Department of Communications, Energy & Natural Resources

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

Silvermines Monitoring Report - Round 2 (2013)

Final

CDM Smith

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Section 1

Introduction

1.1 Objectives and Scope

The Department of Communications, Energy and Natural Resources (the Department) appointed CDM Smith Ireland Ltd (CDM Smith) to undertake a programme of environmental monitoring at the closed mine sites of Silvermines and Avoca for a three year period, commencing in 2013.

The scope of the field investigation activities was defined in the Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan, (Document Ref: 95735/40/DG01, dated 26 February 2013) 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 August-September 2013. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG08, dated October 2013) which contains all field observations and laboratory analytical results collected during the monitoring programme.

1.2 Background of Silvermines Mining Area

The Silvermines mining area is located in the northern foothills of the Silvermine Mountains in Co. Tipperary. The area has been mined intermittently for over one thousand years for a range of commodities including lead, zinc, copper, silver, barite and sulphur. The mining sites include Ballygown (BG), Garryard (GA), Gorteenadiha, Magcobar (MA) and Shallee South (ShS) /East (ShE), and cover an area of approximately 2,300 ha as shown on Map 1 in **Appendix A**. The last working mine, a barite operation at Magcobar, closed in 1993. Just over a decade previously, the final base metal mine shut down, following the cessation of underground operations by Mogul Mines Ltd. (Mogul) at Garryard. The latter operation resulted in the generation of significant volumes of fine to coarse grained sand 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 River) 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 60ha in area with surface elevations ranging from approximately 54.0m to 56.5m. 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 50m. Excess water drains via a decant system 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 (TDSs). Subsoils are thin (<2 metres) or absent on hilltops and thicker (>2 metres) along valley floors. The Gortmore area is underlain by alluvial sediments along the Kilmastulla River valley. Similarly the groundwater vulnerability ranges from Extreme in the upland areas to Moderate in low-lying areas.

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

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

Section 2

Methodology

2.1 Field Sampling Methods

2.1.1 Groundwater Sampling

Two groundwater monitoring wells were sampled 26 August 2013, as listed in Table 1 and shown on Map 2 in **Appendix A**. Four of the monitoring wells were omitted from the monitoring programme because in the first round of sampling they were either found buried, or believed to be destroyed.

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

Water quality indicator parameters were monitored in the field during low-flow purging using a flow-through cell to minimise oxidation by the atmosphere. Water quality indicator parameters include temperature, pH, ORP, conductivity and dissolved oxygen (DO). Purging continued until the field parameters had stabilised. The results were recorded approximately every five minutes during the purging process on the Groundwater Purging and Sampling Form. Field sheets are contained in Appendix H and physio-chemical field data are summarised in Appendix A of the Data Report.

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

The following exceptions to the low flow sampling procedure applied:

- TMF1 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 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.

Water Level

Groundwater levels were measured at the two wells and seven additional wells (Table 1) located within the TMF near its perimeter from 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.

2.1.2 Surface Water Sampling

Twenty-eight surface water locations were sampled between 26 August and 2 September 2013, as listed in Table 2 and shown on Maps 2 to 4 in **Appendix A**. Five samples could not be obtained because there was no flow at SW2-SM 'Northern Adit' and the stream bed was dry at SW1-GAR, SW2-GAR, SW5-SHAL and SW7-SHAL. For one of the samples, SW5-GAR, a volume of sample was collected that was sufficient only for dissolved metals analysis due to the low flow conditions.

Surface water sampling was conducted consistent 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 are not disturbed.

Table 2 Location of Surface Water Monitoring Points

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW10-GORT-US	GM	180196	172397	Immediately upstream of the outfall on the Kilmastulla River	Yes	NR
SW10-GORT-Discharge	GM	180196	172397	Wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW10-GORT-DS	GM	180196	172397	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW12-GORT-Discharge	GM	179562	172140	Sample of wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW12-GORT-DS	GM	179562	172140	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW14-GORT	GM	179336	172164	Site located on Kilmastulla River, downstream of TMF	Yes	NR
SW17-GORT	GM	180538	173038	Site located on Kilmastulla River, upstream of TMF	Yes	NR
SW18-GORT	GM	179772	172666	Site of discharge from the main pond on the TMF	Yes	NR
SW19-GORT	GM	180097	172982	Discharge at the bottom of the decant	Yes	Flume
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Flume
SW2-SM- North	BG	184258	171619	Discharge from 'Northern' adit.	No - No discharge	No Flow
SW2-SM-South	BG	184244	171584	Discharge from 'Southern' adit.	Yes	Bucket and Stopwatch
SW3-SM	BG	184258	171412	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)	Yes	Flume
SW4-SM-GA	BG	183961	172483	Site on Silvermines Stream (downstream of all mine workings)	Yes	Marsh McBirney
SW6-MAG	MG	182776	171399	Foilborrig Stream diverted around Magcobar Pit. Sampling site is just south of R499 road.	Yes	NR
SW1-GAR	GA	182116	171322	Stream sampled south of R499 road (south of old Mogul Yard)	No (dry)	NR
SW2-GAR	GA	181804	171376	Drainage south of R499 road.	No (dry)	NR
SW3-GAR	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Flume
SW4-GAR	GA	181335	171404	NW oriented stream occurring west of Mogul Yard. Sample site is south of R499 road.	Yes	Flume
SW5-GAR	GA	181950	171418	Discharge from Knight Shaft	Yes – dissolved metals only	No overflow discharge
SW7-GAR	GA	181523	171493	Discharge from smaller settlement pond	Yes	Bucket and Stopwatch
SW8-GAR	GA	181695	171531	Drainage from western part of Mogul Yard sampled in open drain, south of railway	Yes	Low flow not measurable
SW9-GAR	GA	181881	171557	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of railway	Yes	Low flow not measurable

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flume
SW12-GAR	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Bucket and Stopwatch
SW1-SHAL	ShS	180703	171776	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.	Yes	Flume
SW4-SHAL	ShS	180324	171089	Water-course occurring west of 'Drum Dump' and Shallee South workings.	Yes	Estimated (low flow not measurable)
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 (dry)	No Flow
SW6-SHAL	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Flume
SW7-SHAL	ShS	180595	171353	Stream occurring east of Field Shaft	No (dry)	No Flow
SW9-SHAL	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Flume
SW10-SHAL	ShS	180609	171499	Drainage running parallel to R499. Site occurs at northern edge of the southernmost Shallee tailings impoundment.	Yes	Low flow not measurable
SW12-SHAL	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Bucket and Stopwatch

Notes:
Abbreviations: GM- Gortmore; BG- Ballygown; MG- Magcobar; GA- Garryard; ShS- Shallee South, NR-Not Required

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.

Flow Measurements

Flow was measured at 17 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). Twenty four locations are required to have flow measured, however at the time of sampling there was no flow at four locations (i.e. the streambed was dry or there was no discharge from the shaft or adit) and the flow was so low it was could not be measured at three locations (refer to Table 2).

Surface water flow results are discussed in Section 5.1 and the data and measurement methodologies are contained in Appendix B of the Data Report. A portable flume was used for small discharges and streams while for very small discrete discharges, a stop watch and calibrated volume container was used. At one location a Marsh McBirney meter was used to measure flow velocities and depths at regular intervals across the stream by wading.

2.1.3 Vegetation Sampling

Twenty vegetation samples were collected between 27 and 29 August 2013, from the recently remediated Areas A and B at Gortmore TMF, as listed in Table 3 and shown on Map 5 in **Appendix A**.

Vegetation sampling was conducted 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
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

Twenty soil samples were collected between 27 and 29 August 2013, from the recently remediated Areas A and B at Gortmore TMF, as listed in Table 3 and shown on Map 5 in **Appendix A**.

Soil sampling was conducted consistent 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 10 cm 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 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 containing known concentrations of the 18 metals was shipped blind to ALcontrol 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.

Soil and Vegetation

- Soil:
  - Two duplicate soil samples were collected;
  - One decontamination blank was collected by pouring DI water over the soil sampling equipment after decontamination; and
  - One standard reference material containing known concentrations of the 22 metals were shipped blind to ALS Minerals (SRM certificate for NIST 2710 is contained in Appendix G of the Data Report).
- Vegetation:
  - Two duplicate vegetation samples were collected;
  - One decontamination blank was collected by pouring DI water over the vegetation sampling equipment after decontamination; and

- Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1515 (a certified standard of apple leaves) was used (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 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		
SMGD01.2	GW Duplicate	Duplicate of TMF2
SMDB01.2	GW Decontamination blank	DI pumped though pump after decon at site TMF2
SMSD01.2	SW Duplicate	Duplicate of SW4-GAR
SMSD02.2	SW Duplicate	Duplicate of SW2-SM South
SMSD03.2	SW Duplicate	Duplicate of SW12-SHAL
SMDB02.2	SW Decontamination blank	DI water poured over SW sampling beaker after decon at site SW1-SHAL
SMSR01.2	Standard Reference Material	Water ERA Lot #P216-740A
SMSR02.2	Standard Reference Material	Water ERA Lot #P216-740A
WB01.2	Water blank	Deionised water (Lennox Batch TE130701W)
Soil and Vegetation		
SM56-V	Vegetation Duplicate	Duplicate of SM19-V
SM57-V	Vegetation Duplicate	Duplicate of SM40-V
SM56-S	Soil Duplicate	Duplicate of SM19-S
SM57-S	Soil Duplicate	Duplicate of SM40-S
SMDB03.2	Vegetation Decontamination blank	DI water poured over shears after final decon
SMDB04.2	Soil Decontamination blank	DI water poured over trowel after final decon
SMSR03.2	Standard Reference Material	Soil NIST 2710

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 resealable plastic bag and placed inside of all shipping and transport containers. All samples were hand delivered or shipped by courier to the laboratory specified. 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 ALcontrol

Analyses of water samples were performed by ALcontrol. Water (both surface water and groundwater) samples were dispatched from its distribution centre in Dublin and analysed at its facility in North Wales. ALcontrol 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, conductivity, Total Dissolved Solids, ammoniacal nitrogen as N, potassium, sodium, chloride, fluoride, calcium (total and dissolved), magnesium (total and dissolved), nitrate as NO_3 and nitrite as NO_2, orthophosphate, sulphate, total alkalinity as $CaCO_3$, free cyanide, total and dissolved metals including Al, Sb, Ag, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Tl, Sn, U, V and Zn. Additionally for surface water, acidity, Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) were analysed.

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. As noted in the Monitoring Plan, ALcontrol is certified for most of the analyses and the few analyses for which certifications are not available are not critical for comparison to regulatory standards.

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 CAL Ltd

CAL Ltd, a subsidiary of Natural Resource Management Ltd, analysed the vegetation sample and they are accredited to ISO 17025 by the United Kingdom Accreditation Service. Vegetation samples were analysed for zinc, arsenic, cadmium and lead by ICP-OES (Zn) and ICP-MS (As, Cd, Pb). Samples were dried to 80 degrees to constant weight and ground to <1mm. A representative split sample was digested using 50% nitric acid at elevated temperature and pressure.

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

ALS Minerals (formerly OMAC Laboratories), Loughrea, Co. Galway analysed the soil sample 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:

$$\%R = \frac{A}{T} \times 100$$

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). The SRMs used for this project are discussed below.

3.1.2 Precision

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

RPD is calculated as follows:

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

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

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

3.1.3 Blanks

Several different types of "blank" samples may be generated to assist in evaluating general data usability. Periodic analysis of laboratory method blanks ensures there is no carryover of contaminants between samples because of residual contamination on the instrument or from contaminants introduced in the laboratory. Laboratory method blanks are typically laboratory pure water, acids or sand that have been processed through all of the procedures, materials, reagents, and labware used for sample preparation and analysis. In addition to the laboratory blanks, decontamination blanks were generated in the field 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 groundwater and surface water samples were created in the field and submitted blind to the laboratory (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 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 cleaning or decontamination procedure.
- Standard Reference Material (SRM):
  - Two certified water SRMs were sent blind to the ALcontrol (Sample IDs SMSR01.2 and SMSR02.2) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P216-740A. The Certificate of Analysis is provided in Appendix G of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.
  - Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1515 a certified standard of apple leaves was used (certificate is contained in Appendix G of the Data Report).

- One certified soil SRM was sent blind to the ALS Minerals (Sample ID SMSR03.2 to evaluate laboratory accuracy. The certified SRM was NIST 2710. The Certificate of Analysis is provided in Appendix G of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.

- Water Blank: To ensure that the water used for equipment decontamination is analyte free, one water blank sample was collected of the DI water.

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 ALcontrol for analysis. Table 5 provides the results of the 21 metals for the four duplicate samples and the calculated RPD between each pair of samples. Note if both the original and duplicate results were less than the detection limit then the RPD was zero, but this cannot be done if there are different detection limits.

For sample pair SW4-GAR/SMSD01.2 there were fourteen exceedances in total with the RPD values ranging from 53 to 196%. This was indicative of a poor quality duplicate pair and the numerous high RPDs could not be explained. ALcontrol was asked to retest sample SMSD01.2 as the reported values were considered to be low for SW4-GAR. The retested results are shown in Table 5 and there were only six exceedances of the RPD. These high RPDs can be attributed to low concentrations near the detection limits which typically have higher variability.

The majority of RPD values shown in Table 5 are below 50 %. The RPDs for the following parameters are very good: barium (0 to 4%), cadmium (3 to 21 %), cobalt (8 to 13 %), manganese (0.5 to 7 %) and iron (1.5 to 12%). The RPDs range for nickel (5 to 43%) and lead (0.5 to 44%) were slightly higher but still considered good.

The RPDs that were above 50% included antimony for each sample pair ranging from 55 to 186 % RPD and aluminium (130 %RPD) and zinc (135 % RPD) for sample pair SW12-Shal/SMSD03.2. For parameters detected near or below the limit of detection such as molybdenum, selenium, tin, vanadium, arsenic, chromium and copper, there were one or two high RPDs for each parameter. According to ALcontrol, the variability in antimony can be attributed to the difficulties in “washing out” the ICP-MS systems following a high sample in the laboratory. Detections of dissolved antimony are discussed in detail in Section 3.2.2.

The elevated RPD identified are not considered to significantly impact the integrity of the results or preclude their use for evaluation. The highest reported value of the duplicate pair is selected for interpretive use in Section 4 therefore providing a conservative evaluation.

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

Sample Description Dissolved Metal	LOD (µg/l)	TMF2	SMGD01.2	RPD	SW4-GAR	SMSD01.2	RPD	SW2-SM South	SMSD02.2	RPD	SW12-SHAL	SMSD03.2	RPD
Aluminium	<2.9	<2.9	<2.9	0	<2.9	<2.9	0	<2.9	<2.9	0	103	22	**130**
Antimony	<0.16	0.564	1.79	**-104**	1.18	3.54	**-100**	<0.16	4.42	**-186**	0.535	0.943	**-55.2**
Arsenic	<0.12	5.09	5.39	-5.73	0.714	0.887	-21.6	0.257	0.668	**-88.9**	0.357	0.353	1.13
Barium	<0.03	567	556	1.96	243	252	-3.6	142	142	0	132	135	-2.25
Cadmium	<0.1	<0.1	<0.1	0	1.62	2	-21.0	4.57	4.45	2.66	<0.1	<0.1	0
Chromium	<0.22	1.29	1.39	-7.46	1.07	2.24	**-70.7**	0.763	2.37	**-103**	0.271	0.31	-13.4
Cobalt	<0.06	0.773	0.708	8.78	8.59	10.3	-18.1	0.065	0.06	8.00	0.125	0.142	-12.7
Copper	<0.85	<0.85	<0.85	0	2.6	4.86	**-60.6**	<0.85	<0.85	0	<0.85	<0.85	0
Iron	<19	198	195	1.53	1030	971	5.9	<0.19	<19	0	86.8	77	12.0
Lead	<0.02	1.71	1.29	28.0	0.873	1.36	-43.6	0.795	0.838	-5.27	17.1	17.2	-0.58
Manganese	<0.04	910	916	-0.66	2070	2080	-0.5	0.534	0.5	6.58	29.2	30.1	-3.04
Mercury	<0.01	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0
Molybdenum	<0.24	0.709	1.53	**-73.3**	0.39	1.53	**-119**	<0.24	1.57	**-147**	0.268	0.365	-30.6
Nickel	<0.15	0.648	0.42	42.7	10.9	13.9	-24.2	5.36	4.98	7.35	<0.15	<0.15	0
Selenium	<0.39	<0.39	0.756	**-63.9**	<0.39	<0.39	0	<0.39	0.776	**-66.2**	<0.39	<0.39	0
Silver	<1.5	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0
Thallium	<0.96	<0.96	<0.96	0	<0.96	<0.96	0	<0.96	1.85	**-63.3**	<0.96	<0.96	0
Tin	<0.36	<0.36	<0.36	0	0.951	3.73	**-119**	<0.36	2.26	**-145**	<0.36	<0.36	0
Uranium	<1.5	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0
Vanadium	<0.24	<0.24	<0.24	-0	0.258	0.725	**-95.0**	0.331	0.721	**-74.1**	<0.24	<0.24	0
Zinc	<0.41	1.9	3.12	-48.6	472	571	-19.0	1840	1810	1.64	53.2	10.4	**135**

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

Vegetation Duplicates

Table 6 provides the results of the four metals for the two duplicate vegetation samples and the calculated RPD between each pair of samples. All the RPD values are below the +/- 50 % RPD values anticipated for field samples. The RPD values range from 0 to 46 % which is good for field vegetation duplicates. Some of the larger differences are the result of homogeneous duplicates of vegetation material being difficult to generate in the field. In addition, low concentrations near the detection limits typically have higher variability.

