Bucket and stopwatch
SW12-GORT Discharge	1.5	10/09/2018	Bucket and stopwatch
DS-GORT	184	10/09/2018	Float method
US-SHAL	4.8	11/09/2018	Marsh McBirney
SW4-SHAL	0.1	11/09/2018	Bucket and stopwatch
SW5-SHAL	No Flow	11/09/2018	No Flow
SW6-SHAL	5.2	13/09/2018	Bucket and stopwatch
SW15-Shal	No Flow	12/09/2018	No Flow
SW9-SHAL	10.4	11/09/2018	Marsh McBirney
SW12-SHAL	6	11/09/2018	Bucket and stopwatch
SW13-SHAL	0.9	11/09/2018	Marsh McBirney
SW1-SHAL	11.1	11/09/2018	Marsh McBirney
DS-SHAL	69.2	11/09/2018	Marsh McBirney
DS-Gorteenadiha	37.8	11/09/2018	Marsh McBirney
SW5-GAR	-	12/09/2018	Not accessible for flow
SW12-GAR	0.8	12/09/2018	Flume
SW10-GAR	1.7	12/09/2018	Flume
SW7-GAR	0.1	10/09/2018	Bucket and stopwatch
SW3-GAR	0.8	12/09/2018	Marsh McBirney

Site Name	Flow l/s	Date	Method
SW1-SM	16	13/09/2018	Marsh McBirney
SW3-SM	25	13/09/2018	Marsh McBirney
SW2-SM-South	0.2	13/09/2018	Bucket and stopwatch
SW5-SM	29	13/09/2018	Marsh McBirney
SW6-SM	26.7	13/09/2018	Marsh McBirney
SW4-SM-GA	30	13/09/2018	Marsh McBirney

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 25 aid with the interpretation of the loading of Sulphate and dissolved Cadmium, Lead, Manganese, Nickel and Zinc to rivers.

The dissolved metal with the highest mass loading was Zinc ranging from 0.3 to 1,788 g/day with a median value of 157 g/day overall. The largest mass load of Zinc (1,788 g/day) was found at sampling point, Downstream-Shallee.

SW10-Gar (the discharge from the tailings lagoon) had a Zinc load of 322 g/day. In March 2018, the discharge pipe from the tailings lagoon was blocked and water was discharging over, and possibly through, the western embankment, resulting in concerns over bank stability. Accordingly, since Spring 2018, the SW10-Gar sampling point has been moved slightly downstream to capture all 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 88 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 0.69 g/day, which increases to 67 g/day downstream of the mine workings (SW3-SM). The Zinc loading at SW2-SM-South was 29 g/day, while the northern adit was not sampled, due to very low flow conditions. Downstream of these locations, at SW5-SM, the Zinc load would be expected to be a combination (approximately 96 g/day) of the individual loads from locations SW1-SM, SW3-SM, the northern adit discharge (when sampled) and SW2-SM-South. However, the calculated Zinc load (based on measured values) at SW5-SM was 376 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.

Table 25 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day

Site Description	Date Sampled	Flow l/s	Flow l/day	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
SW10-GORT Disch	10/09/18	0.1	8,640	1780000	15379	0.04	0.0003	0.282	0.002	143	1.24	4.3	0.037	72.2	0.624
SW12-GORT Disch	10/09/18	1.5	129,600	1110000	143856	0.04	0.005	0.1	0.013	5830	756	6.1	0.791	79.5	10.30
DS-GORT	10/09/18	184	15,897,600	61700	980882	0.04	0.636	2	31.80	55.7	885	1.24	19.71	27.7	440
US-SHAL	11/09/18	4.8	414,720	293000	121513	3.32	1.38	8.94	3.71	355	147	10.7	4.44	1860	771
SW4-SHAL	11/09/18	0.1	8,640	23900	206	0.681	0.006	6.08	0.053	48	0.415	4.17	0.036	92.2	0.797
SW5-SHAL	11/09/18	[1]	No Flow	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW6-SHAL	11/09/18	5.2	449,280	26500	11906	1.03	0.463	237	106	77.6	34.86	8.3	3.73	161	72.33
SW15-Shal	11/09/18	[1]	No Flow	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW9-SHAL	11/09/18	10.4	898,560	21100	18960	1.52	1.37	151	136	60.2	54.09	8.95	8.04	318	286
SW12-SHAL	11/09/18	6	518,400	29900	15500	0.826	0.428	248	129	863	447	7.88	4.08	187	96.94
SW13-SHAL	11/09/18	0.9	77,760	196000	15241	0.898	0.070	8.08	0.628	93.4	7.26	10.3	0.801	478	37.17
SW1-SHAL	11/09/18	11.1	959,040	21700	20811	1.35	1.29	116	111	49	46.99	8.44	8.09	294	282
DS-SHAL	11/09/18	69.2	5,978,880	39900	238557	0.913	5.46	77.9	466	62.7	375	3.9	23.32	299	1788
DS-Gorteenadiha	11/09/18	37.8	3,265,920	10600	34619	0.563	1.84	82	268	20	65.32	2.21	7.22	66.4	217
SW1-GAR	12/09/18	[1]	No Flow	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW5-GAR	12/09/18	[2]	[2]	533000	[2]	1.65	[2]	6.10	[2]	1070	[2]	61.3	[2]	8980	[2]
SW12-GAR	12/09/18	0.8	69,120	683000	47209	32.8	2.27	6.03	0.417	323	22.33	38.9	2.69	11900	823
SW10-GAR	12/09/18	1.7	146,880	340000	49939	6.87	1.01	3.37	0.495	129	18.95	9.45	1.39	2190	322
SW7-GAR	12/09/18	0.1	8,640	150000	1296	0.088	0.0008	0.10	0.0009	4.37	0.038	1.66	0.014	35.4	0.306
SW3-GAR	12/09/18	0.8	69,120	298000	20598	3.25	0.225	3.64	0.252	75.5	5.22	7.84	0.542	1270	87.78
SW1-SM	13/09/18	16	1,382,400	11700	16174	0.04	0.055	0.1	0.138	1.5	2.07	0.2	0.276	0.5	0.691
SW3-SM	13/09/18	25	2,160,000	9600	20736	0.04	0.086	0.421	0.909	1.5	3.24	0.2	0.432	30.8	66.53
SW2-SM-South	13/09/18	0.2	17,280	27600	477	4.49	0.078	1.25	0.022	1.5	0.026	4.86	0.084	1660	28.68
SW5-SM	13/09/18	29	2,505,600	10400	26058	0.298	0.747	0.724	1.81	3.78	9.47	0.515	1.29	150	376
SW6-SM	13/09/18	26.7	2,306,880	10500	24222	0.234	0.540	1.44	3.32	3.73	8.60	0.549	1.27	148	341
SW4-SM-GA	13/09/18	30	2,592,000	11400	29549	0.187	0.485	1.63	4.22	1.5	3.89	0.578	1.50	149	386

[1] No Flow [2] Not accessible for flow sampling

Downstream the calculated dissolved Zinc load at SW6-SM was calculated at 341 g/day. Between SW6-SM and SW4-SM-GA, the Zinc load increases by 13.2% from 341 g/day to 386 g/day. The increase in dissolved Zinc load along this stretch was identified in previous rounds (February 2016, August 2016 and March 2017, February 2018) 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 771 g/day and 217 g/day, respectively. The stream emerging from the Shallee mining area (SW1-Shal) contributed a Zinc load of 282 g/day. An additional drainage ditch (SW13-Shal) had a Zinc load of 37 g/day. Therefore, it would be expected that the dissolved Zinc load at DS-Shal would be a combination (1,307 g/day) of the individual loads from these locations. However, the calculated Zinc load at DS-Shal was 1,788 g/day indicating a possible additional source of dissolved Zinc in this river stretch. Additionally, between the Garryard SW3-Gar location and Upstream-Shal location, there was an increase in dissolved Zinc load from 87 g/day to 771 g/day. This increase indicates that a diffuse contribution of dissolved Zinc is likely along this stretch of river.

The mass loads of dissolved Lead at US-Shal and DS-Gorteenadiha, located directly upstream of the Shallee mining area was calculated to be 4 g/day and 268 g/day, respectively. The highest load of dissolved Lead (466 g/day) was found at Downstream-Shal. At SW6-Shal (Field shaft) the Lead load was estimated to be 106 g/day which increased to 111 g/day downstream at SW1-Shal. The Lead load increased further between SW1-Shal and DS-Shal (111 to 466 g/day). Similar to dissolved Zinc, the increase in dissolved Lead in this area indicates a possible additional source of dissolved Lead in this river stretch.

There was no flow at location SW19-Gort, the stream draining the surface of the TMF, during this monitoring round. Of the two discharges from the wetland at Gortmore TMF, SW12-Gort-Discharge (10 g/day) had the higher loading of dissolved Zinc, relative to the loading from the flow at SW10-Gort-Discharge (0.6 g/day). These values are significantly different to the loading values from Round 1, during the high flow monitoring (Round 1 calculated Zinc loading of 776 g/day at SW10-Gort-Discharge, 658 g/day Zinc loading at SW12-Gort-Discharge and Zinc loading value of 159 g/day at SW19-Gort, the stream draining the TMF). Overall, discharges from the Garryard and Shallee mining areas (Downstream-Shal – 1,788 g/day) provided the greatest mass loads of dissolved Zinc to the Kilmastulla River.

In previous rounds, the apparent lower loading at SW19-Gort has highlighted an additional diffuse source of dissolved Zinc. This has previously been exemplified by the seeps located at the southern edge of the TMF which discharge to the adjacent wetlands. During this monitoring round in September, no current discharges were observed from the seeps on the day of sampling, where flows had been recorded during February 2018.