Table 6 Vegetation Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Total Metal	SM19-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM40-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	<0.1	<0.1	0	0.33	0.25	27.6
Cadmium	0.07	0.05	33.3	0.08	0.11	-31.6
Lead	0.47	0.75	-45.9	5.35	4.35	20.6
Zinc	22.1	20.9	5.58	26.5	26.7	-0.75

Soil Duplicates

Table 10 provides the results of the 12 metals for the two duplicate soil samples and the calculated RPD between each pair of samples. All bar one of the RPD values are below the +/- 50 % RPD values anticipated for field samples with values ranging from 0 to 19 % RPD which is excellent. The only exception was for arsenic in one duplicate pair (SM40-S/ SM56-S) with an RPD of 111 %. This could be attributed to soil duplicate samples being difficult to homogenise in the field. In addition, low concentrations near the detection limits typically have higher variability. The highest reported value of the duplicate pair is selected for interpretive use in Section 4.

Table 7 Soil Duplicate Pairs Reported Values (µg/l) and Calculated % RPD

Metal	SM19-S (mg/kg)	SM56-S (mg/kg)	% RPD	SM40-S (mg/kg)	SM57-S (mg/kg)	% RPD
Aluminium	6,300	6,200	1.6	6,600	6,700	-1.5
Arsenic	6	7	-15.4	2	7	**-111**
Barium	50	50	0	50	50	0
Cadmium	0.5	*<0.5*	0	*<0.5*	*<0.5*	-
Chromium[1]	17	16	6.1	16	16	0.0
Copper	22	24	-8.7	23	28	-19.6
Iron	13,700	14,200	-3.6	14,200	14,900	-4.8
Mercury	*<1*	1	0	*<1*	1	0
Manganese	836	900	-7.4	576	614	-6.4
Nickel	18	17	5.7	21	22	-4.7
Lead	23	23	0	21	23	-9.1
Zinc	59	61	-3.3	62	66	-6.3

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

3.2.2 Decontamination Blanks

Surface Water and Groundwater

Three decontamination blanks were created by pumping DI water through or pouring water over the sampling equipment after decontamination and sent to ALcontrol for analysis. Table 8 provides the results of the 21 metals for the three decontamination blanks along with the results of the DI water blank also created in the field.

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 0.01 to 2.9 µg/l except for iron with a detection limit of 19 µg/l.

Low level detections were observed for 9 dissolved metals ranging from 0.062 to 10.8 µg/l. Two of the metals (molybdenum and zinc) were also detected in the DI water blank. Detections of dissolved antimony, arsenic, barium, lead, selenium, thallium, and tin were also found in the decontamination blanks but not the DI water blank. Dissolved chromium was detected in the water blank but none of the decontamination blanks.

In total there were 16 detections of dissolved metals in the decontamination blanks. All the detections in the decontamination blanks associated with water samples were less than 10 times the detection limit. All the detections were significantly less than the assessment criteria outlined in Section 4; therefore, these low concentrations in the blanks do not affect interpretation of results.

To assess the level of cross-contamination between samples in the field, the concentrations in the decontamination blanks were compared with the concentration in the preceding environmental samples. The concentrations in the blanks were generally less than 10% of the concentration in the preceding environmental samples. Three exceptions were the detection of dissolved antimony, molybdenum and zinc in SMDB02.2 which were determined to be 65%, 44% and 45% of the preceding environmental sample, respectively. Molybdenum and zinc were detected in the DI water blank and therefore the detections are not indicative of cross-contamination. The dissolved antimony detections are discussed below.

The results from the laboratory method blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory. The following detections of dissolved metals in the method blanks were reported and could contribute to the detections in the decontamination blanks shown in Table 8:

- Two detections in Sample Batch 130829-50 (0.837µg/l antimony and 0.389 µg/l molybdenum);
- Three detections in Sample Batch 130904-77 (0.803 µg/l antimony, 0.031 µg/l barium and 0.343 µg/l molybdenum); and
- Four detections in Sample Batch 130830-54 (2.647 µg/l antimony, 0.122 µg/l arsenic, 0.748 µg/l molybdenum and 2.64 µg/l tin.

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

Type		Water						Vegetation	Soil	
Sample Description / Dissolved Metal	LOD (µg/l)	Water Blank WB01.2 (µg/l)	Laboratory Method Blank W-10403 (µg/l)	Decon blank SMDB01.2 (µg/l)	Laboratory Method Blank W-10485 (µg/l)	Decon blank SMDB02.2 (µg/l)	Laboratory Method Blank W-10521 (µg/l)	Decon blank SMDB03.2 (µg/l)	Decon blank SMDB04.2 (µg/l)	Laboratory Method Blank W-10493 (µg/l)
Sample batch:		*130816-44*		*130829-50*		*130904-77*		*130830-54*		
Aluminium	<2.9	<2.9	NP	<2.9	NP	<2.9	NP	<2.9	<2.9	NP
Antimony	<0.16	<0.16	*0.7*	***0.364***	*0.837*	***0.392***	*0.803*	***10.8***	<0.16	*2.647*
Arsenic	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	***0.305***	<0.12	*0.122*
Barium	<0.03	<0.03	<0.03	**0.075**	<0.03	**0.062**	*0.031*	**0.81**	<0.03	<0.03
Cadmium	<0.1	<0.1	NP	<0.1	NP	<0.1	NP	<0.1	<0.1	NP
Chromium	<0.22	**0.309**	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22
Cobalt	<0.06	<0.06	NP	<0.06	NP	<0.06	NP	<0.06	<0.06	NP
Copper	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	NP	<19	NP	<19	NP	<19	<19	NP
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	**0.109**	<0.02	<0.02
Manganese	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mercury	<0.01	<0.01	NP	<0.01	NP	<0.01	NP	<0.01	<0.01	NP
Molybdenum	<0.24	**0.322**	*0.395*	***0.314***	*0.389*	<0.24	*0.343*	***2.89***	<0.24	*0.748*
Nickel	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Selenium	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	**0.467**	<0.39	<0.39
Silver	<1.5	<1.5	NP	<1.5	NP	<1.5	NP	<1.5	<1.5	NP
Thallium	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	**1.72**	<0.96	<0.96
Tin	<0.36	<0.36	<0.36	<0.36	0.437	<0.36	0.415	***6.71***	<0.36	*2.64*
Uranium	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Vanadium	<0.24	<0.24	NP	<0.24	NP	<0.24	NP	<0.24	<0.24	NP
Zinc	<0.41	**12.8**	<0.41	**0.86**	<0.41	**4.03**	<0.41	**3.31**	**0.965**	<0.41

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
NP means result was Not Provided by the laboratory.

It was noted that the parameters detected in the method blanks for both sample batches were similar to those in the decontamination blank samples. The detections of dissolved antimony were investigated with the laboratory. ALcontrol explained that antimony can be very difficult to "wash out" of the ICP-MS systems following a high concentration sample. The batch blanks that were tested immediately after the highest calibration standard at 1,000 µg/l, contained dissolved antimony that "washed out". ALcontrol does not expect these results to be less than the limit of detection. This issue will be discussed with the laboratory in further detail prior to the next sampling round.

Overall, the decontamination blank samples do not indicate any cross-contamination in the field and the detections were significantly less than the assessment criteria outlined in Section 4 and therefore the results are considered acceptable.

Vegetation and Soil

To assess the level of cross-contamination between vegetation samples in the field, the concentrations in decontamination blank SMDB03.2 were examined (Table 8). The detection of zinc and molybdenum can be attributed to the concentrations in the DI water. Detections were generally less than 10 times the detection limit with the exception of dissolved antimony, barium, molybdenum and tin, all of which were detected in the laboratory method blank (except barium). Also note that dissolved arsenic was detected in the laboratory method blank at 0.122 µg/l. ALcontrol explained that the detection of dissolved antimony was likely due to the preceding environmental sample which was analysed in the laboratory and contained high antimony (698 µg/l). As previously discussed, washing out the ICP-MS systems following a high concentration sample is difficult. It can be concluded that none of the parameters of concern for vegetation samples (arsenic, cadmium, lead and zinc) where detected in the decontamination blank at levels that would indicate cross-contamination of samples in the field.

To assess the level of cross-contamination between soil samples in the field, the concentrations in decontamination blank SMDB04.2 were examined (Table 8). The only detection was for dissolved zinc which can be attributed to the concentrations in the DI water blank.

3.2.3 Standard Reference Materials

SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.2 and SMSR02.2) to evaluate laboratory accuracy. The ALcontrol 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 18 requested metals.

Reported values for dissolved aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, selenium, thallium, vanadium and zinc are in excellent agreement with the certified value (%R ranged from 90 to 106%).

One of the reported values for dissolved antimony, molybdenum and nickel in ID SMSR01.2 were low at 85 %, 88 %, and 89 % respectively, which fall slightly outside of the acceptable range. However, the second reported value is within the acceptable range and therefore the reported values are considered usable.

The reported values for dissolved silver were low for both samples at 89 and 86 % RPD. The values were just outside the acceptable range indicating that there may be a bias in the results for silver.

However silver is not considered a contaminant of concern and therefore the overall interpretation of the results for silver is not affected.

SRM Soil

One blind SRM (NIST 2710) was sent to ALS Minerals. The ALS Minerals laboratory report is provided in Appendix F of the Data Report. The following Table 10 summarises the SRM 2710 results and provides the calculated %R values for the 11 requested metals.

Reported values for arsenic and copper were in excellent agreement with the certified value (%R ranged from 92 to 94 %). The cadmium, nickel, lead and zinc were within 20 percent of the certified values and are considered acceptable (% R ranged from 82 to 85 %). The reported values for iron and manganese were low (% R ranged from 71 to 73 %). The values for aluminium, barium, and chromium are very low compared to the certified values (% R ranged from 25 to 49 %). The certified values are the “true” total values based on complete decomposition of the sample (fusion or hydrofluoric acid) or non-destructive techniques and two or more independent analytical methods. The aqua regia used for the sample digestion does not completely decompose some of the aluminium silicate minerals and other matrix minerals resulting in low values for aluminium, barium, iron and manganese. The value for chromium is not certified and “should not be used for quality control” evaluations. Aluminum, barium, iron and manganese reported values in the soil samples are biased low and any use of these values should be noted with this observation.

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

Sample Description Dissolved Metal	Certified Value (µg/l)	Acceptance Limits (%)	SMSR01.2 (µg/l)	% R	SMSR02.2 (µg/l)	% R
Aluminium	1860	86.0 - 115.1	1860	100	1740	94
Antimony	406	86.0 - 112.1	346	**85**	371	91
Arsenic	413	86.2 - 110.9	383	93	380	92
Barium	2180	90.4 - 109.2	2110	97	2120	97
Cadmium	245	87.3 - 106.9	223	91	228	93
Chromium	825	90.3 - 110.1	824	100	752	91
Cobalt	759	92.9 -110.9	803	106	741	98
Copper	691	89.3 - 109	675	98	639	92
Iron	781	88.5 - 112	722	92	699	90
Lead	538	89 - 111	528	98	584	109
Manganese	316	91.1 - 108.9	311	98	293	93
Molybdenum	260	88.8 - 108.8	228	**88**	244	94
Nickel	2290	90.0 - 110.0	2010	**88**	2110	92
Selenium	179	87.2 - 112.8	171	96	166	93
Silver	387	89.1 - 110.1	345	**89**	333	**86**
Thallium	652	87 - 112	642	98	717	110
Vanadium	746	91.2 - 107	745	100	675	90
Zinc	1570	89.8 - 110.8	1410	90	1500	96

Notes:
Bold indicates an exceedance in acceptance limits

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

Metal	Certified Value (mg/kg)	SMSR03.2 (mg/kg)	% R
Aluminium	64,400	15,800	25
Arsenic	626	588	94
Barium	707	310	44
Cadmium	21.8	17.9	82
Chromium[1]	39	19	49
Copper	2,950	2,710	92
Iron	33,800	24,800	73
Manganese	10,100	7,180	71
Nickel	14.3	12	84
Lead	5,532	4,560	82
Zinc	6,952	5,890	85

1. Chromium is not certified

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

ALcontrol conducts a range of activities associated with both quality control and assessment to assure the quality of test results. Specifically ALcontrol 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 was 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 separately sourced standard to 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 ALcontrol laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding times were exceeded for total dissolved solids in the laboratory. For several samples the holding times were exceeded in the laboratory for free cyanide, which is 7 days with preservative. The holding times were exceeded by 1 to 7 days. Note that all the reported values for free cyanide were below the detection limit of 0.05 mg/l. We will work with the laboratory to prevent the free cyanide and total dissolved solids holding times being exceeded in the future. These exceedances of the holding times are typically considered acceptable from a technical perspective given the preservation and conservative nature of holding times.

ALcontrol provided the associated analytical quality control samples (AQC) data. The percentage recovery results for the AQC samples that were performed with the regular environmental samples were checked against the individual lower control and upper control limits. All AQC samples run with the environmental samples were within these upper and lower control limits. The results of method blanks were also assessed as described in Section 3.2.2 above.

3.3.2 CAL Ltd.

CAL provided the results for the following samples:

- SRMs: CAL analysed SRM NIST 1515 after every 10 samples for a total of two analyses. The results are provided in the laboratory report in Appendix F of the Data Report (reported as CRM NIST 1515). SRM NIST 1515 is a certified standard of apple leaves provided by the USA National Institute of Standards & Technology. The certificate of analysis is provided in Appendix G of the Data Report**.** In addition, CAL routinely analysed an in-house reference material (a dried ground grass sample, GST002). The reference material was analysed three times for arsenic, cadmium, lead and zinc;
- Duplicates: CAL did not analyse duplicates of the field samples. However, the two analyses of SRM NIST 1515 can be used to evaluate precision; and
- Blanks: CAL performed three method blanks during the analyses of arsenic, cadmium, lead and zinc. The method blanks were clean aqueous solutions.

SRM

Table 11 provides the results of the two analyses of SRM NIST 1515 and the % R values.

Table 11 SRM NIST 1515 Reported Values and Calculated % R and % RPD

Total Metal	Certified Value (mg/kg)	Certified value Acceptance Range (mg/kg)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R	% RPD
Arsenic	0.038	0.031-0.45	0.22	579	0.17	447	25.6
Cadmium	0.013	0.011-0.015	0.01	77	0.01	77	0
Lead	0.47	0.446-0.494	0.37	79	0.36	77	2.74
Zinc	12.5	12.2-12.8	13.3	106	12.5	100	6.20

The zinc results are considered acceptable with the % R value of 100 %, however one value is slightly high with an R of 106 %. The reported cadmium values may be slightly low (% R is 77); however, all values are very near the detection limit. The lead values may be slightly low (% R is 77 and 79 %). The cadmium, lead and zinc values are considered acceptable to use, noting the values may be slightly low for cadmium and lead and slightly high for zinc.

As shown, the values reported by the laboratory for the arsenic concentrations are much higher than the certified value. The laboratory report by CAL (provided in Appendix F of the Data Report) discussed these results and states:

- SRM NIST 1515 was previously re-analysed together with three other CRMs of comparable matrix which bracket the value for 1515 at the beginning of the project. For the other CRMs, there is a small consistent negative bias: opposite of 1515, which led CAL Ltd to the conclusion that the value given by NIST 1515 for arsenic is highly suspect. However, there is still confidence in the reported arsenic results because the other CRMs gave reasonable agreement with their certified values;
- The methods (this applies to lead as well) used to establish the certified value (ICP-MS) are different from those used at the certification laboratory. Frequently differences between results are obtained from alternate methodologies; and
- Method blanks did not indicate arsenic carryover/contamination.

As previously discussed, CAL also analysed an in-house reference material (GST002 a dried ground grass sample). The reported values are compared to historical mean and standard deviation values using a control chart. If the reported values for GST002 are outside +/- 2 standard deviations of the historical mean, corrective action is taken and all samples reanalysed. If two consecutive GST002 results are between 2 and 3 standard deviations on the same side of the mean, the samples are also reanalysed. All results for the in-house reference material were acceptable.

Duplicates

As previously discussed, the laboratory did not perform duplicate analyses of the field samples. However, the analyses of the SRM NIST 1515 (Table 11) can be considered duplicate samples. As shown in Table 11, the precision was good. The lead values were 0.36 and 0.37 mg/kg, all cadmium were 0.01 mg/kg and the zinc values were 12.5 and 13.3 mg/kg, with calculated %RPDs ranging from 0 to 6.2 %. The two values of arsenic ranged from 0.17 to 0.22 mg/kg with an RPD of 25.6 % which is a little higher but still considered acceptable.

Blanks

As previously discussed, CAL performed method blanks (3 for arsenic, cadmium, lead and zinc). All zinc results were below reporting limits (non-detects); arsenic values ranged from below reporting limits to to 0.005 mg/l; cadmium values ranged from below reporting limits to 0.001 mg/l; and lead values ranged from below reporting limits to 0.003 mg/l. All reported values were below the critical values and therefore are considered acceptable.

3.3.3 ALS Minerals

ALS Minerals provided the results for the following samples:

- SRMs: ALS Minerals analysed two in-house standard reference materials (GBM908-10 and MRGeo08). Each material was analysed once;
- Duplicates: ALS Minerals analysed a duplicate of one of the field samples; and
- Blanks: ALS Minerals performed one method blank during the analyses.

SRM

ALS Minerals analysed two in-house standard reference materials GBM908-10 and MRGeo08 the results are contained in Appendix F of the Data Report. ALS Minerals provided a target range (upper and lower bound) for each metal and standard. All reported values for both SRMs were within the target range therefore the analytical results are accurate and acceptable to use.

Duplicates

The following Table 12 provides the reported values for the duplicate soil samples performed by ALS Minerals and the resulting RPD for the sample pair. All the RPD values are very low (typically less than 11 %) except for the RPD of 50 % for arsenic. The reported values for arsenic for sample SM08-S were 3 and 5 mg/kg (relatively low values) and falls within ALS Minerals target range for arsenic.

Table 12 Laboratory Duplicate Reported Values for Soils (mg/kg) and % RPD

Sample Description	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
SM08-S Duplicate	5,000	3	50	<0.5	14	27	13,500	<1	631	13	28	60
SM08-S	5,000	5	50	<0.5	14	25	13,400	<1	615	14	25	55
% RPD	0	-50	0	0	0	7.7	0.7	0	2.6	-7.4	11.3	8.7

Blanks

ALS Minerals analysed one blank and the results are reported in Appendix F of the Data Report. All values were below the reporting limits (non-detect). The reporting limits ranged from a high of 100 mg/kg for aluminium and iron and a low of 0.5 mg/kg for cadmium. These results indicate that no cross-contamination occurred in the laboratory during the sample analysis.

3.4 Summary of Data Checks

3.4.1 Field physio-chemical Versus Laboratory Data

Table 13 summarises the field and laboratory results for pH and conductivity and provides the calculated %RPD values. 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 conductivity was less than 19 % which is very good, with only one exceeding 50% (SW4-Shal with a RPD of 52%). The RPDs between laboratory and field pH were also good and generally less than 18.1 % which is very good. There were 3 samples with pH RPDs between 26 and 21 %. The field pH and conductivity are more representative of actual conditions and is used for interpretive purposes. Overall the RPDs between the field and laboratory data are considered satisfactory.

Table 13 Field physio-chemical data and Laboratory Reported Values and Calculated % RPD

Sample Description	pH Lab (pH Units)	pH Field (pH Units)	% RPD	Conductivity @ 20 deg.C Lab (mS/cm)	Specific Cond. @ 25 deg.C Field (mS/cm)	% RPD
TMF1	7.8	7.17	8.4	0.398	0.462	-14.9
TMF2	7.44	6.61	11.8	0.426	0.500	-16.0
SW10-GORT-DISC	7.82	7.56	3.4	1.81	2.108	-15.2
SW10-GORT-DS	8.28	7.77	6.4	0.532	0.606	-13.0
SW10-GORT-US	8.24	7.36	11.3	0.535	0.599	-11.3
SW12-GORT-DISC	8.08	7.13	12.5	1.87	2.102	-11.7
SW12-GORT-DS	8.14	8.07	0.9	0.568	0.666	-15.9
SW14-GORT	8.45	8.14	3.7	0.506	0.508	-0.4
SW17-GORT	8.31	7.74	7.1	0.402	0.464	-14.3
SW18-GORT	7.93	7.38	7.2	2.27	2.719	-18.0
SW19-GORT	7.72	7.74	-0.3	2.22	2.684	-18.9
SW10-GAR	8.37	8.13	2.9	0.889	1.051	-16.7
SW12-GAR	8.16	7.52	8.2	1.41	1.71	-19.2
SW3-GAR	8.4	8.35	0.6	0.848	1.001	-16.5
SW4-GAR	7.77	6.74	14.2	0.376	0.449	-17.7
SW7-GAR	8.31	7.99	3.9	0.579	0.649	-11.4
SW8-GAR	7.9	6.61	17.8	1.8	2.145	-17.5
SW9-GAR	8.06	7.13	12.2	1.72	2.061	-18.0
SW1-SM	7.9	6.59	18.1	0.172	0.192	-11.0
SW2-SM South	7.5	5.72*	26.9	0.439	0.509	-14.8
SW3-SM	8	7.08	12.2	0.194	0.224	-14.4
SW4-SM-GA	7.96	8.05	-1.1	0.33	0.376	-13.0
SW6-MAG	7.58	7.85	-3.5	0.556	0.632	-12.8
SW1-SHAL	7.8	8.2	-5.0	0.149	0.16	-7.1
SW10-SHAL	7.42	6.71	10.0	0.15	0.159	-5.8
SW12-SHAL	6.72	6.83	-1.6	0.0443	0.052	-16.0
SW4-SHAL	7.49	7.29	2.7	0.225	0.383	**-52.0**
SW6-SHAL	6.84	4.53	40.6	0.14	0.148	-5.6
SW9-SHAL	7.6	5.65	29.4	0.146	0.158	-7.9

Notes:
Bold indicates an exceedance in acceptance limits
* Difficulties stabilising pH readings in the field

3.4.2 Internal Consistency Analysis

The analyses were checked for internal consistency using both charge balance and mass balance relationships.

The charge balance was calculated as follows:

(Σ(Cations x charge) - Σ(Anions x charge))/ (Σ(Cations x charge) + Σ(Anions x charge)) x 100%

Where, “cations” refers to the molar concentration of positively charged ions (millimoles/L) and “anions” to the molar concentration of negatively charged ions.

The mass balance was calculated using the following relationship:

(TDS-Calc – TDS-Meas)/TDS-Meas x 100%

TDS-Calc was calculated by summing the concentrations of all species in mg/l. Adjustments were made in cases where the species that would be formed upon evaporation (laboratory analytical procedure to yield TDS-Meas) was in a different form than that provided by the laboratory. For instance, the bicarbonate concentration was multiplied by a factor of 0.49 to account for loss of carbon dioxide gas during evaporation.

By evaluating both the mass balance and charge balance, conclusions can be drawn about the accuracy and completeness of the analysis. The possible mass balance and charge balance combinations and the corresponding interpretations are shown in Table 14.

The general acceptance criteria for internal consistency are ±10 % for both the charge balance and the mass balance. The charge balance was consistently within acceptable limits, with most values below 2 % and all less than 5.5 % which is excellent. The mass balance, in many cases (bolded values) did not meet these criteria. However most values were less than 20 %; which overall is very good considering the complex nature of some of the samples with high metal concentrations. Higher mass balance values were observed in samples from the Ballygown area and SW4-Shal. The fact that the high values are all negative suggests that either one or more parameters were under-reported by the analytical laboratory and/or one or more parameters present within the samples were not analysed (e.g. silica).

Table 14 Charge Balance and Mass Balance Results

Site Description	TDS (Calc) (mg/l)	TDS (Meas) (mg/l)	Cations minus anions	Charge Balance % Diff	Mass Balance% Diff	Conclusion
TMF1	260	299	-0.30	-2.98	**-13.1**	Missing cations
TMF2	270	299	-0.23	-2.16	-9.73	Missing cations
SW10-GORT-DISC	1679	1900	2.54	4.51	**-11.6**	Missing anions
SW10-GORT-DS	359	394	-0.09	-0.68	-8.98	Missing cations
SW10-GORT-US	350	399	0.09	0.64	**-12.2**	Missing anions
SW12-GORT-DISC	1711	2220	0.74	1.32	**-22.9**	Too many cations
SW12-GORT-DS	401	446	-0.12	-0.83	**-10.2**	Missing cations
SW14-GORT	353	396	-0.09	-0.67	**-10.8**	Missing cations
SW17-GORT	263	272	-0.01	-0.07	-3.48	Missing cations
SW18-GORT	2480	2900	1.39	1.81	**-14.5**	Too many cations
SW19-GORT	2411	2860	2.53	3.36	**-15.7**	Too many cations
SW1-SM	100	219	-0.17	-4.32	**-54.5**	Missing cations
SW2-SM South	290	577	-0.21	-1.86	**-49.7**	Missing cations
SW3-SM	119	250	-0.16	-3.44	**-52.5**	Missing cations
SW4-SM-GA	210	360	-0.18	-2.19	**-41.6**	Missing cations
SW1-SHAL	88	111	-0.04	-1.13	**-20.5**	Missing cations
SW4-SHAL	140	249	0.06	1.06	**-43.8**	Missing anions
SW6-SHAL	83	97.3	-0.17	-5.53	**-14.6**	Missing cations
SW9-SHAL	85	140	-0.03	-0.90	**-39.0**	Missing cations
SW10-SHAL	87	107	0.00	-0.04	**-18.2**	Missing cations
SW12-SHAL	21	31.4	0.01	1.76	**-32.3**	Missing anions
SW6-MAG	414	573	-0.40	-2.99	**-27.7**	Missing cations
SW3-GAR	696	815	0.30	1.26	**-14.6**	Missing anions
SW4-GAR	257	300	0.06	0.68	**-14.2**	Missing anions
SW7-GAR	404	469	0.29	1.95	**-13.8**	Missing anions
SW8-GAR	1852	2100	0.47	0.80	**-11.8**	Too many cations
SW9-GAR	1770	2010	1.94	3.45	**-11.9**	Too many cations
SW10-GAR	754	851	0.05	0.21	**-11.4**	Missing anions
SW12-GAR	1289	1530	1.70	4.04	**-15.7**	Too many cations

Notes:
Bold indicates an exceedance of the acceptance criteria

The specific conductivity (SC) of the solutions can be used to further evaluate the internal consistency. The specific conductivity total dissolved solids (SC/TDS) ratio of natural waters varies, but typically ranges from ranges from 1 to 1.8. By comparing both the calculated TDS (TDS- Calc) and the measured TDS (TDS-Meas) to SC, an evaluation can be made of the reliability of these analyses. The majority of the ratios in Table 15 are within the range for natural waters and therefore the analyses are considered reliable. The one exception on the high range (SW12-SHAL with ratio of 2.5 for SC/TDS-Calc) had the lowest measured conductivity and TDS. At these low levels, the relationships are less accurate. Another exception was SW4-Shal with ratio of 2.7 for SC/TDS-Calc) where the RPDs between laboratory and field conductivity was less 52%. When the laboratory conductivity of 225 uS/cm was used to calculate SC/TDS-Calc the ratio was 1.6 which is within typical range and therefore it is believed there was an error with the field conductivity result.

Figure 1 shows the relationship between specific conductivity and TDS and that there is a strong positive correlation between SC and both the calculated (R^2=0.99) and measured (R^2=0.97) TDS.

Table 15 Comparison of Specific Conductivity to Total Dissolved Solids (SC/TDS) Ratio

Sample Description	Sample Type	Specific Conductance (uS/cm)	TDS (Calc) (mg/l)	TDS (Meas) (mg/l)	Ratio SC/ TDS (Calc)	Ratio SC/ TDS (Meas)
TMF1	GW	462	260	299	1.8	1.5
TMF2	GW	500	270	299	1.9	1.7
SW10-GORT-DISC	SW	2108	1679	1900	1.3	1.1
SW10-GORT-DS	SW	606	359	394	1.7	1.5
SW10-GORT-US	SW	599	350	399	1.7	1.5
SW12-GORT-DISC	SW	2102	1711	1530	1.2	1.4
SW12-GORT-DS	SW	666	401	446	1.7	1.5
SW14-GORT	SW	508	353	396	1.4	1.3
SW17-GORT	SW	464	263	272	1.8	1.7
SW18-GORT	SW	2719	2480	2900	1.1	0.9
SW19-GORT	SW	2684	2411	2860	1.1	0.9
SW1-SM	SW	192	100	219	1.9	0.9
SW2-SM South	SW	509	290	577	1.8	0.9
SW3-SM	SW	224	119	250	1.9	0.9
SW4-SM-GA	SW	376	210	360	1.8	1.0
SW1-SHAL	SW	160	88	111	1.8	1.4
SW4-SHAL	SW	383	140	249	2.7	1.5
SW6-SHAL	SW	148	83	97.3	1.8	1.5
SW9-SHAL	SW	158	85	140	1.9	1.1
SW10-SHAL	SW	159	87	107	1.8	1.5
SW12-SHAL	SW	52	21	31.4	2.5	1.7
SW6-MAG	SW	632	414	573	1.5	1.1
SW3-GAR	SW	1001	696	815	1.4	1.2
SW4-GAR	SW	449	257	300	1.7	1.5
SW7-GAR	SW	649	404	469	1.6	1.4
SW8-GAR	SW	2145	1852	2100	1.2	1.0
SW9-GAR	SW	2061	1770	2010	1.2	1.0
SW10-GAR	SW	1051	754	851	1.4	1.2
SW12-GAR	SW	1710	1289	1530	1.3	1.1

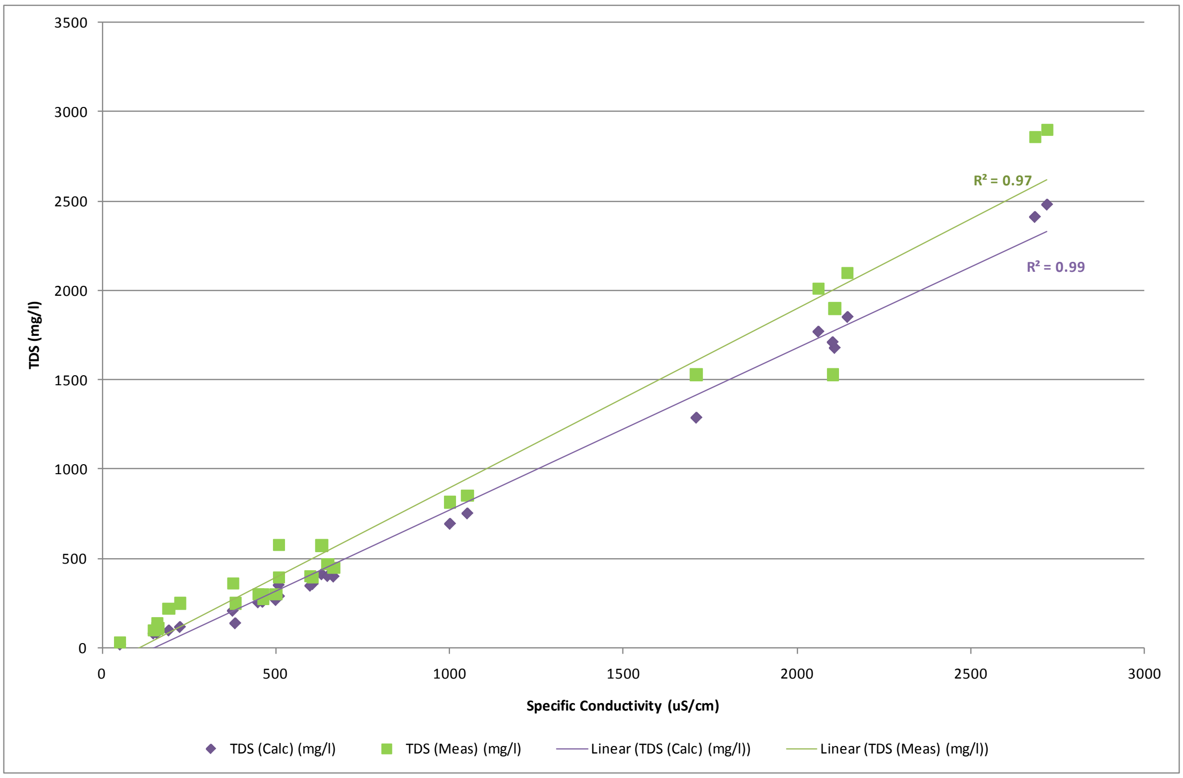

Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

3.4.3 Comparison of Total and Dissolved Metals

Total metals are the concentration of metals determined in an unfiltered sample (combination of metals contained in the solid sediments, colloidal particles and in the dissolved phase), while dissolved metals are those which pass through a 0.45µm membrane filter. Dissolved metals are more biologically available than total metals.