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 26 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 26 Reporting the Mann-Kendall Results

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

Notes: The confidence coefficient is 0.95
Null Hypothesis: The null hypothesis is that there is no trend.
The p-value is the probability that the null hypothesis is true.
The Mann-Kendall test requires the following information for a trend to be calculated: A sample size of at least three 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 27 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 27 Mann-Kendall Trend Analysis of data from November 2006 to September 2018

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. Cadmium	16	0.021	-46	Decreasing
	Diss. Lead	16	0.447	-5	No Trend
	Diss. Manganese	16	0	-72	Decreasing
	Diss. Nickel	16	0.083	-33	Likely Decreasing
	Diss. Zinc	16	0.175	-23	No Trend
SW10-Gort-Discharge	Diss. Cadmium	13	0.005	-42	Decreasing
	Diss. Lead	13	0.218	-14	No Trend
	Diss. Manganese	13	0.295	10	No Trend
	Diss. Nickel	13	0.011	-38	Decreasing
	Diss. Zinc	13	0.064	-26	Likely Decreasing
SW12-Gort-Discharge	Diss. Cadmium	12	0.527	1	No Trend
	Diss. Lead	12	0.369	6	No Trend
	Diss. Manganese	12	0.19	14	No Trend
	Diss. Nickel	12	0.058	-24	Likely Decreasing
	Diss. Zinc	12	0.473	2	No Trend
SW6-Shal	Diss. Cadmium	14	0.194	17	No Trend
	Diss. Lead	14	0.457	3	No Trend
	Diss. Manganese	14	0.194	-17	No Trend
	Diss. Nickel	14	0.334	-9	No Trend
	Diss. Zinc	14	0.225	-15	No Trend
SW14-Gort	Diss. Cadmium	13	0.184	-16	No Trend

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
(Kilmastulla River)	Diss. Lead	13	0.218	14	No Trend
	Diss. Manganese	13	0.429	-4	No Trend
	Diss. Nickel	13	0.029	-32	Decreasing
	Diss. Zinc	13	0.184	-16	No Trend

The results of the Mann-Kendall test show that:

- Dissolved Manganese and Cadmium concentrations are decreasing at SW10-Gar; dissolved Nickel is likely decreasing;
- Dissolved Cadmium and Nickel are decreasing at SW10-Gort-Discharge; dissolved Zinc is likely decreasing;
- No statistically significant trend was observed in the data for SW6-Shal and at SW12-Gort-Discharge except dissolved Nickel was likely decreasing at SW12-Gort-Discharge; and
- Dissolved Nickel is 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

The concentrations and loadings for individual sample results from this monitoring event are summarised in Table 25. Table 28 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling events in April 2013, March 2014, February 2015, February 2016, May 2017 and February 2018 and the low flow sampling events in August 2013, September 2014, August 2015, August 2016 and September 2018.

The following points detail the September 2018 (low flow) sampling event concentrations and loading values in the context of previous results:

- In September 2018, the tested dissolved metal concentrations were generally similar to the average concentrations across the majority of the main discharges;
- Dissolved metal concentrations in SW2-SM-South were similar to the average values previously recorded (2013-2017) during low flows, with the sample result for dissolved Zinc (1,660 µg/l) below the average;
- The dissolved Zinc concentration at SW6-Shal (161 µg/l) was lower than the average (184 µg/l), with the calculated Zinc loading of 72 g/day close to the estimated average load during low flow (76.8 µg/day);
- At SW10-Gar, the dissolved Cadmium concentration (6.87 µg/L) was lower than the average concentration (13.81 ug/L) during low flow events;
- SW10-Gort-discharge and SW12-Gort-Discharge drain the Gortmore wetlands into the Kilmastulla River. At SW10-Gort-Discharge, the dissolved Lead concentration of 0.28 µg/l was above the average during low flow (0.13 µg/l), while taking flow into account, the calculated Lead loading for this event was below the average loading of 0.01 g/day;

- The Manganese concentration (5,830 µg/L) is the new maximum measured concentration at SW12-Gort-discharge. In terms of flow and loading, the Manganese loading (756 g/day) for this monitoring event is above the average (480 g/day) but below the estimated maximum loading during low flow events (1,620 g/day);
- At SW12-Gort-Discharge, the dissolved Zinc concentration (79.5 µg/l) is the minimum measured and the estimated loading (10.3 g/day) is the minimum calculated during low flow events respectively;
- While the concentration measured from a single grab sample can be higher during a low flow event than a high flow event, it is generally the case that the measured concentrations of dissolved Cadmium, Manganese and Lead are higher during high flow events and the concentrations and are also within the same order of magnitude for the two flow regimes. Taking flow values into account, the data for the period 2013 – 2018 show that the loadings of dissolved Cadmium, Manganese and Lead are lower during the lower flow events than during the higher flow events, though generally the loading of each metal is within the same order of magnitude for the two flow regimes;
- While the same general trend of higher concentrations and loadings of dissolved Zinc is observed during the higher flow events, the data for the period 2013 – 2018 show that loading of dissolved Zinc, at locations SW12-Gort-Discharge, SW-10_Gort-Discharge and SW10-Gar, during the high flow events is an order of magnitude greater than during the lower flow events.

Table 28 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in primary discharges from 2013-2018

		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	1.6		0.2		2.2		3.4		5.5		1.7		5.1		0.1		7.1		1.5	
(l/s)	Max	3		1.5		9.2		6.2		50.7		4.4		33.0		4.5		22.0		7.5	
	Mean	2.2		0.91		5.3		4.7		24.6		2.9		12.5		1.2		11.5		3.1	
	units	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**	**µg/l**	**g/day**
Cd	Min	4.72	0.68	4.32	0.08	0.91	0.25	0.80	0.24	18.80	8.87	6.87	1.95	0.12	0.06	0.04	0.00	0.10	0.06	0.04	0.01
	Max	5.56	1.34	5.06	0.59	1.30	0.95	1.33	0.71	32.60	109.00	21.70	5.81	0.38	1.08	0.50	0.07	0.78	1.48	0.50	0.11
	Mean	5.196	0.943	4.67	0.37	1.17	0.53	0.97	0.41	26.80	58.53	13.81	3.99	0.23	0.31	0.12	0.02	0.47	0.55	0.16	0.04
Pb	Min	1.03	0.15	0.84	0.02	236	91.0	183	53.7	0.98	0.74	1.04	0.19	0.10	0.06	0.05	0.00	0.01	0.01	0.02	0.00
	Max	1.69	0.29	1.31	0.12	591	470	352	189	2.41	9.03	8.51	2.28	0.47	1.34	0.28	0.02	0.11	0.21	0.10	0.03
	Mean	1.21	0.22	1.02	0.08	417	199	259	108	1.64	3.71	3.67	0.97	0.30	0.41	0.13	0.01	0.07	0.08	0.06	0.01
Mn	Min	0.5	0.07	0.38	0.02	60.7	18.7	46.4	15.1	74.1	35.0	126	18.9	35.7	28.5	143	1.24	165	102	249	66.20
	Max	1.86	0.48	1.50	0.08	97.9	71.4	99.0	53.2	273	990	321	68.3	91.5	132	808	314	346	542	5830	1620
	Mean	1.139	0.227	0.73	0.05	79.2	36.0	70.3	29.5	184	454	205	49.2	57.0	54.4	350	62.62	256	266	1835	480
Zn	Min	1940	277	1560	28.68	179	48.10	153	45.2	5390	2540	2190	322	607	291	72.2	0.62	332	205	79.5	10.3
	Max	2140	503	1870	238	252	188	253	136	13000	40800	7150	1920	1040	1730	790	229	849	1610	229	122
	Mean	2032	368	1733	138	228	104	184	76.8	10082	22307	3415	869	798	779	330	50.09	613	673	148	44.4

Section 6

Groundwater Levels

Groundwater levels were measured at the two wells outside the Gortmore TMF and seven additional wells located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder. Table 29 provides the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevation outside the TMF decreased from 48.25 m Ordnance Datum (OD) at the upgradient location TMF1 to 45.69 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 elevations at TMF1 and TMF2 during Round 2 were measured as 0.48 and 0.35 meters, respectively, lower than the elevations measured in February 2018, and 0.08 and 0.31 meters, respectively, lower than the elevations measured during the single monitoring event undertaken in May 2017.

Within the tailings area, the water levels generally ranged from 2.31 to 4.58 m below the top of the tailings surface. The exceptions were in BH3A-GORT-06, BH4A-GORT-06, and BH6A-GORT-06 (see Map 2 of Appendix A) where deeper water levels were recorded. The groundwater elevations measured in September within the TMF varied between 48.38 to 53.02 m OD. Groundwater elevations measured in February 2018 ranged from 48.76 to 54.29 m OD.

Table 29 Measures Groundwater Levels in September 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	12/09/2018	10:45	0.755	1.35	48.25
TMF2		12/09/2018	09:30	2.31	2.77	45.69
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	12/09/2018	12:45	2.75	3.40	53.02
BH2A-GORT-06		12/09/2018	12:30	3.75	4.28	52.01
BH3A-GORT-06		12/09/2018	11:45	8.23	8.56	48.38
BH4A-GORT-06		12/09/2018	12:15	5.01	5.53	51.15
BH5A-GORT-06		12/09/2018	12:00	4.58	5.01	51.63
BH6A-GORT-06		12/09/2018	13:00	5.05	5.74	51.04
BH6B-GORT-06		12/09/2018	13:15	3.50	4.22	52.46

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 September 2018 and water levels were measured in seven additional monitoring wells. Sampling and analysis were undertaken at 29 surface water locations in September 2018 with flows measured at 22 locations. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QA/QC samples and laboratory reports were also reviewed. Overall the data quality is considered acceptable and the data can be used to compare to the assessment criteria and for evaluation of loads.