Normally the dissolved metal concentrations would be less than the total metals because they are a portion of the total concentration. This was checked for the key metals barium, cadmium, lead, nickel and zinc, by calculating the %RPD between the total and dissolved metals to evaluate if the concentrations were indistinguishable. Refer to **Appendix B** for the full tabulation of results.

The total metals were greater than or equal to the dissolved metals with the exception of 10 out of 140 results, where the RPD was greater than 50%. The exceptions were of some nickel and zinc results and many of which had reported values close to the limit of detection. The total concentrations were significantly higher than the dissolved concentrations for lead. A relationship between high suspended solids and the highest differences in total versus dissolved metals is not apparent for lead. However the highest differences between total and dissolved for barium did correspond to higher suspended solids in some samples with suspended solids concentrations ranging from 5 to 23 mg/l. The total and dissolved concentrations were very similar for cadmium, nickel and zinc.

Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater, surface water, vegetation and soil and a comparison of the analytical results against selected assessment criteria. 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 16 provides a summary of the reported results of the two groundwater samples. Included in the table are the minimum, maximum and mean dissolved meta 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 16 Summary of Dissolved Metal Concentrations in Groundwater

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Aluminium	<2.9	2	0	1.45	1.45	-
Antimony	<0.16	2	2	1.79	2.05	1.92
Arsenic	<0.12	2	2	2.47	5.39	3.93
Barium	<0.03	2	2	144	567	356
Cadmium	<0.1	2	0	0.05	0.05	-
Chromium	<0.22	2	2	0.703	1.39	1.05
Cobalt	<0.06	2	2	0.535	0.773	0.654
Copper	<0.85	2	0	0.425	0.425	-
Iron	<19	2	1	9.5	198	104
Lead	<0.02	2	2	0.268	1.71	0.989
Manganese	<0.04	2	2	51.6	916	484
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	2	1.25	1.53	1.39
Nickel	<0.15	2	2	0.648	2.01	1.329
Selenium	<0.39	2	1	0.195	0.756	0.476
Silver	<1.5	2	0	0.75	0.75	-
Thallium	<0.96	2	0	0.48	0.48	-
Tin	<0.36	2	0	0.18	0.18	-
Uranium	<1.5	2	0	0.75	0.75	-
Vanadium	<0.24	2	0	0.12	0.12	-
Zinc	<0.41	2	1	0.205	3.12	1.66

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

Dissolved barium (567 µg/l), iron (198 µg/l).and manganese (916 µg/l) were found in the highest concentrations in TMF2, which were significantly higher than the concentrations in TMF1. Dissolved arsenic was detected in both wells with the highest concentration at TMF2 of 5.39 µg/l. Detections of dissolved chromium, lead and zinc were reported which were slightly more elevated in TMF2 than in TMF1.

4.1.2 Surface Water Sample Results

Surface water samples were collected for two major categories: the first includes mine adit discharges and discharges from wetlands as well as some drainage ditches and the second includes the rivers and streams. Table 17 provides a summary of the reported results of the 14 discharge/ drainage samples and Table 18 provides a summary of the reported results of the 14 river and stream samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV) for dissolved meta concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

Discharges and Drainage

Table 17 Summary of Dissolved Metal Concentrations in Discharges and Drainage

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	14	6	1.45	103	10.8	26.7
Antimony	<0.16	14	14	0.218	4.42	1.22	1.07
Arsenic	<0.12	14	14	0.197	0.894	0.51	0.21
Barium	<0.03	14	14	10.2	225	76	79.3
Cadmium	<0.1	14	10	0.05	20.1	5.36	7.17
Chromium	<0.22	14	14	0.225	2.99	1.06	0.93
Cobalt	<0.06	14	14	0.065	10.8	1.98	2.7
Copper	<0.85	14	10	0.425	10	2.71	2.53
Iron	<19	14	9	9.5	3300	287	869
Lead	<0.02	14	14	0.04	183	21.8	50.8
Manganese	<0.04	14	14	0.534	1070	296	346
Mercury	<0.01	14	1	0.005	0.012	-	-
Molybdenum	<0.24	14	11	0.12	2.01	0.55	0.49
Nickel	<0.15	14	13	0.075	80.6	18.5	22.2
Selenium	<0.39	14	5	0.195	0.776	0.36	0.24
Silver	<1.5	14	0	0.75	0.75	-	-
Thallium	<0.96	14	10	0.48	44.8	7.42	12.8
Tin	<0.36	14	8	0.18	2.26	0.57	0.59
Uranium	<1.5	14	0	0.75	0.75	-	-
Vanadium	<0.24	14	6	0.12	0.821	0.31	0.27
Zinc	<0.41	14	14	21	20800	3670	6060

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

SW8-GAR (drainage from the western part of the Mogul Yard) had the highest concentrations of zinc (20,800 µg/l) and nickel (80.6 µg/l). The highest dissolved aluminium was at SW12-Shal (stoned lined drainage channel at Shallee) with a value of 103 µg/l and the highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 183 µg/l. Dissolved arsenic was detected in all discharge and drainage samples ranging from values of 0.197 to 0.894 µg/l. There was only one detection of dissolved mercury at 0.0123 µg/l in SW5-Gar. SW12-Gort-Disc a discharge from Gortmore TMF wetland had the highest concentration of iron (3300 µg/l) and manganese (1070 µg/l).

Rivers and Streams

Table 18 Summary of Dissolved Metal Concentrations in Rivers and Streams

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	14	4	1.45	25.2	4.73	6.67
Antimony	<0.16	14	9	0.08	3.54	0.79	0.99
Arsenic	<0.12	14	14	0.26	2.74	0.79	0.61
Barium	<0.03	14	14	42.6	840	202	199
Cadmium	<0.1	14	9	0.05	5.67	0.8	1.49
Chromium	<0.22	14	13	0.11	2.64	1.22	0.95
Cobalt	<0.06	14	12	0.03	17.3	2.34	5.07
Copper	<0.85	14	5	0.425	6.27	1.53	1.96
Iron	<19	14	10	9.5	1790	230	522
Lead	<0.02	14	12	0.01	127	15.3	37.8
Manganese	<0.04	14	14	1.04	6770	687	1830
Mercury	<0.01	14	0	0.005	0.005	-	-
Molybdenum	<0.24	14	8	0.12	0.918	0.36	0.28
Nickel	<0.15	14	11	0.075	13.9	3.9	4.5
Selenium	<0.39	14	1	0.195	0.398	-	-
Silver	<1.5	14	0	0.75	0.75	-	-
Thallium	<0.96	14	1	0.48	2.62	-	-
Tin	<0.36	14	5	0.18	3.73	0.66	1
Uranium	<1.5	14	0	0.75	0.75	-	-
Vanadium	<0.24	14	7	0.12	0.785	0.39	0.3
Zinc	<0.41	14	13	0.205	853	201	260

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

SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc than the rest of the rivers and streams sampled in the Silvermines area (<0.41 and 4.86 µg/l, respectively). However SW17-Gort has background concentrations of manganese (49.2 µg/l) and aluminium (25.2 µg/l).

SW3-Gar (stream containing both tailings lagoon discharges and downstream of the Mogul Yard) has the highest concentrations of cadmium (5.67 µg/l) and zinc (853 µg/l).

4.1.3 Vegetation Sample Results

Table 19 provides a summary of the results of the 20 vegetation samples from the recently remediated Areas A and B at Gortmore TMF. Included in this table are the mean, minimum, maximum, and standard deviation (SDEV). The values were calculated by substituting 0.05 for arsenic values <0.1 mg/kg and only using the original result of the field duplicate samples.

Table 19 Summary of Vegetation Concentrations (mg/kg) at Gortmore TMF

	Arsenic	Cadmium	Lead	Zinc
Number	20	20	20	20
Minimum	0.05	0.03	0.37	15.9
Maximum	0.33	0.18	5.35	33.7
Mean	0.11	0.09	1.51	25.4
SDEV	0.081	0.044	1.24	5.10

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

The highest arsenic concentration (0.33 mg/kg) and lead (5.35 mg/kg) were found in a sample SM40-V. The highest cadmium concentration (0.18 mg/kg) was in vegetation sample SM01-V and the highest zinc concentration (33.7 mg/kg) was in vegetation sample SM08-V. SM01-V and SM40-V are located at the edge of the site, the north-eastern edge and southern edge, respectively. SM08-V is located in the centre of the northern capped area. Eleven detections of arsenic were greater than the reporting limit of 0.1 mg/kg.

4.1.4 Soil Sample Results

Table 20 provides a summary of the results of the 20 soil samples from the recently remediated Areas A and B at Gortmore TMF. Included in this table are the mean, median, minimum, maximum, and standard deviation (SDEV). The values were calculated by using the highest result from the duplicate pair where applicable.

Table 20 Summary of Soil Concentrations (mg/kg) at Gortmore TMF

Metal	Number	Minimum	Maximum	Mean	SDEV	Median	Median in Irish soil *
Aluminium	20	5000	8100	6340	865	6250	34800
Arsenic	20	3	11	6.15	2.1	5.5	7.3
Barium	20	40	90	58	12.8	50	230
Cadmium	20	0.25	0.6	0.373	0.1	0.25	0.33
Chromium	20	13	20	15.9	2.1	16	43
Copper	20	11	33	23.5	6.6	25	16.2
Iron	20	12300	18700	14300	1600	14000	18700
Mercury	20	0.5	1	0.575	0.2	0.5	0.09
Manganese	20	371	1275	760	228	709	462
Nickel	20	11	22	18	3.1	19	17.5
Lead	20	21	36	25.7	4.3	24.5	24.8
Zinc	20	40	71	59.9	8.7	62	62.6

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

Compared to Irish soils, the median concentrations of the samples are higher for copper, manganese and nickel. The median concentrations are approximately the same as Irish soils for arsenic, cadmium, lead and zinc. The median concentrations are lower for aluminium, barium and iron compared to Irish soils.

The highest arsenic concentration (11 mg/kg) was found in a sample SM31-S. The highest lead (36 mg/kg) and zinc (71 mg/kg) concentrations were in soil sample SM15-S. These values are only slightly higher than the Irish median values. The majority of values for cadmium were <0.5 mg/kg;

however, six locations had values just at or above the detection limit. Similarly the majority of values for mercury were <1 mg/kg with 5 values just at the detection limit of 1 mg/kg.

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 for 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 21. 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 where possible as the assessment criteria because it is the most appropriate for assessment of one value; however, the AA was used in the absence of the MAC or 95%ile. To supplement the Irish legislation, screening criteria were selected from Oak Ridge National Laboratory (Suter and Tsao, 1996) for certain metals including aluminium, barium, cobalt, manganese and uranium (Table 21).

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 area was determined to be 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 21.

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 22. 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 two main receptors to 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 21 and Table 22).

Table 21 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
Ortho-phosphate as P	mg/l	0.035	**0.075**	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
Free Cyanide	mg/l	**0.01**	-	S.I. No. 272 of 2009	
Fluoride	mg/l	**0.5**	-	S.I. No. 272 of 2009	
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. 327 of 2012	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; the value 30 applies where the water hardness > 100 mg/l CaCO3.
Lead	µg/l	**7.2**	-	S.I. No. 327 of 2012	
Mercury	µg/l	0.05	**0.07**	S.I. No. 327 of 2012	
Nickel	µg/l	**20**	-	S.I. No. 327 of 2012	
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
Uranium	µg/l	-	**2.6**	Oak Ridge National Laboratory	Invertebrates only - Lowest Chronic Value for Daphnids

Table 22 Surface Water and Groundwater Assessment Criteria for Drinking Water

Parameter	Unit	Parametric value
pH	pH units	>6.5 to <9.5
Chloride	mg/l	250
Conductivity	mS/cm	2.5
Free Cyanide	mg/l	0.05
Ammonium	mg/l	0.3
Fluoride	mg/l	1.5
Nitrate as NO3	mg/l	50
Nitrite as NO2	mg/l	0.5
Sulphate	mg/l	250
Sodium	mg/l	200
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
Mercury	µg/l	1
Nickel	µg/l	20
Selenium	µg/l	10

4.2.2 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 23 summarises the maximum content in feedingstuff for arsenic, cadmium and lead applicable to the vegetation samples collected. No values are available for zinc.

Table 23 Assessment Criteria for Vegetation (mg/kg)

<table>
<tr><th>Undesirable Substance</th><th colspan="2">Directive 2002/32/EC</th><th colspan="2">Oak Ridge National Laboratory</th></tr>
<tr><th></th><th>Product Intended for Animal Feed</th><th>Maximum Content in Animal Feed (mg/kg)</th><th>Plants</th><th>Wildlife No Effect / Low Effect Level (mg/kg)</th></tr>
<tr><td>Arsenic</td><td>Feed materials</td><td>2</td><td rowspan="4">Concentrations for adverse effects in whitetail deer (dietary exposure)</td><td>0.621 / 6.211</td></tr>
<tr><td>Cadmium</td><td>Feed materials of Vegetable Origin</td><td>1</td><td>8.787 / 87.871</td></tr>
<tr><td>Lead</td><td>Green Fodder</td><td>30</td><td>72.88 / 728.78</td></tr>
<tr><td>Zinc</td><td>n/a</td><td>None</td><td>1457.6 / 2915.1</td></tr>
</table>

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 CAL drying and digestion methods for the vegetation samples probably yield slightly higher values than those reported to a moisture content of 12 % and using 5 % nitric acid. Therefore any comparisons to the measured values to the standards in Table 23 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 23 is for digestion by wildlife (whitetail deer) taken from the Oak Ridge National Laboratory (Sample *et al.*, 1996).

4.2.3 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 24 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 24 summarises the screening level and threshold values and the information sources.

Table 24 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
Cadmium	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	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. Efroymson *et al*. (1997); 4. Ford (2004).

4.3 Comparison to Assessment Criteria

A comparison of the groundwater and surface water analytical results was made against the relevant assessment criteria for ecological and human health as described in Section 4.2. The dissolved metal concentrations are assessed as they are more biologically available than total metals and non-dissolved metals are generally removed from drinking water by filtration. Table B-2 in **Appendix B** highlights the exceedances of the assessment criteria. Where there was an exceedance of the ecological assessment criteria, the result is highlighted in purple; for an exceedance of the human health criteria the result is highlighted in blue. In some cases the reported values exceed both the ecological and human health criteria and these results are highlighted in pink.

A comparison of the vegetation results was made against the relevant assessment criteria as described in Section 4.2. Table B-3 in **Appendix B** highlights the exceedances of the assessment criteria for vegetation; where there is an exceedance in the maximum concentration in Feeding Stuff, the result is highlighted in pink and exceedances of the no effect and low effect levels for digestion in wildlife is highlighted in blue and purple, respectively.

A comparison of the soil results was made against the relevant assessment criteria as described in Section 4.2. Table B-4 in **Appendix B** highlights the exceedances of the assessment criteria for soil; where there is an exceedance in the threshold for soil where sewage sludge might be applied, the result is highlighted in pink and exceedances of a threshold for plants or mammals is highlighted in blue and purple, respectively.

Groundwater, surface water, vegetation and soil results and exceedances of the relevant assessment criteria are discussed in this section.

4.3.1 Groundwater Assessment

In groundwater, the pH was found to be within the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria with an average of pH 6.89. The specific conductance ranged from 0.462 to 0.500 mS/cm which was well within the criteria for human health of 2.5 mS/cm.

Sulphate was within normal ranges with values ranging from 2.2 to 32.1 mg/l, which was well below the criteria for human health of 250 mg/l. Ammonia and fluoride were less than the limit of detection.

For dissolved metal concentrations, the only exceedances of the assessment criteria in groundwater samples were barium and manganese, with higher concentrations in the downgradient monitoring well. Barium exceeded the ecological health criteria of 4 µg/l in both monitoring wells; TMF1 had a result of 144 µg/l and TMF2 had a result of 567 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1 had a result of 51.6 µg/l and TMF2 had a result of 916 µg/l.

4.3.2 Surface Water Assessment

The pH in surface waters in the Silvermines mining area was found to be near neutral, ranging from 4.53 to 8.35, with an average of 7.25. There were three exceedances in the assessment criteria for pH was at SW2-Sm-South adit discharge (5.72 pH), SW6-Shal (Field Shaft) (4.53 pH) and SW9-Shal (downstream of Field Shaft) (5.65 pH) which were below the acceptable range for human health of 6.5 to 9.5 pH. Low acidity results were detected at three locations in the Garryard area which ranged from 5.48 to 11 mg/l (as HCL) with the highest acidity at SW8-GAR (drainage from the western part of the Mogul Yard). The conductivity ranged from 0.052 to 2.72 mS/cm with an average of 0.908 mS/cm. There were two exceedances in the human health criteria (2.5 mS/cm) at SW18-Gort (2.719 mS/cm) and SW19-Gort (2.684 mS/cm) which discharge from the main pond on the TMF.

Nutrients in surface water were generally considered acceptable with a few exceptions where the ecological assessment criteria were exceeded for ammonia and ortho-phosphate. The ammonia ecological assessment criteria (0.14 mg/l) was exceeded at the downstream location on the Silvermines River (SW4-Sm-Ga – 0.274 mg/l) which is also downstream of a small wastewater treatment plant. This was also the only location that the criteria for ecological health (0.075 mg/l) for ortho-phosphate was exceeded with a value of 0.145 mg/l. SW10-Shal (0.234 mg/l) (drainage running along the main road) and SW4-Shal (0.342 mg/l) had the highest ammonia and the criteria for human health (0.3 mg/l) was also exceeded at SW4-Shal.

Fluoride results were elevated ranging from 1.47 to 1.93 mg/l in three of drainage sites in the Garryard area. Both the ecological and human health (1.5 mg/l) criteria were exceeded at four locations.

Sulphate exceeded the criteria for human health (250 mg/l) at all of the discharge and drainage locations in the Garryard and Gortmore areas, with the exception of SW7-Gar (141 mg/l). The sulphate results that exceeded the criteria ranged from 384 to 1700 mg/l. SW3-Gar, the stream containing both tailings lagoon discharges and downstream of the Mogul Yard, also had high sulphate of 340 mg/l which exceeded the human health criteria.

Dissolved Metals Assessment

Concentrations of dissolved barium, cadmium, lead, manganese, nickel and zinc were elevated and exceeded the assessment criteria in many locations as discussed below, see the Table B-2 in **Appendix B** for the full listing. The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with high results even at upstream locations SW1-SM (47.1 µg/l) and SW17-Gort (288 µg/l), and is not discussed further. Dissolved arsenic was detected at all locations but was significantly below both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria, with the highest concentration of 2.74 µg/l at SW4-Shal.

In the Ballygown area (Map 4 of **Appendix A**) where the Silvermines stream is located, in addition to dissolved barium, dissolved cadmium and zinc exceeded the assessment criteria at certain locations. The southern adit SW2-SM discharges to the Silvermines stream and had cadmium (4.57 µg/l) and zinc (1840 µg/l) above the ecological assessment criteria of 0.9 µg/l for cadmium and 100 µg/l for zinc. Further downstream at SW4-SM-GA, dissolved zinc was also above the ecological assessment criteria at a concentration of 383 µg/l. SW6-Mag downstream of the Magcobar area also had dissolved cadmium (1.15 µg/l) and zinc (508 µg/l) above the ecological assessment criteria.

At Gortmore TMF (Map 2 of **Appendix A**), dissolved cadmium and zinc, exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. Levels of dissolved lead and nickel were relatively low. The concentration of dissolved cadmium exceeded the ecological assessment criterion of 0.9 µg/l with values ranging from 1.03 to 2.49 µg/l at SW18-Gort and SW19-Gort. Dissolved zinc also exceeded the ecological assessment criteria of

100 µg/l at SW10-Gort Discharge, SW18-Gort and SW19-Gort with results ranging from 175 to 2,200 µg/l. The concentration of zinc increased on the Kilmastulla River from 4.86 µg/l at the upstream location, SW17-Gort, to 42.1 µg/l at SW14-Gort but remained below the assessment criteria. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garrymore and Shallee. The loading from these areas are discussed in Section 5. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at several locations, with results ranging from 63.3 to 1070 µg/l. The exceptions were at SW19-Gort (1.6 µg/l, the decant from the TMF) and upstream of SW12-Gort Discharge in the Kilmastulla River where the values ranged between 47.6 to 49.2 µg/l.

At Shallee (Map 3 of **Appendix A**), dissolved lead exceeded the both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations, with concentrations ranging from 17.2 to 183 µg/l. The highest concentration was from the Field Shaft discharge (SW6-Shal). At SW4-Shal which is upstream of the mining area, the dissolved lead concentration was 4.27 µg/l (below both the assessment criteria). With the exception of SW12-Shal (stone lined drainage channel) and SW4-Shal (upstream location), dissolved zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 122 to 194 µg/l.

In the Garryard area (Map 3 of **Appendix A**), some of the highest concentrations of dissolved metals were observed. SW8-Gar (drainage from the western part of the Mogul Yard) had the highest concentrations of dissolved zinc (20,800 µg/l) and nickel (80.6 µg/l). It should be noted that the flow at SW8-Gar was extremely low and that the results might be representative of groundwater seeps rather than yard runoff. Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l. The only exception was SW7-Gar, the discharge from the smaller settlement pond, which had a concentration of 21 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium, with the exception of two locations (SW4-GAR – 1.62 µg/l and SW5-GAR – 2.53 µg/l) that only exceeded the ecological criteria and one location that was less than the detection limit (SW7-Gar <0.1 µg/l). Lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at one location; SW9-Gar with a concentration of 12.5 µg/l. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at these four locations with values ranging from 21.3 to 80.6 µg/l. Dissolved manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all locations, with results ranging from 202 to 2080 µg/l. The highest concentration of dissolved manganese was at SW4-Gar which was also above the ecological assessment criteria.

4.3.3 Vegetation Assessment

Based on the summary in Table 19 (maximum values) and the CAL laboratory report in Appendix F of the Data Report, no measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium or lead exceeded the Maximum Content standards in Table 23. The measured concentrations in the vegetation were also all below both the no effect and low effect levels provided in Table 23.

4.3.4 Soil Assessment

In general, the measured soil concentrations are below the screening levels for arsenic, cadmium, copper, nickel, lead and zinc shown in Table 24 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 24. These values consider that in many cases the grazing animals consume the plant leaves and roots containing soil.

The reported value for arsenic in SM31-S was 11 mg/kg, which was slightly above the ORNL benchmark concentration of 10 mg/kg. The reported values for zinc concentrations were above the ORNL benchmark concentration of 50 mg/kg for all samples, with the exception of SM05-S and SM06-S. In general this value is viewed as conservatively low and all reported values were significantly lower than the maximum values for concentrations of zinc of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998. None of the reported values for any of the parameters exceeded the maximum values for soil specified in the Use of Sewage Sludge in Agriculture Regulations.

Section 5

Flows, Loads and Trend Analysis

5.1 Surface Water Flows

No river flow gauging stations are present within the Silvermines mining area. The nearest gauge on the Kilmastulla River is Coole (EPA station 25044) which is 10 km downstream. The flow record from 1 April to 5 September 2013 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >2 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 0.7 m^3/s. The recorded flow at the Coole gauging station shows that the flows were relatively low during the monitoring period with no extreme high flows and the baseline decreasing to 0.4 m^3/s in July and August 2013, which is close to the 95%-ile flow of 0.3 m^3/s.

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 which was 0.16 m^3/s (CDM Smith, 2013). It is estimated that the flows would have been close to the 95%-ile in the Silvermines mining area for the July and August period.

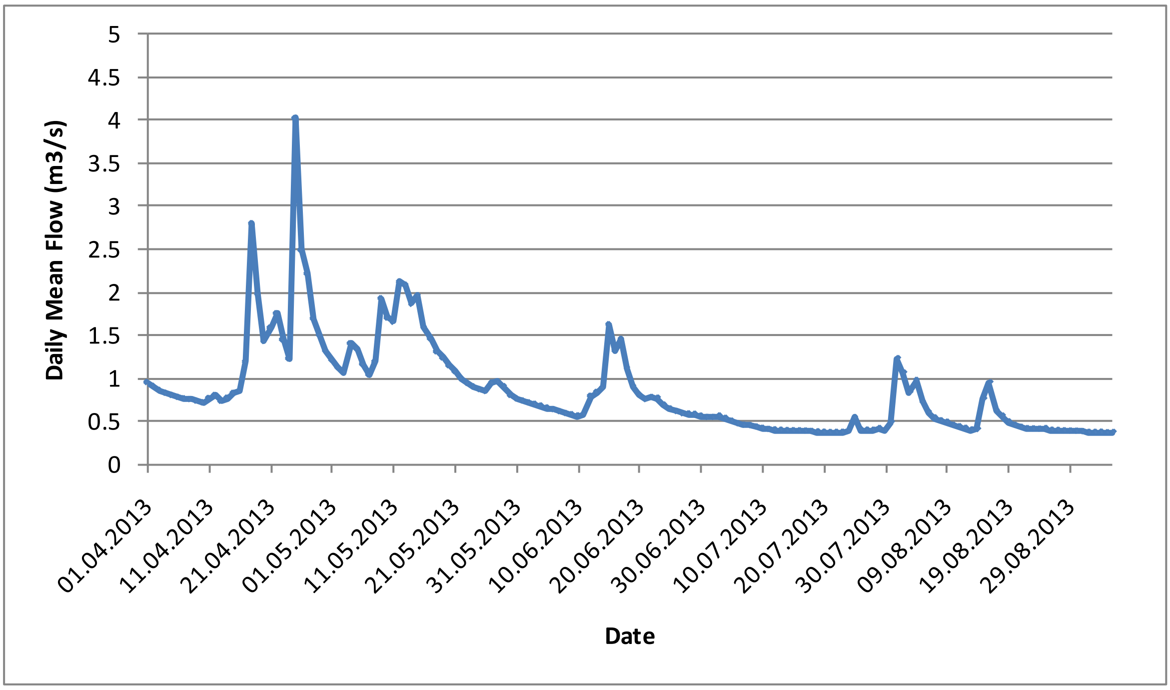

Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 Apr to 5 Sep 2013

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 25 presents a summary of the results from the flow measured in August and September 2013 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 25 Surface Water Flow Value Measured in August/ September 2013

Site Name	Flow l/s	Date
SW10_GORT Discharge	0.217	27/08/2013
SW12_GORT Discharge	2.05	27/08/2013
SW19_GORT	0.014	27/08/2013
SW1-SM	4.23	29/08/2013
SW2-SM South Discharge	1.50	29/08/2013
SW2-SM North Discharge	No Discharge	29/08/2013
SW3-SM	6.63	29/08/2013
SW4-SM-GA	8.45	29/08/2013
SW1-GAR	Dry	28/08/2013
SW2-GAR	Dry	28/08/2013
SW3-GAR	2.87	28/08/2013
SW4-GAR	0.015	28/08/2013
SW5-GAR	No Overflow Discharge	28/08/2013
SW7-GAR	0.003	28/08/2013
SW8-GAR	Low flow immeasurable	28/08/2013
SW9-GAR	Low flow immeasurable	28/08/2013
SW10-GAR	2.12	28/08/2013
SW12-GAR	0.008	28/08/2013
SW1-SHAL	3.28	02/09/2013
SW4-SHAL	0.004	02/09/2013
SW5-SHAL	Dry	02/09/2013
SW6-SHAL	3.40	02/09/2013
SW7-SHAL	Dry	02/09/2013
SW9-SHAL	4.17	02/09/2013
SW10-SHAL	Low flow immeasurable	02/09/2013
SW12-SHAL	0.051	02/09/2013

5.2 Loading Analysis

5.2.1 Loading Analysis Methodology

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

5.2.2 Loading Results and Discussion

The calculated mass loads in Table 26 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 to 433 g/day with an average of 81.3 g/day overall.

Table 26 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day

Site Description	Date Sampled	Flow l/s	pH	Sulphate		Cadmium		Lead		Manganese		Nickel		Zinc	
			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
SW1-SM	29/08/2013	4.23	6.59	5300	1940	0.05	0.02	0.01	0.004	7.23	2.64	0.075	0.03	0.205	0.07
SW2-SM South	29/08/2013	1.5	5.72	26000	3370	4.57	0.59	0.838	0.11	0.534	0.07	5.36	0.69	1840	238
SW3-SM	29/08/2013	6.63	7.08	7100	4070	0.225	0.13	0.837	0.48	1.04	0.6	0.075	0.04	80	45.9
SW4-SM-GA	29/08/2013	8.45	8.05	15100	11000	0.521	0.38	1.53	1.12	9.04	6.6	0.497	0.36	375	274
SW10-GORT-DISC	27/08/2013	0.22	7.56	969000	18100	0.05	0.001	0.05	0.001	191	3.58	8.51	0.16	175	3.28
SW12-GORT-DISC	27/08/2013	2.05	7.13	1100000	195000	0.05	0.01	0.04	0.01	1070	190	6.22	1.1	99.9	17.7
SW19-GORT	27/08/2013	0.01	7.74	1630000	2010	2.49	0.003	0.347	0.0004	1.93	0.002	16	0.02	2200	2.71
SW3-GAR	28/08/2013	2.87	8.35	340000	84200	5.67	1.4	1.09	0.27	330	81.7	7.9	1.96	853	211
SW4-GAR	28/08/2013	0.01	6.74	88800	114	1.62	0.002	0.873	0.001	2080	2.67	13.9	0.02	571	0.73
SW7-GAR	28/08/2013	0.003	7.99	141000	33.2	0.05	0.00001	0.131	0.00003	202	0.05	1.19	0.0003	21	0.005
SW10-GAR	28/08/2013	2.12	8.13	384000	70500	10.6	1.95	1.04	0.19	321	58.9	11.8	2.17	2360	433
SW12-GAR	28/08/2013	0.01	7.52	746000	496	17.9	0.01	3.57	0.002	262	0.17	33.4	0.02	7900	5.25
SW1-SHAL	02/09/2013	3.28	8.2	16700	4730	0.737	0.21	75.3	21.3	53.2	15.1	4.92	1.39	122	34.6
SW4-SHAL	02/09/2013	0.004	7.29	1000	0.35	0.05	0.00002	4.27	0.001	6770	2.34	10.9	0.004	42.6	0.01
SW6-SHAL	02/09/2013	3.4	4.53	14100	4140	0.809	0.24	183	53.7	61	17.9	7.89	2.32	154	45.2
SW9-SHAL	02/09/2013	4.17	5.65	14100	5080	0.857	0.31	127	45.8	54.2	19.5	7.19	2.59	194	69.9
SW12-SHAL	02/09/2013	0.05	6.83	2400	10.6	0.05	0.0002	17.2	0.08	30.1	0.13	0.075	0.0003	53.2	0.23

Notes:
Sites with no flow on the day of sampling are omitted from the table.