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

The overall conclusions are as follows:

- TMF1 (located upgradient of Gortmore TMF) and TMF2 (located downgradient) exceeded the drinking water criteria for Manganese (50 µg/L) with concentrations of 94 µg/L and 1,020 µg/L respectively. There is no drinking water threshold for Barium in the drinking water regulations (S.I. No. 106 of 2007); however, concentrations of 160 µg/l and 597 µg/l were reported at TMF1 and TMF2, 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 3.1 µg/l, respectively) than the rest of the rivers and streams sampled in the mining areas and are both well below the ecological assessment criteria of 100 µg/l.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. For example, SW5-Gar (Knights Shaft) had the highest concentrations of dissolved Nickel (61.3 µg/L) and Iron (1,500 µg/L) and SW12-GAR had the highest concentration of Zinc (11,900 µg/L). There is no drinking water threshold for Zinc in the drinking water regulations (S.I. No. 106 of 2007); in relation to ecological assessment criteria for Zinc, four of the five locations in Garryard exceeded the dissolved Zinc ecological assessment criteria of 100 µg/l with values ranging from 1,270 µg/L (SW3-GAR) to 11,900 µg/L (SW12-GAR). Two of the Garryard locations exceeded both the ecological (0.9 µg/l) and drinking water (5 µg/l) assessment criteria for Cadmium, with concentrations of 6.87 µg/L (SW10-GAR) and 32.8 µg/L SW12-GAR). Dissolved Manganese was above the criteria for drinking water assessment (50 µg/l) at all Garryard locations with the exception of SW7-GAR. Arsenic concentrations were below the drinking water criteria (10 µg/L) at each of the Garryard locations, ranging from 1.16 µg/L to 3.55 µg/L.

- Within the Shallee mining area, dissolved lead exceeded the drinking water (10 µg/l) assessment criteria at five locations; at SW6-Shal (237 µg/l), which is a discharge monitoring location, and at four drainage / stream monitoring locations, SW1-SHAL (116 µg/l), SW9-SHAL (151 µg/l), and the highest concentration SW12-SHAL (248 µg/l), while the downstream location exceeded the value with a concentration of 77.9 µg/l (SW9-SHAL (151 µg/l)).
- At one location in the Silvermines area (SM-SW1 <1µg/l), dissolved zinc was not detected. With the exception of SM-SW1, within the mining areas of Shallee, Garryard and Silvermines, dissolved zinc was detected at all of the remaining monitoring locations, with concentrations in those mining areas ranging from 30.8 µg/L to 11,900 µg/l (SW12-GAR), the majority of which locations exceeded the ecological assessment criteria of 100 µg/l. The concentration of dissolved Zinc at DS-SHAL on the Yellow River tributary was 299 µg/l.
- In the Gortmore area, the concentration of dissolved zinc increased on the Kilmastulla River from 3.11 µg/l at the upstream location (SW17-Gort), to 53.7 µg/l downstream at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard, Shallee and Gorteenadiha. The discharge location within Gortmore had a concentration of 79.5 µg/l (SW12-Gort-Discharge).
- The dissolved metal with the highest mass loading was Zinc, ranging from 0.3 to 1,788 g/day with a median of 157 g/day. The largest mass load of Zinc (1,788 g/day) was found at DS-SHAL which is located on the Kilmastulla River, downstream of Gortmore TMF. The highest load of dissolved Lead was found at DS-SHAL (466 g/day).
- Flows ranged from 0.1 l/s at SW4-Shal to 184 l/s at DS-Gort.
- This monitoring round took place following the drought period of the summer of 2018. Particular locations within overall site showed marked differences in flows relative to the high flow monitoring in Round 1 of 2018, while at other locations, the differences in flows were not as significant. In the Silvermines mining area, while flows were higher in Round 1, the flows in Round 2 were of the same order of magnitude. In the Garryard area, flows at SW10-GAR and SW12-GAR were an order of magnitude lower during Round 2 monitoring.
- Within the overall site, one location had significantly lower flows in Round 2; within the Gortmore mining area, the flow at Gort-DS (downstream) in Round 2 was 184 l/s compared to a flow of 3,620 l/s in Round 1.
- 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 are likely to 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 stream walk survey in the vicinity of the Shallee stream and Yellow Bridge River confluence to confirm absence/presence of additional inflows; this will continue for the next monitoring round to determine if there are any additional flows during the high flow event;
- Continuation of the inspection of the outflow of the Garryard tailings lagoon to ensure the outflow is free flowing and blockages do not exist; and
- Continued required turnaround time for total organic carbon (TOC) analysis to ensure that the holding time is not exceeded.

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

- SW6-Shal: Sampling this location requires crawling under the fence to get access to the discharge using a bucket and stopwatch to measure flow (flow may not be accurately measured). During the next sampling round (2019 round 1), an attempt will be made to locate a flow and sampling point just downstream. If this is not possible due to additional discharges contributing to the flow, samples will only be collected at the downgradient location (SW15-Shal) during 2019 round 3. If this is the case, additional inspections and recommendations will be made for future sampling. In update from the 2019 R3 (February) visit, it was not possible to get a flow measurement downstream of SW6-Shal as the area is unsuitable for flow measurement (wide, pooled area). The sample was collected under the fence, but additional controls were put in place (the sampler wore a hard hat). The site and issues were documented with pictures and notes and will be reviewed with the client and sampling team before the next sampling campaign.
- SW4-Shal: Currently this location is accessed by walking over sheets of galvanised metal under which the conditions are not known; the rationale of sampling this location will be evaluated. The metal concentrations and loads for this location are very low and apparently reflect conditions upgradient of the Shallee mining area. If so, another location along this stream segment will be selected. For the 2019 R3 visit, an alternative access route was used. This sampling site is at the margin of the Departments land. The sampling team spoke to the farmer that owns the field adjacent to this site. The farmer granted access to the land and this site can now be accessed by walking through fields with no H&S risk. Samplers should call in to the farmer on each sampling occasion before accessing the farmers land.
- SW5-SM: Access to this location requires crossing a field containing a bull. Based on measured concentrations and metal loads, sampling near this location is important. During 2019 round 3, a safer access route will be located via the road to the west or a location downgradient from SW5-SM with safe access will be located and sampled. For the 2019 R3 visit the bull was not in the field; however, another access route, that does not require accessing the field where the bull is sometimes located, has been found. This access route will be used going forward.

Section 8

References

CDM Smith (2013). Monitoring Report for the Silvermines Mining Area Round 1 2013. June 2013. Document Ref: 95735/40/DG/06.

Efroymson, R.A., Will, M.E., Suter II, G.W. and Wooten, A.C. (1997). Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN.

Environment Agency (2015). Technical Guidance to Implement Bioavailability-Based Environmental Quality Standards for Metals. April 2015. Environment Agency, Bristol, UK.

EPA (2007). Towards A National Soil Database (2001-CD/S2-M2). Synthesis Report. Environmental RTDI Programme 2000–2006.

European Communities (Undesirable Substances in Feedingstuffs) Regulations, 2003. (S.I. 317 of 2003)

European Communities Drinking Water Regulations, 2007 (S.I. No. 106 of 2007).

European Communities Environmental Objectives (Surface Water) Regulations, 2009 (S.I. 272 of 2009).

Ford, K.L. (2004). Risk Management Criteria for Metals at BLM Mining Sites, National Science and Technology Center, Denver, CO.

Hedberg, Y., Herting, G. and Odnevall Wallinder, I. (2011). Risks of using membrane filtration for trace metal analysis and assessing the dissolved metal fraction of aqueous media – a study on Zinc, Copper and Nickel. *Environmental Pollution,* 159, 1144-1150.

Higgins, S.F., Agouridis, C.T. and Gumbert A.A. (2008). Drinking Water Quality Guidelines for Cattle. University of Kentucky – College of Agriculture.

National Academy of Science (1972). Water Quality Criteria. US Environmental Protection Agency. EPA R3–73–033.

Sample, B.E., Opresko D.M., and Suter G.W. II. (1996). Toxicological Benchmarks for Wildlife. 1996 Revision. Oak Ridge National Laboratory. Oak Ridge, TN.