The largest mass load of zinc was the discharge from the tailings lagoon SW10-GAR (433 g/day). Further downstream at SW3-GAR which is located in a stream containing the SW10-GAR discharge and the western part of the Mogul yard, the loading appears to decrease to 211 g/day of zinc. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River. It was noted that the calculated loads from the smaller settlement pond SW7-Gar were negligible.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 0.07 g/day, which increases to 45.9 g/day downstream of the mine workings (SW3-SM). The southern adit (SW2-SM) also contributes 238 g/day of dissolved zinc to the stream. This balances well with the calculated mass load at SW4-SM-GA of 274 g/day (46 + 238 = 284 g/day). The Silvermines stream contributes this load to the Kilmastulla River.

The highest load of dissolved lead was from the Field Shaft (SW6-Shal) with a calculated value of 53.7 g/day. The dissolved lead decreases slightly further downstream to 45.8 g/day at SW9-Shal which could be an indication that it infiltrates into the ground. At SW1-Shal (a water course that runs parallel to the road and discharges to the Yellow Bridge River), a load of 21.3 g/day was observed.

Of the two wetland discharges at Gortmore TMF, SW12-Gort-Discharge had the highest loading of dissolved zinc at 17.1 g/day whereas SW10-Gort-Disc had 3.28 g/day of zinc. Discharges from the Garryard area (SW3-Gar – 211 g/day) and Shallee area (SW1-Shal – 34.6 g/day) therefore provided the greatest mass loads of dissolved zinc to the Kilmastulla River.

5.3 Trend Analysis

No suitable historic data were found to conduct a meaningful trend analysis. Concentration time trend evaluations will be carried out as additional data are collected throughout the monitoring programme using an appropriate statistical package. This will be carried out for key parameters of concern at select locations such as the discharges from the wetland and tailings lagoon and downstream on the Kilmastulla River.

Table 27 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling event in April 2013 (R1) and the low flow sampling event in August 2013 (R2). As can be seen from Table 27 the concentrations of dissolved cadmium, manganese and zinc are generally at similar concentrations in both April and August.

However in some cases the concentrations were significantly lower in August during low flow. Examples included dissolved cadmium and zinc in the SW10-Gar, SW10-Gort-Disc and SW12-Gort-Disc discharges. Values of dissolved cadmium in these discharges ranged from 0.05-10.6 µg/l in low flow to 0.102-18.8 µg/l in high flow. Values of dissolved zinc in these discharges ranged from 99.9-2360 µg/l in low flow to 332-5390 µg/l in high flow. Often, discharge concentrations are higher during high flow due to flushing of metals from the mine workings. This difference in concentrations and loadings of dissolved zinc was reflected in the Kilmastulla River at SW14-Gort where the ecological assessment criterion of 100 µg/l was exceeded in April with a reported value of 108 µg/l and it was significantly lower than the assessment criterion in August with a value of 42.1 µg/l.

Table 27 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August due to the low flow conditions. Concentrations of dissolved lead (Table 27) were also consistently lower in August during low flow. The only instances where concentrations were higher in the low flow season was for dissolved manganese in the SW10-Gar, SW10-Gort-Disc and SW12-Gort-Disc discharges. This also resulted in a higher loading of dissolved manganese in the low flow sampling event from the SW10-Gar and the SW12-Gort-Disc discharges.

Table 27 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in the Main Discharges and on the most downstream location on the Kilmastulla River in 2013

Site Description	Date Sampled	Flow	Cadmium		Lead		Manganese		Zinc	
		l/s	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day
SW2-SM South	R1 04/04/2013	2.35	4.72	0.958	1.03	0.209	1.55	0.315	1970	400
	R2 29/08/2013	1.5	4.57	0.59	0.838	0.11	0.534	0.07	1840	238
SW6-SHAL	R1 02/04/2013	5.51	0.905	0.431	236	112	60.7	28.9	179	85.2
	R2 02/09/2013	3.4	0.809	0.24	183	53.7	61	17.9	154	45.2
SW10-GAR	R1 03/04/2013	5.46	18.8	8.87	1.56	0.736	74.1	35	5390	2540
	R2 28/08/2013	2.12	10.6	1.95	1.04	0.19	321	58.9	2360	433
SW10-Gort-Disc	R1 27/03/2013	5.13	0.142	0.063	0.209	0.093	64.4	28.5	656	291
	R2 27/08/2013	0.22	0.05	0.001	0.05	0.001	191	3.58	175	3.28
SW12-Gort-Disc	R1 26/03/2013	7.14	0.102	0.063	0.069	0.043	165	102	332	205
	R2 27/08/2013	2.05	0.05	0.01	0.04	0.01	1070	190	99.9	17.7
SW14-Gort	R1 26/03/2013	-	0.271	-	1.71	-	68.6	-	108	-
	R2 27/08/2013	-	0.104	-	1.17	-	70.4	-	42.1	-

Notes
- is not measured / calculated

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 28 displays the measured depth to groundwater and calculated groundwater elevations. All groundwater level data are contained in Appendix C of the Data Report.

The groundwater elevations outside the TMF decreased from 48.4 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.0 mOD at the downgradient location TMF2. These elevations are consistent with the groundwater flow in the bedrock being south-westerly towards the Kilmastulla River. The groundwater gradient was calculated to be 0.002, however the level of the river is unknown.

Within the tailings area, measured water levels were in the range of 2.8 to 4.6m below the top of the tailings pond. The exceptions were in BH3A-GORT-06 and BH6A-GORT-06 where deeper water levels were recorded. The groundwater elevations within the TMF varied between 48.3 to 53.2 m OD.

Table 28 Measures Groundwater Levels August 2013

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	26/08/2013	10:30	0.62	1.21	48.4
TMF2		26/08/2013	12:50	2.05	2.51	46.0
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	26/08/2013	15:45	3.59	4.24	52.2
BH2A-GORT-06		26/08/2013	15:55	3.45	3.98	52.3
BH3A-GORT-06		26/08/2013	15:00	8.27	8.60	48.3
BH4A-GORT-06		26/08/2013	15:10	4.66	5.18	51.5
BH5A-GORT-06		26/08/2013	15:35	4.01	4.44	52.2
BH6A-GORT-06		26/08/2013	15:25	5.51	6.20	50.6
BH6B-GORT-06		26/08/2013	15:25	2.79	3.51	53.2

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 August 2013 and water levels were measured in seven additional monitoring wells. Twenty-eight surface water locations were sampled and analysed in August/September 2013 with flows measured at 17 of the locations. Twenty vegetation and soil samples were collected and analysed in August 2013. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QC/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 groundwater, surface water, vegetation and soil 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:

- Dissolved metal concentrations in the two groundwater monitoring wells that were sampled only had exceedances of the assessment criteria for dissolved barium and manganese, with higher concentrations in the downgradient monitoring well TMF2 (567 and 916 µg/l, respectively). Dissolved barium exceeded the ecological health criteria and dissolved manganese exceeded the human health criteria in both monitoring wells. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- SW8-GAR (drainage from the western part of the Mogul Yard) had the highest concentrations of zinc (20,800 µg/l) and nickel (80.6 µg/l). It was noted that the flow at SW8-Gar was extremely low and that the results might be representative of groundwater seeps rather than yard runoff. The highest dissolved aluminium was at SW12-Shal (stoned lined drainage channel at Shallee) with a value of 103 µg/l and the highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 183 µg/l.

- SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc (<0.41 and 4.86 µg/l, respectively) than the rest of the rivers and streams sampled in the Silvermines area.

- The concentration of zinc increases on the Kilmastulla River to 42.1 µg/l at SW14-Gort (most downstream location) but remained below the ecological assessment criteria of 100 µg/l. The stream with the highest concentrations of dissolved zinc (853 µg/l) was the stream containing both tailings lagoon discharges and downstream of the Mogul Yard (SW3-Gar).

- The dissolved metal with the highest mass loading was zinc at the discharge from the tailings lagoon SW10-GAR with 433 g/day. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River. The highest mass load of dissolved lead was from the

Field Shaft (SW6-Shal) with 53.7 g/day; however, the load decreased further downstream which could be an indication that it infiltrates into the ground.

- No measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium or lead exceeded the Maximum Content standards or the no effect and low effect levels.

- One reported value for arsenic in soil sample SM31-S was at 11 mg/kg, which was slightly above the ORNL benchmark concentration of 10 mg/kg. The reported values for zinc concentrations were above the conservative ORNL benchmark concentration of 50 mg/kg for all samples (with the exception of SM05-S and SM06-S) but all reported values were significantly lower than the maximum values for concentrations of zinc of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations.

7.2 Recommendations for the Monitoring Programme

We have no recommendations to make at this time.

Section 8
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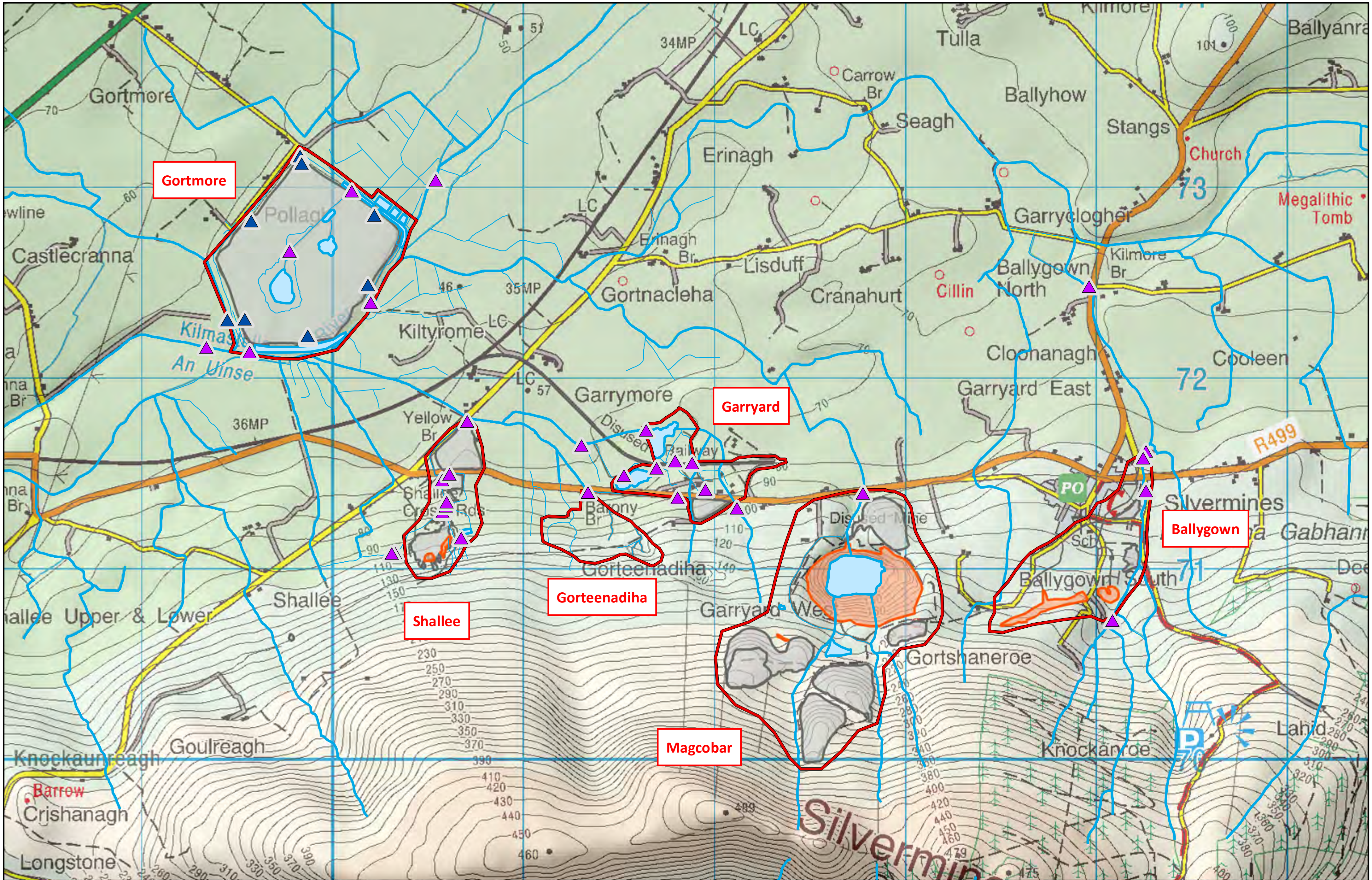
Appendix A

Figures



Map 1 - Silvermines - Overview

Drawn by: OC Date: 28/11/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\05_MonRptR2\MXD\01_SilverMon1.mxd

CDM Smith

Source: © Ordnance Survey Ireland.

Legend

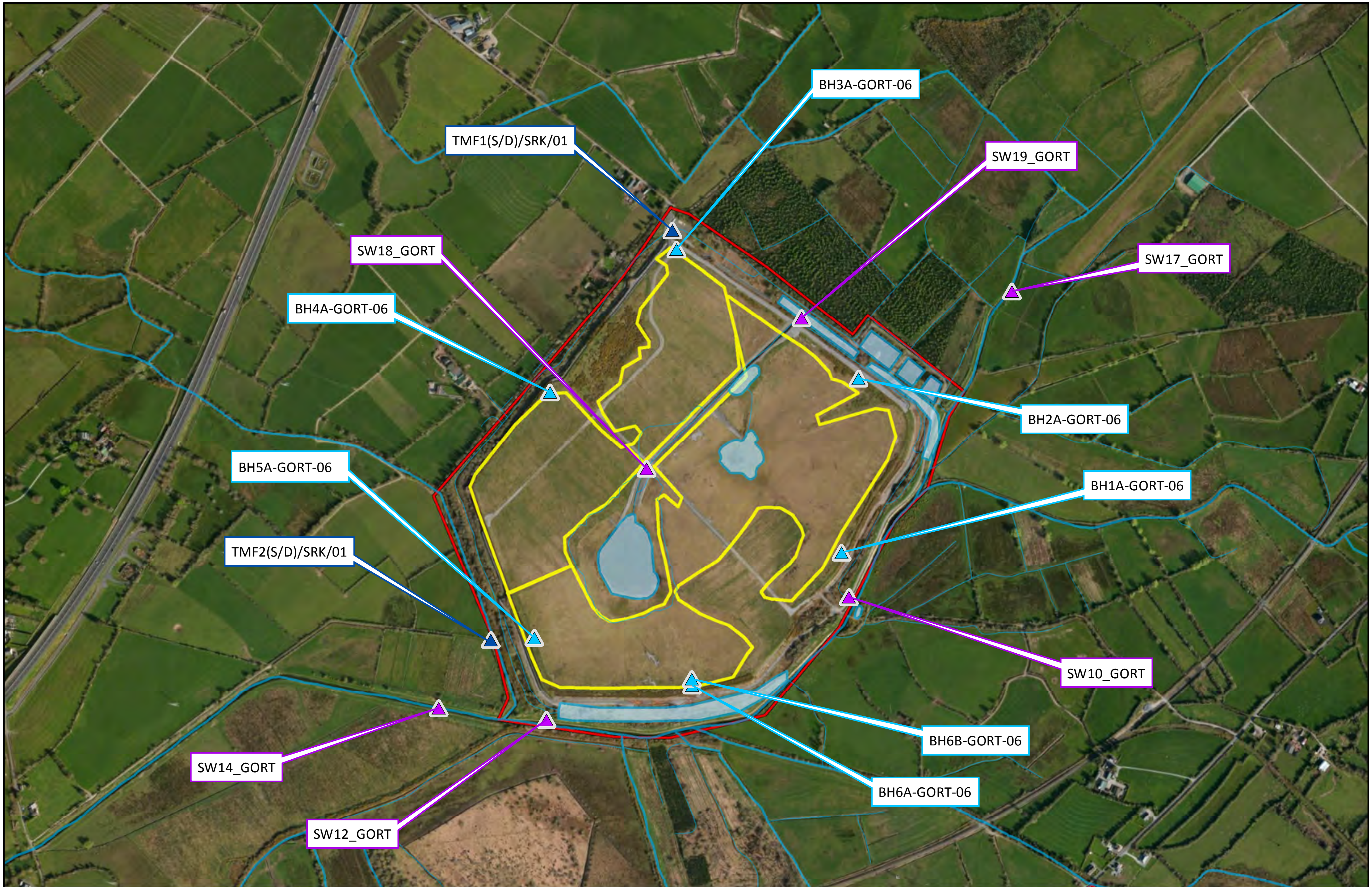
Sampling Locations
- Surface water
- Groundwater