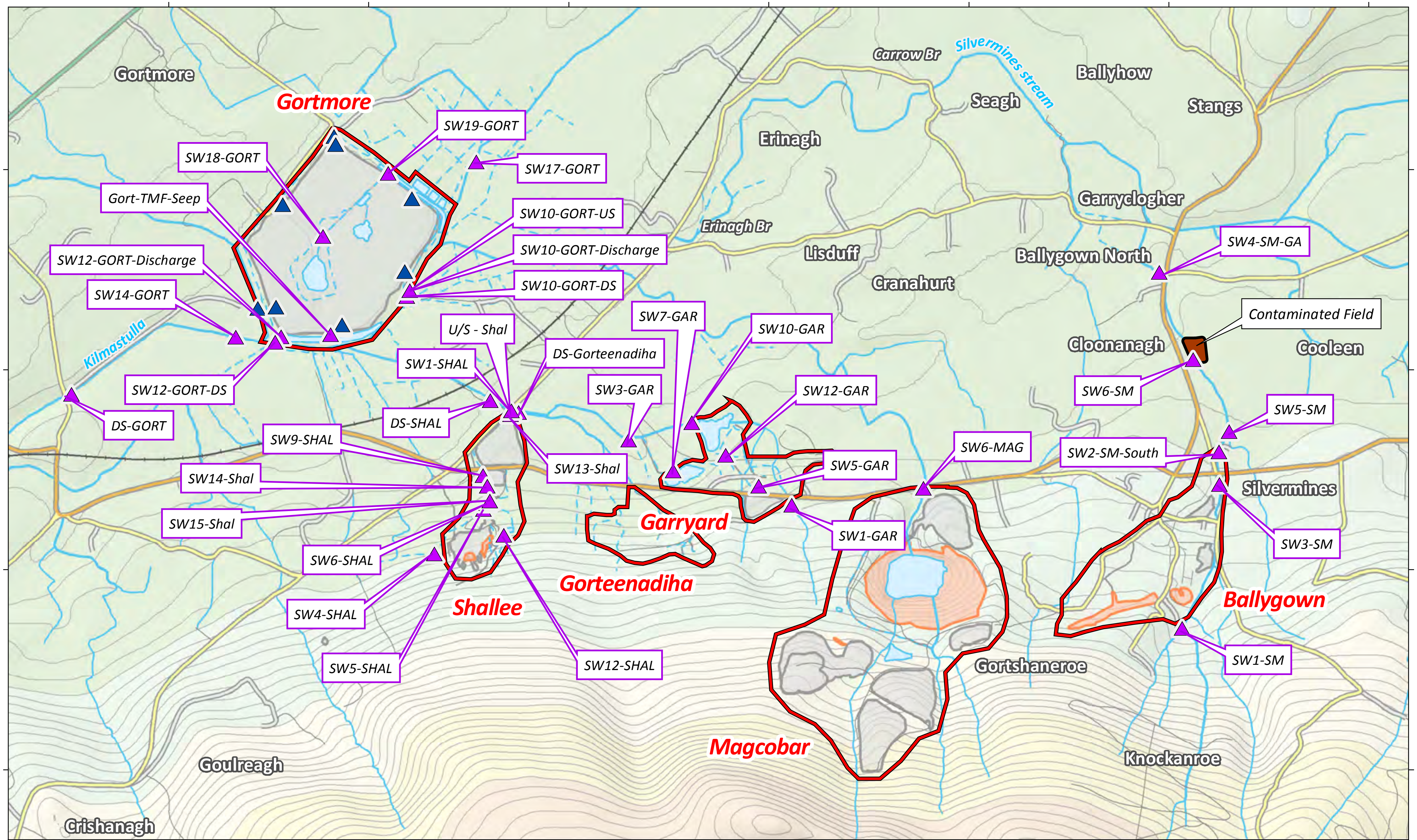
Soltanpour, P.N. and Raley, W.L. (2007). Livestock Drinking Water Quality. Livestock Series no. 4.908. Colorado State University.

Suter, G.W. II and Tsao. C.L. (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

USEPA (2005). Ecological Soil Screening Levels. Office of Solid Waste and Emergency Response, Washington, DC.

Appendix A

Figures



Map 1 - Silvermines - Overview

Drawn by: OC Date: 24/10/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\MXD\01_SilverMon1.mxd

CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater

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

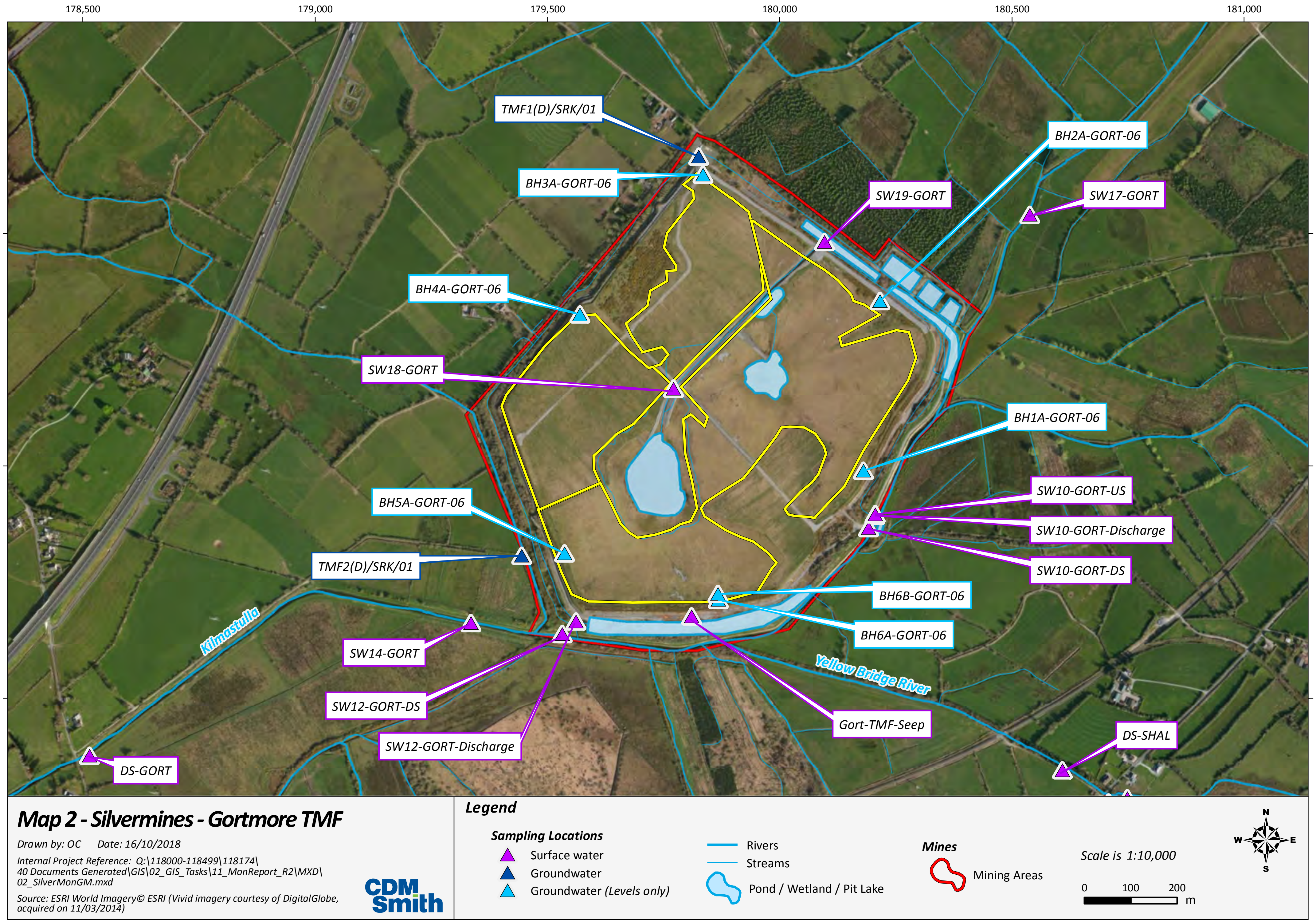
Mines

- 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



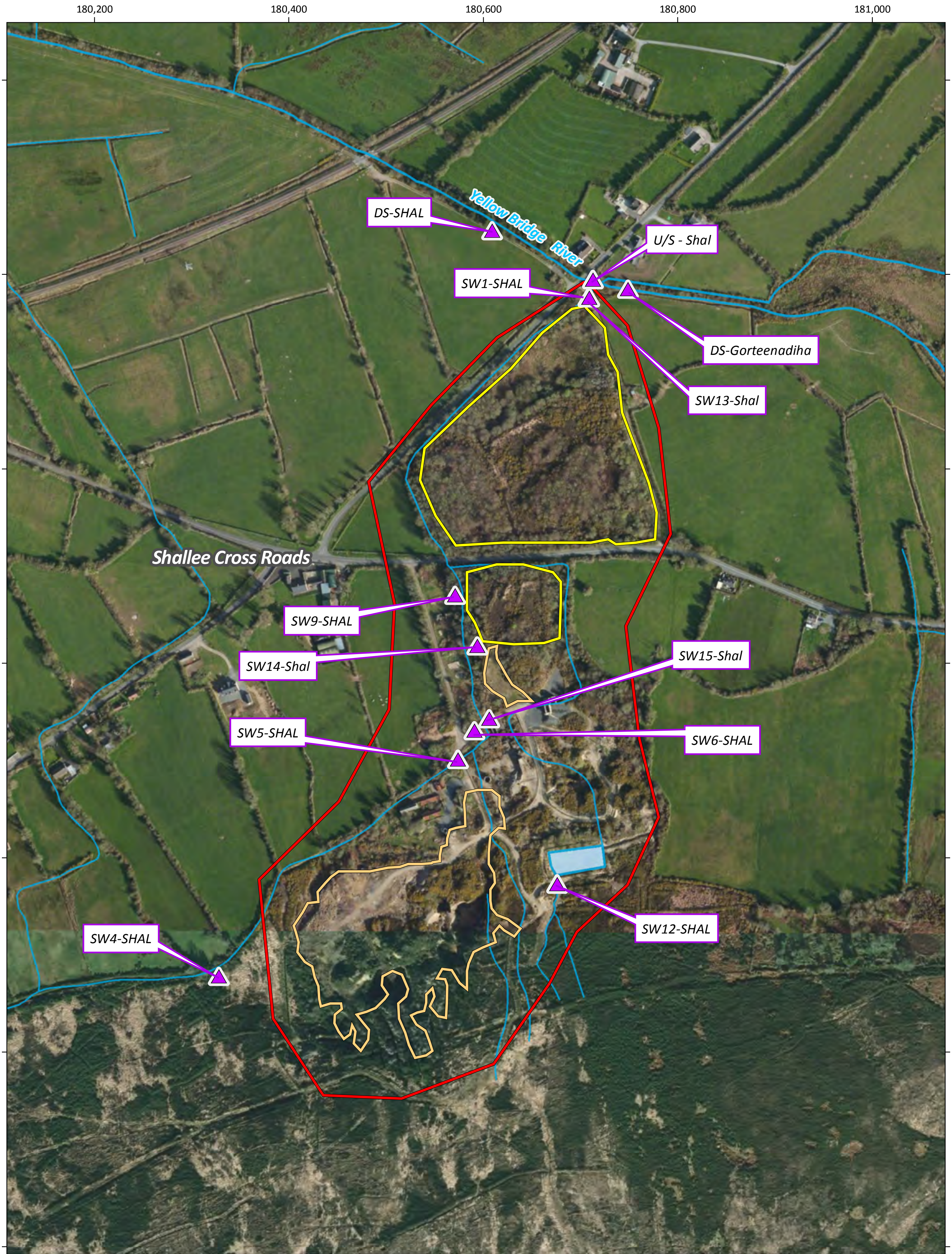
Map 2 - Silvermines - Gortmore TMF

Drawn by: OC Date: 16/10/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\MXD\02_SilverMonGM.mxd