- Rivers
- Streams
- Pond / Wetland / Pit Lake

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

Scale is 1:25,000

0 125 250 500 750 1,000 m



Map 2 - Silvermines - Gortmore TMF

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CDM Smith Source: © ESRI Base Map

Legend

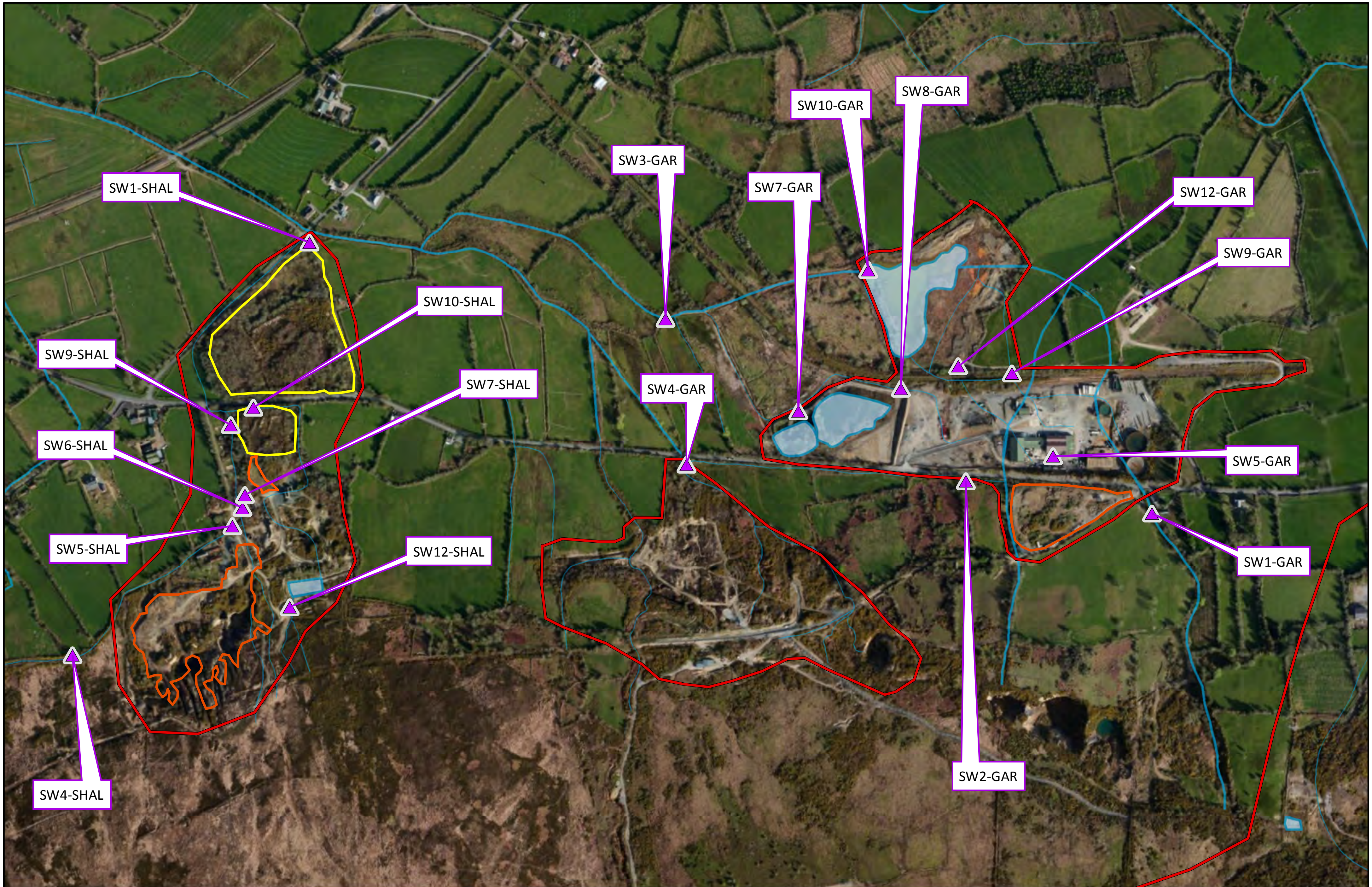
Sampling Locations

- Surface water
- Groundwater
- Groundwater (Levels only)

- Rivers
- Streams
- Pond / Wetland

Mines

- Mining Area



Map 3 - Silvermines - Shallee South and Garryard

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CDM Smith Source: © ESRI Base Map

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

Mining Areas

Tailings / Tailings Pond

Spoil Heap / Stockpile Dump / Waste Drum Dump

Scale is 1:8,000

0 125 250 m

Map 4 - Silvermines - Magcobar and Ballygown

Drawn by: OC Date: 28/11/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\05_MonRptR2\MXD\04_SilverMonMa_BG.mxd

CDM Smith Source: © ESRI Base Map

Legend

Sampling Locations
- Surface water

- Rivers
- Streams
- Pit Lake

Mines
- Mining Areas
- Spoil Heap / Stockpile Dump

Scale is 1:10,000

0 125 250 500 m

Map 5 - Silvermines - Gortmore - Soil and Vegetation

Drawn by: OC Date: 28/11/2013

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\05_MonRptR2\MXD\05_SilverMonVeg.mxd

CDM Smith

Source: © ESRI Base Map

Legend

Sampling Locations

- Areas A and B (soil and 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 1:6,000

0 50 100 200 m

Appendix B

Analytical Data Tables and Assessment Criteria

Table B-1 Comparison of Total Versus Dissolved Metals
Concentrations in groundwater adits and surface water

SDG	Sample Description	Date Sampled	Suspended solids, Total	Barium (tot.unfilt)	Barium (diss.filt)	%RPD	Cadmium (tot.unfilt)	Cadmium (diss.filt)	%RPD	Lead (tot.unfilt)	Lead (diss.filt)	%RPD	Nickel (tot.unfilt)	Nickel (diss.filt)	%RPD	Zinc (tot.unfilt)	Zinc (diss.filt)	%RPD
		Units	mg/l	µg/l	µg/l		µg/l	µg/l		µg/l	µg/l		µg/l	µg/l		µg/l	µg/l	
130829-50	TMF1	26/08/2013	-	202	144	-33.5	*0.25*	*0.05*	-	2.21	0.268	-156.7	3.92	2.01	-64.4	5.05	*0.205*	-184.4
130829-50	TMF2	26/08/2013	-	667	567	-16.2	*0.25*	*0.05*	-	27.2	1.71	-176.3	3.08	0.648	-130.5	10.6	1.9	-139.2
130831-34	SW10-GORT-DISC	27/08/2013	<4	119	10.9	-166.4	*0.25*	*0.05*	-	*0.25*	0.05	-133.3	4.54	8.51	60.8	115	175	41.4
130831-34	SW10-GORT-DS	27/08/2013	<2	194	167	-15.0	*0.25*	*0.05*	-	2.64	0.454	-141.3	1.5	0.9	-50.0	24.1	24.8	2.9
130831-34	SW10-GORT-US	27/08/2013	<2	181	168	-7.4	*0.25*	*0.05*	-	2.52	0.487	-135.2	1.53	1.04	-38.1	23.7	21.2	-11.1
130831-34	SW12-GORT-DISC	27/08/2013	<2	13.3	91.6	149.3	*0.25*	*0.05*	-	*0.25*	0.04	-144.8	5.73	6.22	8.2	200	99.9	-66.8
130831-38	SW12-GORT-DS	27/08/2013	2	224	175	-24.6	*0.25*	0.114	-74.7	6.7	1.29	-135.4	*0.25*	1.46	141.5	66.2	55.6	-17.4
130831-38	SW14-GORT	27/08/2013	3.5	252	172	-37.7	*0.25*	0.104	-82.5	6.77	1.17	-141.1	*0.25*	1.25	133.3	54.8	42.1	-26.2
130831-38	SW17-GORT	27/08/2013	<2	321	288	-10.8	*0.25*	*0.05*	-	*0.25*	*0.01*	-	*0.25*	*0.075*	-	*1.5*	4.86	105.7
130831-38	SW18-GORT	27/08/2013	5	18.1	10.2	-55.8	1.4	1.03	-30.5	25.3	1.43	-178.6	14.8	13.7	-7.7	785	654	-18.2
130831-38	SW19-GORT	27/08/2013	5	26.2	16.6	-44.9	3.3	2.49	-28.0	4.52	0.347	-171.5	17.8	16	-10.7	2430	2200	-9.9
130831-44	SW10-GAR	28/08/2013	<2	26.5	19.3	-31.4	13.7	10.6	-25.5	6.54	1.04	-145.1	13	11.8	-9.7	2570	2360	-8.5
130831-44	SW12-GAR	28/08/2013	<2	15	13.7	-9.1	19.3	17.9	-7.5	4.45	3.57	-21.9	32.7	33.4	2.1	7510	7900	5.1
130831-48	SW3-GAR	28/08/2013	<2	56.8	42.6	-28.6	8.1	5.67	-35.3	5.48	1.09	-133.6	9.28	7.9	-16.1	1150	853	-29.7
130831-48	SW4-GAR	28/08/2013	6	267	243	-9.4	2.3	1.62	-34.7	22	0.873	-184.7	16.4	10.9	-40.3	619	472	-26.9
130831-48	SW7-GAR	28/08/2013	<2	117	111	-5.3	*0.25*	*0.05*	-	*0.25*	0.131	-62.5	2.45	1.19	-69.2	14.8	21	34.6
130831-44	SW8-GAR	28/08/2013	19.5	73.7	21.6	-109.3	18	14.1	-24.3	93.7	1.41	-194.1	75.6	80.6	6.4	21100	20800	-1.4
130831-44	SW9-GAR	28/08/2013	23	47.5	11.3	-123.1	21.2	20.1	-5.3	139	12.5	-167.0	46.5	48.2	3.6	12600	12200	-3.2
130830-54	SW1-SM	29/08/2013	<4	57.3	47.1	-19.5	*0.25*	*0.05*	-	*0.25*	*0.01*	-	0.509	*0.075*	-148.6	*1.5*	*0.205*	-
130830-54	SW2-SM South	29/08/2013	<2	182	142	-24.7	5.18	4.57	-12.5	1.32	0.795	-49.6	1.31	5.36	121.4	1820	1840	1.1
130830-54	SW3-SM	29/08/2013	<4	82.2	67.9	-19.1	*0.25*	0.225	-10.5	2.85	0.837	-109.2	1.01	*0.075*	-172.4	89.1	80	-10.8
130830-54	SW4-SM-GA	29/08/2013	<4	158	136	-15.0	0.803	0.521	-42.6	4.85	1.53	-104.1	1.89	0.497	-116.7	383	375	-2.1
130830-54	SW6-MAG	29/08/2013	<2	74.7	53.1	-33.8	1.46	1.15	-23.8	3.27	0.066	-192.1	7.69	4.45	-53.4	508	428	-17.1
130904-77	SW1-SHAL	02/09/2013	<2	268	212	-23.3	0.699	0.737	5.3	122	75.3	-47.3	*0.25*	4.92	180.7	141	122	-14.4
130904-77	SW10-SHAL	02/09/2013	<2	289	225	-24.9	0.987	0.719	-31.4	131	78.8	-49.8	3.19	5.18	47.6	237	182	-26.3
130904-77	SW12-SHAL	02/09/2013	<2	175	132	-28.0	*0.25*	*0.05*	-	30.3	17.1	-55.7	*0.25*	*0.075*	-	9.09	53.2	141.6
130904-77	SW4-SHAL	02/09/2013	10.5	960	840	-13.3	*0.25*	*0.05*	-	38.9	4.27	-160.4	0.808	10.9	172.4	88	42.6	-69.5
130904-77	SW6-SHAL	02/09/2013	<2	289	224	-25.3	1.35	0.809	-50.1	268	183	-37.7	10.9	7.89	-32.0	192	154	-22.0
130904-77	SW9-SHAL	02/09/2013	<2	293	209	-33.5	1.16	0.857	-30.0	213	127	-50.6	4.19	7.19	52.7	234	194	-18.7

xx RPD greater than 50% i.e. dissolved metal result is greater that total metal

xx RPD less than 50% i.e. total metal result is greater that dissolved

Values less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD

 - Not analysed

RPD - Relative percent difference

Table B-2 Comparison of Groundwater and Surface Water Results to Assessment Criteria