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

CDM Smith



Map 3 - Silvermines - Shallee South

Drawn by: OC Date: 24/10/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\MXD\03_SilverMonSh.mxd

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

CDM Smith

Legend

Sampling Locations
- Surface water

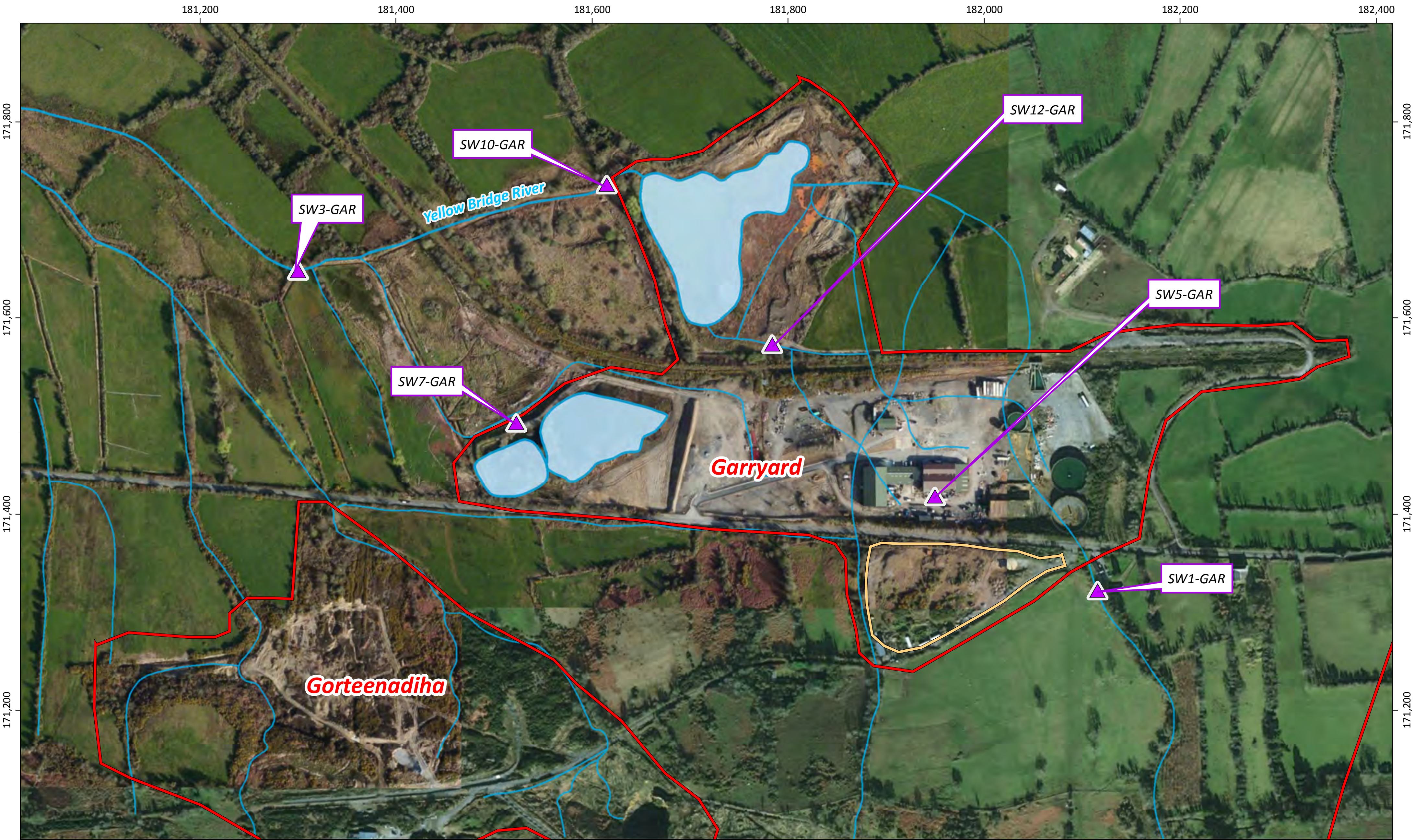
- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Tailings / Tailings Pond
- Spoil Heap / Waste Drum Dump

N E S W

Scale is 1:5,000

0 50 100 m



Map 4 - Silvermines - Garryard

Drawn by: OC   Date: 16/10/2018

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\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

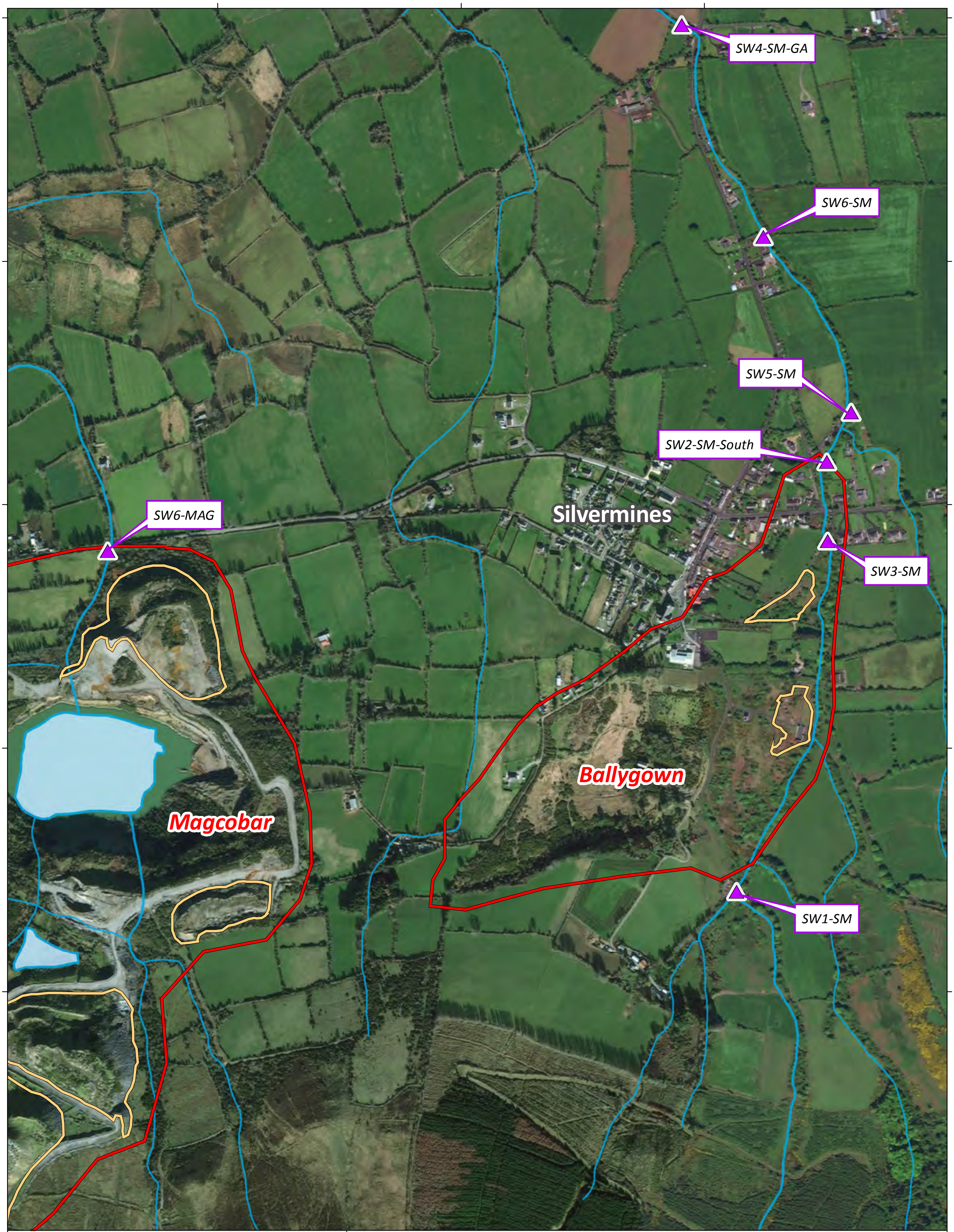
Mining Areas

Stockpile Dump

Scale is 1:5,000

0 50 100 m

N W E S



Map 5 - Silvermines - Magcobar and Ballygown

Drawn by: OC Date: 30/01/2019

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\MXD\05_SilverMonMaBG.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

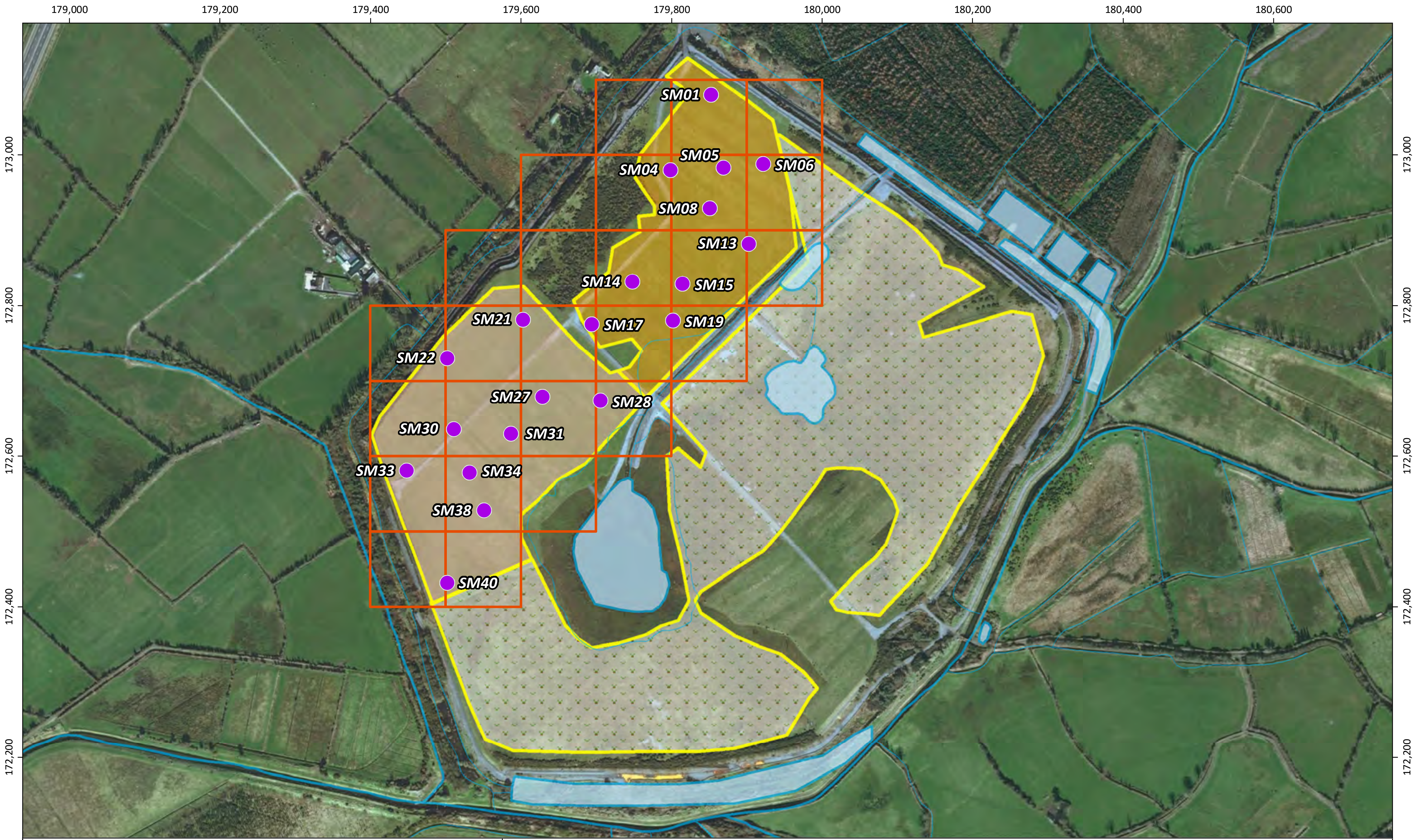
Mining Areas

Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:10,000

0 100 200 m



Map 6 - Silvermines - Gortmore - Vegetation

Drawn by: OC   *Date: 11/12/2018*

Internal Project Reference: Q:\118000-118499\118174\40 Documents Generated\GIS\02_GIS_Tasks\11_MonReport_R2\MXD\06_SilverMonVeg.mxd

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

CDM Smith

Legend

Sampling Locations

Areas A and B *(vegetation samples)*

Grid *(1 ha)*

Sampling Areas

Sampling Area A

Sampling Area B

Sampling Area GS1 to GS3

Rivers

Streams

Pond / Wetland / Pit Lake

Scale is 1:6,500

0 100 200 m

N W E S

Appendix B

Analytical Data Tables and Assessment Criteria

CDM Smith

Table B-1 Comparison of Groundwater and
Surface Water Results to Assessment Criteria R2 (2018)

Sample Description	Type	Area	Date Sampled	pH (field)	Specific Conductance @ deg.C (field)	Oxygen, dissolved (field)	Total Organic Carbon	Ammoniacal Nitrogen as N	Sulphate	Aluminium (diss.filt)	Antimony (diss.filt)	Arsenic (diss.filt)	Barium (diss.filt)	Cadmium (diss.filt)
			Units	pH Units	mS/cm	% Sat	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				4.5 to 9	-	80 to 120*	-	0.14	-	1,900	-	25	4	0.9
Human Health Criteria				6.5 to 9.5	2.5	-	-	0.3	250	200	5	10	-	5
TMF1	Groundwater	GM	12/09/2018	7.35	0.449	7.7	*1.5*	*0.1*	19.7	*5*	*0.05*	3.75	160	*0.04*
TMF2	Groundwater	GM	12/09/2018	7.05	0.495	2.4	*1.5*	*0.1*	3	*5*	*0.05*	4.31	597	*0.04*
SW18-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW19-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW17-GORT	River/Stream	GM	10/09/2018	6.84	0.468	84.5	3.75	*0.1*	16.5	*5*	*0.05*	1.55	282	*0.04*
SW10-GORT US	River/Stream	GM	10/09/2018	7.77	0.555	87.4	3.52	*0.1*	49.3	*5*	*0.05*	1.06	145	*0.04*
SW10-GORT DISCHARGE	Discharge	GM	10/09/2018	7.61	2.849	69.5	4.58	*0.1*	1780	*5*	*0.05*	3.07	37.2	*0.04*
SW10-GORT DS	River/Stream	GM	10/09/2018	7.92	0.559	94.2	*1.5*	*0.1*	51.4	*5*	*0.05*	1.07	148	*0.04*
GORT-TMF-SEEP	Seep	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW12-GORT DISCHARGE	Discharge	GM	10/09/2018	7.30	2.244	31.1	-	1.04	1110	*5*	*0.05*	1.99	126	*0.04*
SW12-GORT DS	River/Stream	GM	10/09/2018	7.97	0.577	101	3.24	*0.1*	89	*5*	*0.05*	1.08	158	0.134
SW14-GORT	River/Stream	GM	10/09/2018	8.22	0.515	105	*1.5*	*0.1*	62	*5*	*0.05*	1.04	157	0.099
DS-GORT	River/Stream	GM	10/09/2018	8.39	0.51	133	*1.5*	0.388	61.7	*5*	*0.05*	1.07	153	*0.04*
SW6-MAG	River/Stream	Mag	10/09/2018	7.93	0.444	99.8	*1.5*	*0.1*	184	*5*	*0.05*	0.855	51.6	0.497
US-SHAL	River/Stream	Shal	11/09/2018	8.05	0.919	96.6	*1.5*	*0.1*	293	*5*	*0.05*	1.6	75.4	3.32
SW4-SHAL	Drainage	Shal	11/09/2018	6.37	0.147	63.1	-	*0.1*	23.9	*5*	*0.05*	0.566	191	0.681
SW5-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW6-SHAL	Discharge	Shal	11/09/2018	6.52	0.153	49.8	-	*0.1*	26.5	*5*	*0.05*	0.836	284	1.03
SW15-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW9-SHAL	River/Stream	Shal	11/09/2018	7.20	0.163	100.1	*1.5*	*0.1*	21.1	*5*	*0.05*	0.821	263	1.52
SW12-SHAL	Drainage	Shal	11/09/2018	4.23	0.110	99.5	-	*0.1*	29.9	153	*0.05*	*0.25*	572	0.826
SW13-SHAL	Drainage	Shal	11/09/2018	6.90	0.574	49.1	-	*0.1*	196	*5*	1.46	3.86	213	0.898
SW1-SHAL	River/Stream	Shal	11/09/2018	7.38	0.166	102.1	*1.5*	*0.1*	21.7	*5*	1.03	0.829	256	1.35
DS-SHAL	River/Stream	Shal	11/09/2018	6.90	0.186	98.1	10.1	0.211	39.9	94.4	*0.05*	0.828	221	0.913
DS-GORTEENADIHA	River/Stream	Gtd	11/09/2018	7.69	0.075	100	9.27	*0.1*	10.6	115	*0.05*	0.771	235	0.563
SW1-GAR	River/Stream	Gar	12/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW5-GAR	Discharge	Gar	12/09/2018	7.09	1.089	39	4.81	1.85	533	*5*	1.29	3.55	52.5	1.65
SW12-GAR	Drainage	Gar	12/09/2018	7.52	1.357	65.6	1.5	0.1	683	*5*	*0.05*	1.81	20.5	32.8
SW10-GAR	Discharge	Gar	12/09/2018	8.16	0.965	92.3	1.5	0.823	340	*5*	*0.05*	1.71	26.4	6.87
SW7-GAR	Drainage	Gar	12/09/2018	7.90	0.681	76.4	-	0.1	150	*5*	*0.05*	1.16	128	0.088
SW3-GAR	River/Stream	Gar	12/09/2018	8.08	0.942	96.7	1.5	0.1	298	*5*	*0.05*	1.73	52.8	3.25
SW1-SM	River/Stream	Bg	13/09/2018	7.64	0.145	93.7	*1.5*	*0.1*	11.7	*5*	*0.05*	0.71	37.5	*0.04*
SW3-SM	River/Stream	Bg	13/09/2018	7.78	0.140	97	*1.5*	*0.1*	9.6	*5*	*0.05*	*0.25*	34	*0.04*
SW2-SM-SOUTH	Discharge	Bg	13/09/2018	7.12	0.510	74.5	-	*0.1*	27.6	*5*	*0.05*	0.504	152	4.49
SW5-SM	River/Stream	Bg	13/09/2018	7.30	0.191	92.8	*1.5*	*0.1*	10.4	*5*	*0.05*	0.579	54.9	0.298
SW6-SM	River/Stream	Bg	13/09/2018	7.48	0.196	94.8	*1.5*	*0.1*	10.5	*5*	*0.05*	*0.25*	60.4	0.234
SW4-SM-GA	River/Stream	Bg	13/09/2018	7.37	0.197	95.6	*1.5*	*0.1*	11.4	*5*	*0.05*	0.553	61.3	0.187

[1] No flow and no sample during the monitoring rounc
- Not analysed or no assessment criteria
xx Less than the Limit of Detection (LOD) - Value given is 0.5 of LOD
* Only applies to rivers or streams (i.e. not discharges)
xx Exceeds Ecological Assessment Criteria
xx Exceeds Human Health Assessment Criteria
xx Exceeds both Ecological and Human Health Criteria