Sample Description	Area	Type	Date Sampled Units	Acidity as HCL mg/l	Alkalinity, Total as CaCO3 mg/l	Hardness as CaCO3 mg/l	Ammoniacal Nitrogen as N mg/l	Chloride mg/l	COD, unfiltered mg/l	Specific Conductance @ deg.C (field) mS/cm	Cyanide, Free mg/l	Dissolved solids, Total mg/l	Fluoride mg/l	Nitrate as NO3 mg/l	Nitrite as NO2 mg/l	Oxygen, dissolved (field) mg/l	pH (field) pH Units	Phosphate (ortho) as P mg/l	Sulphate mg/l	Sodium (diss.filt) mg/l	Suspended solids, Total mg/l
Ecological Criteria				-	-	-	**0.14**	-	-	-	**0.01**	-	**0.5**	-	-	**80 to 120***	**4.5 to 9**	**0.075**	-	-	-
Human Health Criteria				-	-	-	**0.3**	**250**	-	**2.5**	**0.05**	-	**1.5**	**50**	**0.5**	-	**6.5 to 9.5**	-	**250**	**200**	-
TMF1	GW	GM	26/08/2013	-	210	256.2	*0.1*	10.6	-	0.462	*0.025*	299	*0.25*	0.827	*0.025*	11.2	7.17	*0.01*	32.1	8.58	-
TMF2	GW	GM	26/08/2013	-	245	298.9	*0.1*	18.2	-	0.5	*0.025*	299	*0.25*	*0.15*	*0.025*	1.9	6.61	*0.01*	2.2	9.95	-
SW1-SM	River/Stream	BG	29/08/2013	*2*	80	97.6	*0.1*	10	*3.5*	0.192	*0.025*	219	*0.25*	1.88	*0.025*	92.6	6.59	0.0241	5.3	6.21	*2*
SW2-SM South	Discharge	BG	29/08/2013	*2*	235	286.7	*0.1*	13	*3.5*	0.509	*0.025*	577	*0.25*	6.11	*0.025*	73.9	5.72	*0.01*	26	7.03	*1*
SW3-SM	River/Stream	BG	29/08/2013	*2*	95	115.9	*0.1*	10.3	8.62	0.224	*0.025*	250	*0.25*	2.71	*0.025*	95.7	7.08	0.0215	7.1	6.4	*2*
SW4-SM-GA	River/Stream	BG	29/08/2013	*2*	165	201.3	0.274	13.5	8.15	0.376	*0.025*	360	*0.25*	7.27	0.197	95.1	8.05	0.145	15.1	9.13	*2*
SW6-MAG	River/Stream	MG	29/08/2013	*2*	75	91.5	*0.1*	8.4	*3.5*	0.632	*0.025*	573	*0.25*	1.24	*0.025*	97	7.9	*0.01*	248	4.72	*1*
SW10-GORT-DISC	Discharge	GM	27/08/2013	*2*	310	378.2	*0.1*	19.1	20.3	2.108	*0.025*	1900	*0.25*	*0.15*	*0.025*	93.4	7.56	*0.01*	969	7.63	*2*
SW10-GORT-DS	River/Stream	GM	27/08/2013	*2*	260	317.2	*0.1*	16.1	11.3	0.606	*0.025*	394	*0.25*	7.6	*0.025*	112.4	7.77	0.0258	52.8	9.4	*1*
SW10-GORT-US	River/Stream	GM	27/08/2013	*2*	255	311.1	*0.1*	16	10.7	0.599	*0.025*	399	*0.25*	7.48	*0.025*	105.4	7.36	0.0284	48	9.66	*1*
SW12-GORT-DISC	Discharge	GM	27/08/2013	*2*	210	256.2	*0.1*	13.3	16.3	2.102	*0.025*	1530	*0.25*	*0.15*	*0.025*	64.5	7.13	*0.01*	1100	13.8	*1*
SW12-GORT-DS	River/Stream	GM	27/08/2013	*2*	250	305	*0.1*	16.5	10.8	0.666	*0.025*	446	*0.25*	6.84	*0.025*	113	8.07	0.0248	92.5	9.33	2
SW14-GORT	River/Stream	GM	27/08/2013	*2*	235	286.7	*0.1*	16	12.2	0.508	*0.025*	396	*0.25*	6.72	*0.025*	117.6	8.14	0.0241	67.5	10	3.5
SW17-GORT	River/Stream	GM	27/08/2013	*2*	210	256.2	*0.1*	17.8	14.2	0.464	*0.025*	272	*0.25*	7.56	*0.025*	88.3	7.74	0.0346	12.6	11.7	*1*
SW18-GORT	Drainage	GM	27/08/2013	*2*	70	85.4	*0.1*	31.2	14.9	2.719	*0.025*	2900	*0.25*	*0.15*	*0.025*	79.6	7.38	*0.01*	1700	13.8	5
SW19-GORT	Drainage	GM	27/08/2013	*2*	75	91.5	*0.1*	30.6	16.5	2.684	*0.025*	2860	*0.25*	0.589	*0.025*	78.2	7.74	*0.01*	1630	13.4	5
SW10-GAR	Discharge	GA	28/08/2013	*2*	205	250.1	*0.1*	17.2	11.5	1.051	*0.025*	851	*0.25*	*0.15*	*0.025*	93	8.13	*0.01*	384	9.17	*1*
SW12-GAR	Drainage	GA	28/08/2013	*2*	215	262.3	*0.1*	12.5	9.86	1.710	*0.025*	1530	1.47	0.313	*0.025*	80.5	7.52	*0.01*	746	9.61	*1*
SW3-GAR	River/Stream	GA	28/08/2013	*2*	210	256.2	*0.1*	14.4	11.7	1.001	*0.025*	815	*0.25*	*0.15*	*0.025*	105	8.35	*0.01*	340	8.49	*1*
SW4-GAR	River/Stream	GA	28/08/2013	5.48	115	140.3	*0.1*	11.9	14	0.449	*0.025*	300	*0.25*	0.438	*0.025*	42.7	6.74	*0.01*	88.8	7.62	6
SW5-GAR	Discharge	GA	28/08/2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW7-GAR	Discharge	GA	28/08/2013	*2*	200	244	*0.1*	11.6	20.6	0.649	*0.025*	469	*0.25*	*0.15*	*0.025*	83	7.99	*0.01*	141	8.25	*1*
SW8-GAR	Drainage	GA	28/08/2013	11	265	323.3	*0.1*	17.8	15	2.145	*0.025*	2100	1.93	1.35	*0.025*	35.1	6.61	*0.01*	1110	10.6	19.5
SW9-GAR	Drainage	GA	28/08/2013	5.48	185	225.7	*0.1*	12.5	19	2.061	*0.025*	2010	1.78	1.18	*0.025*	20.1	7.13	*0.01*	1110	9.52	23
SW6-SHAL	Discharge	ShS	02/09/2013	*2*	50	61	*0.1*	10.1	7.57	0.148	*0.025*	97.3	*0.25*	1.31	*0.025*	74.3	4.53	*0.01*	14.1	6.86	*1*
SW10-SHAL	Drainage	ShS	02/09/2013	*2*	50	61	0.234	10.1	*3.5*	0.159	*0.025*	107	*0.25*	0.812	*0.025*	55.2	6.71	*0.01*	15.6	5.77	*1*
SW12-SHAL	Drainage	ShS	02/09/2013	*2*	3	3.66	*0.1*	8.4	14.8	0.052	*0.025*	31.4	*0.25*	0.683	*0.025*	96.1	6.83	*0.01*	2.4	4.52	*1*
SW1-SHAL	River/Stream	ShS	02/09/2013	*2*	50	61	*0.1*	10.1	*3.5*	0.160	*0.025*	111	*0.25*	0.907	*0.025*	110	8.2	*0.01*	16.7	5.5	*1*
SW4-SHAL	River/Stream	ShS	02/09/2013	*2*	115	140.3	0.342	12.8	21.2	0.383	*0.025*	249	*0.25*	*0.15*	*0.025*	10.4	7.29	*0.01*	*1*	8.03	10.5
SW9-SHAL	River/Stream	ShS	02/09/2013	*2*	50	61	*0.1*	10.1	*3.5*	0.158	*0.025*	140	*0.25*	1.33	*0.025*	100.00	5.65	*0.01*	14.1	5.33	*1*

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

Table B-2 Comparison of Groundwater and Surface Water Results to Assessment Criteria

Sample Description	Area	Type	Date Sampled / Units	Aluminium (diss.filt)	Antimony (diss.filt)	Arsenic (diss.filt)	Barium (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Iron (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Mercury (diss.filt)	Molybdenum (diss.filt)	Nickel (diss.filt)	Selenium (diss.filt)	Silver (diss.filt)	Thallium (diss.filt)	Tin (diss.filt)	Uranium (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Ecological Criteria				1,900	-	25	4	0.9	3.4	5.1	30	-	7.2	1100	0.07	-	20	-	-	-	-	2.6	-	100
Human Health Criteria				200	5	10	-	5	50	-	2000	200	10	50	1	-	20	10	-	-	-	-	-	-
TMF1	GW	GM	26/08/2013	1.45	2.05	2.47	144	0.05	0.703	0.535	0.425	9.5	0.268	51.6	0.005	1.25	2.01	0.195	0.75	0.48	0.18	0.75	0.12	0.205
TMF2	GW	GM	26/08/2013	1.45	1.79	5.39	567	0.05	1.39	0.773	0.425	198	1.71	916	0.005	1.53	0.648	0.756	0.75	0.48	0.18	0.75	0.12	3.12
SW1-SM	River/Stream	BG	29/08/2013	1.45	0.08	0.26	47.1	0.05	0.419	0.03	0.425	9.5	0.01	7.23	0.005	0.12	0.075	0.195	0.75	0.48	0.18	0.75	0.12	0.205
SW2-SM South	Discharge	BG	29/08/2013	1.45	4.42	0.668	142	4.57	2.37	0.065	0.425	9.5	0.838	0.534	0.005	0.12	5.36	0.776	0.75	1.85	2.26	0.75	0.721	1840
SW3-SM	River/Stream	BG	29/08/2013	1.45	0.08	0.321	67.9	0.225	0.487	0.03	0.425	9.5	0.837	1.04	0.005	0.12	0.075	0.195	0.75	0.48	0.18	0.75	0.12	80
SW4-SM-GA	River/Stream	BG	29/08/2013	9.71	2.27	0.743	136	0.521	1.9	0.071	0.425	9.5	1.53	9.04	0.005	0.873	0.497	0.398	0.75	0.48	1.88	0.75	0.635	375
SW6-MAG	River/Stream	MG	29/08/2013	1.45	0.281	0.286	53.1	1.15	0.335	0.076	1.66	9.5	0.066	16.3	0.005	0.918	4.45	0.195	0.75	0.48	0.18	0.75	0.12	428
SW10-GORT-DISC	Discharge	GM	27/08/2013	1.45	0.218	0.319	10.9	0.05	2.4	0.964	0.979	9.5	0.05	191	0.005	0.504	8.51	0.506	0.75	1.18	0.18	0.75	0.728	175
SW10-GORT-DS	River/Stream	GM	27/08/2013	1.45	0.08	0.756	167	0.05	2.64	0.29	0.425	34.9	0.454	47.6	0.005	0.12	0.9	0.195	0.75	0.48	0.18	0.75	0.785	24.8
SW10-GORT-US	River/Stream	GM	27/08/2013	1.45	0.08	0.692	168	0.05	2.38	0.268	0.425	44.2	0.487	48	0.005	0.12	1.04	0.195	0.75	0.48	0.18	0.75	0.751	21.2
SW12-GORT-DISC	Discharge	GM	27/08/2013	1.45	0.307	0.277	91.6	0.05	2.99	1.05	0.425	191	0.04	1070	0.005	0.12	6.22	0.195	0.75	0.979	0.431	0.75	0.821	99.9
SW12-GORT-DS	River/Stream	GM	27/08/2013	1.45	0.825	0.8	175	0.114	2.26	0.352	0.425	41.2	1.29	82.4	0.005	0.542	1.46	0.195	0.75	0.48	0.854	0.75	0.704	55.6
SW14-GORT	River/Stream	GM	27/08/2013	1.45	0.575	0.736	172	0.104	2.01	0.368	0.425	47.3	1.17	70.4	0.005	0.293	1.25	0.195	0.75	0.48	0.631	0.75	0.649	42.1
SW17-GORT	River/Stream	GM	27/08/2013	25.2	0.08	1.05	288	0.05	0.593	0.124	0.425	70.1	0.01	49.2	0.005	0.272	0.075	0.195	0.75	0.48	0.18	0.75	0.317	4.86
SW18-GORT	Drainage	GM	27/08/2013	1.45	1.6	0.391	10.2	1.03	0.704	1.27	3.58	33.2	1.43	63.3	0.005	0.293	13.7	0.195	0.75	26.5	0.526	0.75	0.292	654
SW19-GORT	Drainage	GM	27/08/2013	1.45	1.05	0.197	16.6	2.49	0.592	1.32	3.21	9.5	0.347	1.93	0.005	0.363	16	0.195	0.75	44.8	0.478	0.75	0.12	2200
SW10-GAR	Discharge	GA	28/08/2013	1.45	1.29	0.493	19.3	10.6	1.77	1.82	1.92	9.5	1.04	321	0.005	0.708	11.8	0.195	0.75	3.78	1.06	0.75	0.498	2360
SW12-GAR	Drainage	GA	28/08/2013	1.45	0.636	0.446	13.7	17.9	0.382	2.33	3.82	105	3.57	262	0.005	0.513	33.4	0.688	0.75	2.6	0.18	0.75	0.12	7900
SW3-GAR	River/Stream	GA	28/08/2013	1.45	0.648	0.684	42.6	5.67	0.922	1.37	1.63	39.5	1.09	330	0.005	0.511	7.9	0.195	0.75	2.62	0.51	0.75	0.12	853
SW4-GAR	River/Stream	GA	28/08/2013	1.45	3.54	0.887	252	1.62	2.24	10.3	2.6	1030	0.873	2080	0.005	0.39	13.9	0.195	0.75	0.48	3.73	0.75	0.725	571
SW5-GAR	Discharge	GA	28/08/2013	1.45	1.83	0.748	32.1	2.53	1.24	10.8	2.02	96.2	5.28	487	0.0123	2.01	21.3	0.195	0.75	1.5	1.2	0.75	0.313	2720
SW7-GAR	Discharge	GA	28/08/2013	9.4	1.28	0.451	111	0.05	0.527	0.089	0.425	9.5	0.131	202	0.005	0.495	1.19	0.195	0.75	0.48	0.427	0.75	0.12	21
SW8-GAR	Drainage	GA	28/08/2013	3.18	0.378	0.493	21.6	14.1	0.651	2.39	3.92	63.4	1.41	990	0.005	0.353	80.6	0.679	0.75	9.78	0.18	0.75	0.12	20800
SW9-GAR	Drainage	GA	28/08/2013	8.74	0.476	0.894	11.3	20.1	0.51	3.22	3.85	3300	12.5	401	0.005	0.738	48.2	0.624	0.75	9.02	0.18	0.75	0.12	12200
SW6-SHAL	Discharge	ShS	02/09/2013	9.18	1.88	0.704	224	0.809	0.227	1.41	10	28.5	183	61	0.005	0.974	7.89	0.195	0.75	0.48	0.471	0.75	0.12	154
SW10-SHAL	Drainage	ShS	02/09/2013	6.5	0.838	0.746	225	0.719	0.225	0.829	2.88	61.9	78.8	58.9	0.005	0.12	5.18	0.195	0.75	0.48	0.18	0.75	0.12	182
SW12-SHAL	Drainage	ShS	02/09/2013	103	0.943	0.357	135	0.05	0.31	0.142	0.425	86.8	17.2	30.1	0.005	0.365	0.075	0.195	0.75	0.48	0.18	0.75	0.12	53.2
SW1-SHAL	River/Stream	ShS	02/09/2013	9.17	1	0.594	212	0.737	0.238	0.922	5.43	51.3	75.3	53.2	0.005	0.12	4.92	0.195	0.75	0.48	0.18	0.75	0.12	122
SW4-SHAL	River/Stream	ShS	02/09/2013	1.45	0.769	2.74	840	0.05	0.54	17.3	0.425	1790	4.27	6770	0.005	0.55	10.9	0.195	0.75	0.48	0.18	0.75	0.12	42.6
SW9-SHAL	River/Stream	ShS	02/09/2013	7.57	0.75	0.469	209	0.857	0.11	1.19	6.27	30.7	127	54.2	0.005	0.12	7.19	0.195	0.75	0.48	0.18	0.75	0.12	194

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

Table B-3 Comparison of Vegetation Results to Assessment Criteria

	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	*0.05*	0.18	1.09	29.5
SM04-V	*0.05*	0.04	0.37	20.1
SM05-V	*0.05*	0.04	0.46	22.5
SM06-V	0.10	0.07	0.74	29.5
SM08-V	*0.05*	0.14	0.71	33.7
SM13-V	*0.05*	0.08	0.53	15.9
SM14-V	0.10	0.17	1.05	22.5
SM15-V	*0.05*	0.15	0.96	24.9
SM17-V	0.21	0.13	2.55	32.5
SM19-V	*0.05*	0.07	0.47	22.1
SM21-V	*0.05*	0.10	1.29	27.0
SM22-V	0.18	0.07	1.88	27.7
SM27-V	0.14	0.10	1.94	25.1
SM28-V	*0.05*	0.07	1.07	24.5
SM30-V	0.15	0.11	2.48	30.1
SM31-V	0.11	0.05	1.61	19.6
SM33-V	0.27	0.08	3.75	33.5
SM34-V	0.11	0.04	0.97	21.3
SM38-V	0.11	0.03	0.97	18.5
SM40-V	0.33	0.08	5.35	26.5

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

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

Table B-4 Comparison of Vegetation Results to Assessment Criteria

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**
SM01-S	6000	4	60	*0.25*	18	12	14200	1	668	21	22	51
SM04-S	5300	4	60	*0.25*	13	11	14200	*0.5*	643	14	29	53
SM05-S	5100	8	60	*0.25*	13	12	13000	*0.5*	709	11	27	40
SM06-S	5000	3	50	*0.25*	14	15	13100	*0.5*	597	13	22	46
SM08-S	5000	5	50	*0.25*	14	25	13400	*0.5*	615	14	25	55
SM13-S	7900	5	50	*0.25*	19	32	18000	*0.5*	845	19	36	71
SM14-S	7200	4	60	0.6	18	26	14800	*0.5*	1060	19	23	63
SM15-S	8100	5	50	*0.25*	20	28	18700	*0.5*	879	20	36	71
SM17-S	6800	9	80	0.5	17	27	14000	*0.5*	1275	19	30	69
SM19-S	6300	7	50	0.5	17	24	14200	*0.5*	900	18	23	61
SM21-S	5900	8	50	0.5	18	26	13900	*0.5*	779	20	21	66
SM22-S	6600	5	70	0.5	16	33	14000	*0.5*	709	19	28	69
SM27-S	7100	9	90	0.5	17	25	15600	*0.5*	1130	21	26	62
SM28-S	6200	4	50	0.6	16	22	13000	1	734	19	22	62
SM30-S	6600	7	80	*0.25*	15	27	14500	*0.5*	634	19	26	61
SM31-S	6700	11	50	0.5	16	24	14000	*0.5*	1000	21	26	66
SM33-S	5900	7	40	0.5	14	21	13400	*0.5*	594	20	23	64
SM34-S	6200	6	60	*0.25*	13	32	12300	*0.5*	371	15	24	53
SM38-S	6200	5	50	*0.25*	14	21	12800	1	435	16	23	50
SM40-S	6700	7	50	*0.25*	16	28	14900	*0.5*	614	22	23	66

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