Table B-1 Comparison of Groundwater and
Surface Water Results to Assessment Criteria R2 (2018)

Sample Description	Type	Area	Date Sampled Units	Chromium (diss.filt) µg/l	Cobalt (diss.filt) µg/l	Copper (diss.filt) µg/l	Iron (diss.filt) µg/l	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Molybdenum (diss.filt) µg/l	Nickel (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) 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	12/09/2018	*0.5*	*0.25*	*0.15*	69	*0.1*	94	*1.5*	*0.2*	*0.5*	*0.5*
TMF2	Groundwater	GM	12/09/2018	*0.5*	0.576	*0.15*	77.4	0.779	1020	*1.5*	0.437	*0.5*	3.18
SW18-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW19-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW17-GORT	River/Stream	GM	10/09/2018	*0.5*	*0.25*	0.305	53	*0.1*	28.8	*1.5*	0.577	*0.5*	3.11
SW10-GORT US	River/Stream	GM	10/09/2018	*0.5*	*0.25*	*0.15*	36.1	0.435	33.6	*1.5*	1	*0.5*	27.7
SW10-GORT DISCHARGE	Discharge	GM	10/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	0.282	143	*1.5*	4.3	*0.5*	72.2
SW10-GORT DS	River/Stream	GM	10/09/2018	*0.5*	*0.25*	*0.15*	47.3	0.561	35.3	6.03	0.981	*0.5*	27.8
GORT-TMF-SEEP	Seep	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW12-GORT DISCHARGE	Discharge	GM	10/09/2018	*0.5*	1.03	*0.15*	332	*0.1*	5830	*1.5*	6.1	*0.5*	79.5
SW12-GORT DS	River/Stream	GM	10/09/2018	*0.5*	*0.25*	1.47	47.1	2.93	160	*1.5*	1.47	*0.5*	53.7
SW14-GORT	River/Stream	GM	10/09/2018	*0.5*	*0.25*	1.23	40.1	2.53	80.1	*1.5*	1.37	*0.5*	43.3
DS-GORT	River/Stream	GM	10/09/2018	*0.5*	*0.25*	1.14	46.7	2.0	55.7	*1.5*	1.24	*0.5*	27.7
SW6-MAG	River/Stream	Mag	10/09/2018	*0.5*	*0.25*	1.65	*9.5*	*0.1*	*1.5*	*1.5*	2.56	*0.5*	188
US-SHAL	River/Stream	Shal	11/09/2018	*0.5*	2.1	1.59	40.4	8.94	355	*1.5*	10.7	*0.5*	1860
SW4-SHAL	Drainage	Shal	11/09/2018	*0.5*	*0.25*	1.44	33.3	6.08	48	*1.5*	4.17	*0.5*	92.2
SW5-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW6-SHAL	Discharge	Shal	11/09/2018	*0.5*	1.58	9.14	37.2	237	77.6	*1.5*	8.3	*0.5*	161
SW15-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW9-SHAL	River/Stream	Shal	11/09/2018	*0.5*	1.13	6.13	34.8	151	60.2	*1.5*	8.95	*0.5*	318
SW12-SHAL	Drainage	Shal	11/09/2018	*0.5*	3.37	1.12	*9.5*	248	863	*1.5*	7.88	*0.5*	187
SW13-SHAL	Drainage	Shal	11/09/2018	*0.5*	0.711	8.5	170	8.08	93.4	6.22	10.3	*0.5*	478
SW1-SHAL	River/Stream	Shal	11/09/2018	*0.5*	1.01	4.45	36.8	116	49	*1.5*	8.44	*0.5*	294
DS-SHAL	River/Stream	Shal	11/09/2018	*0.5*	0.575	13.5	243	77.9	62.7	*1.5*	3.9	0.5	299
DS-GORTEENADIHA	River/Stream	Gtd	11/09/2018	*0.5*	*0.25*	18.2	257	82	20	*1.5*	2.21	0.5	66.4
SW1-GAR	River/Stream	Gar	12/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW5-GAR	Discharge	Gar	12/09/2018	1.01	7.14	1.27	1500	6.1	1070	*1.5*	61.3	*0.5*	8980
SW12-GAR	Drainage	Gar	12/09/2018	*0.5*	2.37	2.44	*9.5*	6.03	323	*1.5*	38.9	*0.5*	11900
SW10-GAR	Discharge	Gar	12/09/2018	*0.5*	0.753	1.89	*9.5*	3.37	129	*1.5*	9.45	*0.5*	2190
SW7-GAR	Drainage	Gar	12/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	*0.1*	4.37	*1.5*	1.66	*0.5*	35.4
SW3-GAR	River/Stream	Gar	12/09/2018	*0.5*	0.512	1.67	*9.5*	3.64	75.5	*1.5*	7.84	*0.5*	1270
SW1-SM	River/Stream	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	*0.1*	*1.5*	*1.5*	*0.2*	*0.5*	*0.5*
SW3-SM	River/Stream	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	0.421	*1.5*	*1.5*	*0.2*	*0.5*	30.8
SW2-SM-SOUTH	Discharge	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	1.25	*1.5*	*1.5*	4.86	*0.5*	1660
SW5-SM	River/Stream	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	0.724	3.78	*1.5*	0.515	*0.5*	150
SW6-SM	River/Stream	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	1.44	3.73	*1.5*	0.549	*0.5*	148
SW4-SM-GA	River/Stream	Bg	13/09/2018	*0.5*	*0.25*	*0.15*	*9.5*	1.63	*1.5*	*1.5*	0.578	*0.5*	149

[1] No flow and no sample during the monitoring rounc
- Not analysed or no assessment criteria

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

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

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Table B-2 Comparison of Surface Water Results to Assessment Criteria for Livestock Drinking Water R2 (2018)

Sample Description	Area	Type	Date Sampled Units	Sulphate mg/l	Aluminium (diss.filt) µg/l	Arsenic (diss.filt) µg/l	Cadmium (diss.filt) µg/l	Chromium (diss.filt) µg/l	Cobalt (diss.filt) µg/l	Copper (diss.filt) µg/l	Lead (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) µg/l
Livestock Criteria				**500**	**5000**	**200**	**50**	**1000**	**1000**	**500**	**100**	**100**	**24000**
SW18-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW19-GORT	Drainage	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW17-GORT	River/Stream	GM	10/09/2018	16.5	5	1.55	0.04	0.5	0.25	0.305	0.1	0.5	3.11
SW10-GORT US	River/Stream	GM	10/09/2018	49.3	5	1.06	0.04	0.5	0.25	0.15	0.435	0.5	27.7
SW10-GORT DISCHARGE	Discharge	GM	10/09/2018	1780	5	3.07	0.04	0.5	0.25	0.15	0.282	0.5	72.2
SW10-GORT DS	River/Stream	GM	10/09/2018	51.4	5	1.07	0.04	0.5	0.25	0.15	0.561	0.5	27.8
GORT-TMF-SEEP	Seep	GM	10/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW12-GORT DISCHARGE	Discharge	GM	10/09/2018	1110	5	1.99	0.04	0.5	1.03	0.15	0.1	0.5	79.5
SW12-GORT DS	River/Stream	GM	10/09/2018	89	5	1.08	0.134	0.5	0.25	1.47	2.93	0.5	53.7
SW14-GORT	River/Stream	GM	10/09/2018	62	5	1.04	0.099	0.5	0.25	1.23	2.53	0.5	43.3
DS-GORT	River/Stream	GM	10/09/2018	61.7	5	1.07	0.04	0.5	0.25	1.14	2	0.5	27.7
SW6-MAG	River/Stream	Mag	10/09/2018	184	5	0.855	0.497	0.5	0.25	1.65	0.1	0.5	188
US-SHAL	River/Stream	Shal	11/09/2018	293	5	1.6	3.32	0.5	2.1	1.59	8.94	0.5	1860
SW4-SHAL	Drainage	Shal	11/09/2018	23.9	5	0.566	0.681	0.5	0.25	1.44	6.08	0.5	92.2
SW5-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW6-SHAL	Discharge	Shal	11/09/2018	26.5	5	0.836	1.03	0.5	1.58	9.14	237	0.5	161
SW15-SHAL	Drainage	Shal	11/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW9-SHAL	River/Stream	Shal	11/09/2018	21.1	5	0.821	1.52	0.5	1.13	6.13	151	0.5	318
SW12-SHAL	Drainage	Shal	11/09/2018	29.9	153	0.25	0.826	0.5	3.37	1.12	248	0.5	187
SW13-SHAL	Drainage	Shal	11/09/2018	196	5	3.86	0.898	0.5	0.711	8.5	8.08	0.5	478
SW1-SHAL	River/Stream	Shal	11/09/2018	21.7	5	0.829	1.35	0.5	1.01	4.45	116	0.5	294
DS-SHAL	River/Stream	Shal	11/09/2018	39.9	94.4	0.828	0.913	0.5	0.575	13.5	77.9	0.5	299
DS-GORTEENADIHA	River/Stream	Gtd	11/09/2018	10.6	115	0.771	0.563	0.5	0.25	18.2	82	0.5	66.4
SW1-GAR	River/Stream	Gar	12/09/2018	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
SW5-GAR	Discharge	Gar	12/09/2018	533	5	3.55	1.65	1.01	7.14	1.27	6.1	0.5	8980
SW12-GAR	Drainage	Gar	12/09/2018	683	5	1.81	32.8	0.5	2.37	2.44	6.03	0.5	11900
SW10-GAR	Discharge	Gar	12/09/2018	340	5	1.71	6.87	0.5	0.753	1.89	3.37	0.5	2190
SW7-GAR	Drainage	Gar	12/09/2018	150	5	1.16	0.088	0.5	0.25	0.15	0.1	0.5	35.4
SW3-GAR	River/Stream	Gar	12/09/2018	298	5	1.73	3.25	0.5	0.512	1.67	3.64	0.5	1270
SW1-SM	River/Stream	Bg	13/09/2018	11.7	5	0.71	0.04	0.5	0.25	0.15	0.1	0.5	0.5
SW3-SM	River/Stream	Bg	13/09/2018	9.6	5	0.25	0.04	0.5	0.25	0.15	0.421	0.5	30.8
SW2-SM-SOUTH	Discharge	Bg	13/09/2018	27.6	5	0.504	4.49	0.5	0.25	0.15	1.25	0.5	1660
SW5-SM	River/Stream	Bg	13/09/2018	10.4	5	0.579	0.298	0.5	0.25	0.15	0.724	0.5	150
SW6-SM	River/Stream	Bg	13/09/2018	10.5	5	0.25	0.234	0.5	0.25	0.15	1.44	0.5	148
SW4-SM-GA	River/Stream	Bg	13/09/2018	11.4	5	0.553	0.187	0.5	0.25	0.15	1.63	0.5	149

xx Exceeds Livestock Assessment Criteria

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

Table B-3 Silvermines Laboratory Analytical Data Vegetation - 2018 Round 2

	Total Arsenic	Total Cadmium	Total Lead	Total Zinc
	mg/kg	mg/kg	mg/kg	mg/kg
Max Concentration in Feeding stuff	**2**	**1**	**30**	**-**
No effect for digestion in wildlife	**0.621**	**8.787**	**72.88**	**1457.6**
Low effect for digestion in wildlife	**6.211**	**87.871**	**728.78**	**2915.1**
SM01-V	0.18	0.065	1.1	32.9
SM04-V	0.12	0.082	0.69	34.7
SM05-V	0.12	0.199	0.81	39.2
SM06-V	0.2	0.083	0.82	31.3
SM08-V	0.07	0.066	0.43	31.4
SM13-V	0.15	0.058	0.86	39.3
SM14-V	0.04	0.182	0.23	32.4
SM15-V	0.09	0.069	0.5	28.7
SM17-V	0.1	0.105	1.12	29.1
SM19-V	0.13	0.216	1.37	36.1
SM21-V	0.08	0.05	0.59	30.6
SM22-V	0.09	0.127	0.81	33.9
SM27-V	0.1	0.164	0.74	43.4
SM28-V	0.15	0.058	1.31	32
SM30-V	0.31	0.029	0.57	24.4
SM31-V	0.13	0.109	1.04	36.5
SM33-V	0.1	0.132	0.37	40.6
SM34-V	0.12	0.198	1.02	42.9
SM38-V	0.1	0.036	0.65	29.3
SM40-V	0.16	0.099	0.67	36.8
SMV001.11	0.08	0.101	1.12	29.1
SMV002.11	0.31	0.04	0.94	30.4

xx Exceeds the Maximum Concentration in Feeding Stuff

xx Exceeds No effect level for digestion in wildlife

xx Exceeds Low effect level for digestion in wildlife

Table B-4 Comparison of Soil Results to Assessment Criteria 2018 Round 2

Metal	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Unit	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Threshold for soil where sewage sludge might be applied	-	-	-	**1**	-	**50**	-	-	-	**30**	**50**	**150**
Threshold for plant toxicity via direct contact/ uptake	-	**18**	-	**32**	-	**70**	-	-	-	**38**	**120**	**160**
Threshold for adverse effects in terrestrial plants	-	**10**	-	**4**	-	**100**	-	-	-	**30**	**50**	**50**
Threshold for toxicity to mammals via dietary transfer	-	**46**	-	**0.36**	-	**49**	-	-	-	**130**	**56**	**79**
TRV for protection of cattle via diet	-	**419**	-	**15**	-	**413**	-	-	-	-	**244**	**1082**
TRV for protection of sheep via diet	-	**352**	-	**12**	-	**86**	-	-	-	-	**203**	**545**
	Al	**As**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
SM01-S	6000	7	70	*0.25*	13	10	11900	*0.5*	647	14	32	55
SM04-S	5800	8	80	0.5	12	9	11600	*0.5*	757	14	36	55
SM05-S	6300	8	80	0.6	13	49	12100	*0.5*	807	18	38	53
SM06-S	5500	8	70	*0.25*	12	8	10700	*0.5*	727	12	31	45
SM08-S	6000	6	70	0.5	13	9	11900	*0.5*	744	12	30	49
SM13-S	7400	11	80	0.5	14	12	14100	*0.5*	1000	15	53	71
SM14-S	6400	6	40	0.6	13	9	9500	*0.5*	577	14	23	49
SM15-S	6900	6	50	0.6	14	10	10200	*0.5*	727	16	22	53
SM17-S	7200	6	80	0.8	15	10	9500	*0.5*	1110	17	31	61
SM19-S	7000	6	50	0.7	14	11	10100	*0.5*	670	16	28	59
SM21-S	6000	7	70	0.6	12	10	10500	*0.5*	641	16	26	56
SM22-S	6800	8	120	0.5	14	12	11600	*0.5*	627	17	34	53
SM27-S	7900	8	110	1	15	11	11700	*0.5*	1100	21	49	107
SM28-S	6300	8	70	0.7	13	10	9600	*0.5*	701	15	30	59
SM30-S	5900	7	60	0.6	12	12	10500	*0.5*	662	16	25	53
SM31-S	6400	8	60	0.6	13	10	10900	*0.5*	806	18	30	62
SM33-S	6600	7	80	0.6	14	12	11800	*0.5*	590	19	36	65
SM34-S	6300	6	40	0.7	13	10	9700	*0.5*	638	16	22	54
SM38-S	6200	6	40	0.6	13	10	10100	*0.5*	646	16	21	54
SM40-S	6500	8	70	0.5	12	10	11300	*0.5*	604	18	27	55

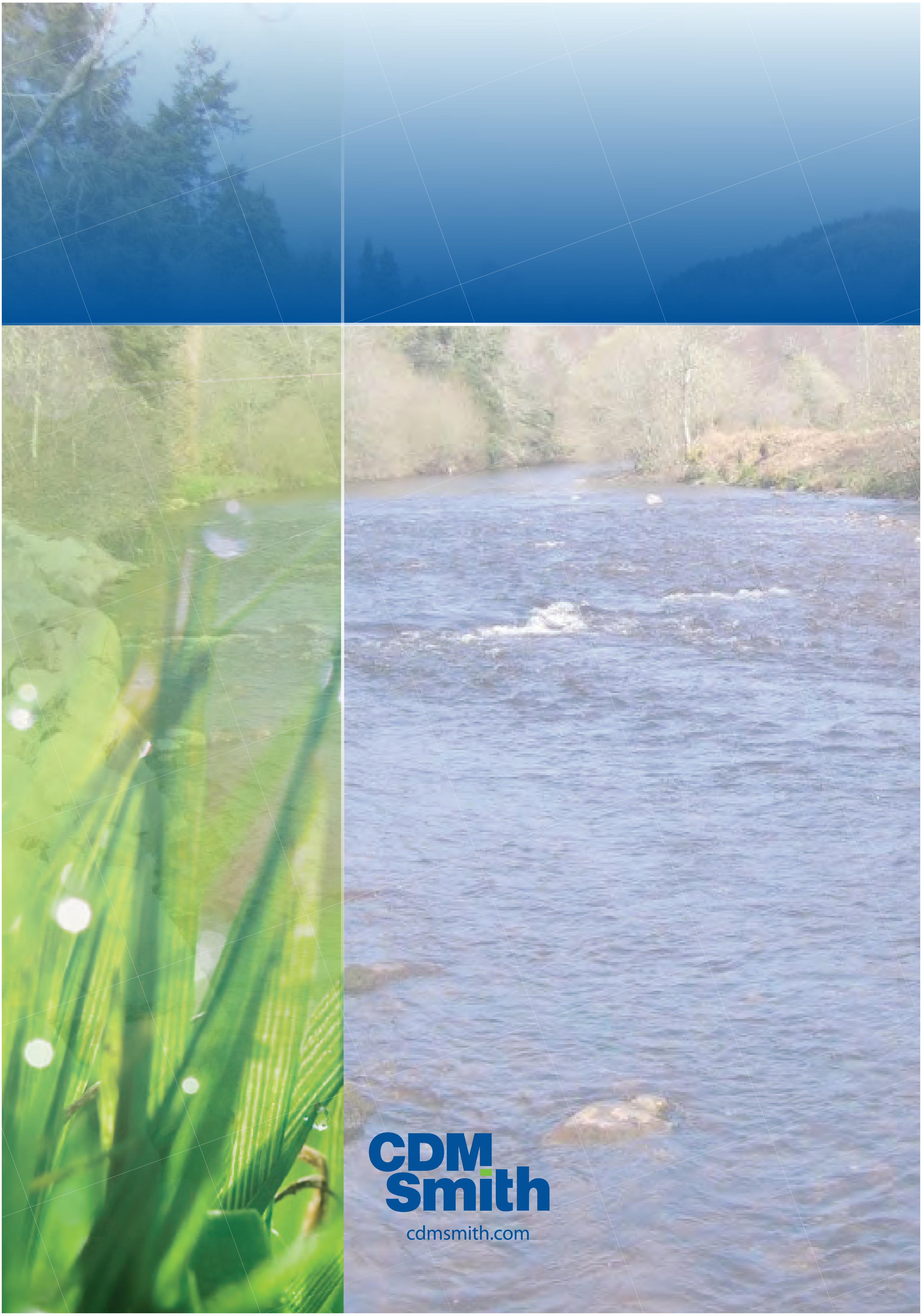
xx Exceeds the Maximum Concentration for Soil where sewage sludge is to be applied

xx Exceeds a threshold for plants

xx Exceeds a threshold for mammals

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

- no assessment criteria



cdmsmith.com