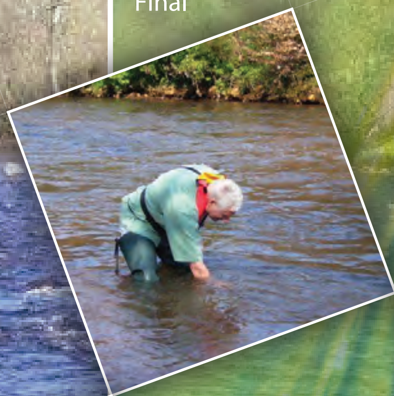
Department of Communications, Energy & Natural Resources

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

Silvermines Monitoring Report - Round 1 (2015)

Final



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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 February 2015. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG19, dated May 2015) 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 on 2 February 2015, as listed in Table 1 and shown on Map 2 in Appendix A. Water levels were measured at an additional seven monitoring wells. Four of the monitoring wells have been removed 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 bgs)	Screen Interval (m bgs)
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 MP1 pump). 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 physico-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

Thirty-two surface water locations were sampled between 2 and 6 February 2015, as listed in Table 2 and shown on Maps 2 to 5 in Appendix A. Two samples could not be obtained because the stream bed was dry at SW7-SHAL and SW10-SHAL. There was slight discharge at SW2-SM 'Northern Adit' for the first time during the monitoring programme and a sample was collected.

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.

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

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

Table 2 Location of Surface Water Monitoring Points

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW10-GORT-US	GM	180206	172396	Immediately upstream of the outfall on the Kilmastulla River	Yes	NR
SW10-GORT-Discharge	GM	180205	172393	Wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW10-GORT-DS	GM	180189	172365	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW12-GORT-Discharge	GM	179562	172165	Sample of wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW12-GORT-DS	GM	179532	172137	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.	Yes	Bucket and Stopwatch
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	Flow Meter
SW4-SM-GA	BG	183961	172483	Site on Silvermines Stream (downstream of all mine workings)	Yes	Flow Meter
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)	Yes	NR
SW2-GAR	GA	181804	171376	Drainage south of R499 road.	Yes	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	No Overflow
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	Flume
SW9-GAR	GA	181881	171557	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of railway	Yes	Flume
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flume

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW12-GAR	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Flume
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	Bucket and Stopwatch
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.	Yes	Flume
SW6-SHAL	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Bucket and Stopwatch
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.	No - Dry	No Flow
SW12-SHAL	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Bucket and Stopwatch
DS-SHAL	ShS	180609	171845	Yellow River downstream of ShS and BG	Yes	Flow Meter

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

Flow Measurements

Flow was measured at 22 locations using various methods depending upon the quantity of flow to be measured and any safety concerns as detailed in the standard operating procedures in the Monitoring Plan (see Table 2). Twenty five locations are required to have flow measured, however at the time of sampling flow couldn't be measured at the discharge from one shaft due to the permanent grating covering it and at two locations the stream-bed was dry (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 some locations with greater flow 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 2 and 4 February 2015, from the recently remediated Areas A and B at Gortmore TMF, as listed in Table 3 and shown on Map 6 in Appendix A.

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

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

Table 3 Location Vegetation and Soil Sampling Sites at Gortmore TMF

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

Annual soil sampling will be undertaken in the summer 2015.

2.1.5 Field QA/QC Samples

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

Groundwater and Surface water

- Groundwater:
  - One duplicate groundwater sample was collected; and
  - One decontamination blank was collected by pouring deionised (DI) water over 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.
- One filtration blank was collected by filtering DI water into the sample bottle. It was collected in order to try to quantify any contamination caused by the filtration procedure.

Vegetation

- Vegetation:
  - Two duplicate vegetation samples were collected by splitting a sample in the field;
  - One decontamination blank was collected by pouring DI water over the vegetation sampling equipment after decontamination; and
  - Three types of standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1568b (rice flour), NIST 1515 (apple leaves) and ERM CD281 were used (rye grass) were used (certificates are 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).

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.

Table 4 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
Groundwater and Surface water		
SMGD01.5	GW Duplicate	Duplicate of TMF2
SMDB01.5	GW Decontamination blank	DI water (Lennox Lab Supplies: Batch No. TE150116W) poured over pump after decon at site TMF2
SMSD01.5	SW Duplicate	Duplicate of SW1-Gar
SMSD02.5	SW Duplicate	Duplicate of SW9-Shal
SMSD03.5	SW Duplicate	Duplicate of SW2-SM-North
SMDB02.5	SW Decontamination blank	DI water (Lennox Lab Supplies. Recorder Code: SW-002-1614. Batch No: TE150116W) poured over SW sampling beaker after final decon at site SW1-SM
SMSR01.5	Standard Reference Material	Wastewater Trace Metals ERA Lot #P234-740A.
SMSR02.5	Standard Reference Material	Wastewater Trace Metals ERA Lot #P234-740A.
WB01.5	Filtration blank	Deionised water filtered onsite (Lennox Lab Suppliers. Batch No: TE150116W)
WB02.5	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: TE150116W)
Vegetation and Soil		
SM56-V	Vegetation Duplicate	Duplicate of SM17-V
SM57-V	Vegetation Duplicate	Duplicate of SM40-V
SMDB03.5	Decontamination blank	DI water (Lennox Lab Supplies, Batch No: TE150116W) poured over shears after decon

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 samples 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.

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 and the sample filtration 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 ALcontrol (Sample IDs SMSR01.4 and SMSR02.4) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P234-740A (Metals). The Certificate of Analysis is provided in Appendix G of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.
  - Three types of standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1568b (rice flour), NIST 1515 (apple leaves) and ERM CD281 were used (rye grass) were used (certificates are contained in Appendix G of the Data Report);

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

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 limit of detection (LOD), then the RPD was zero.

The majority of RPD values shown in Table 5 are below 50 %. The RPDs for the following parameters are excellent: aluminium (0 to 8.5 %), barium (1.5 to 4.6%), cadmium (0 to 7 %), cobalt (0 to 2.7 %), copper (0 to 7.6%), lead (2 to 6%), manganese (1.5 to 13 %) and nickel (0.6 to 4.9%).

The RPDs that were above 50% included antimony for two sample pairs ranging from 106 to 117 % RPD. Dissolved arsenic (86.1 %RPD), molybdenum (100 % RPD), tin (68.4 %RPD) and zinc (58.2 %RPD) also exceeded 50% in one sample pair. Each of these duplicate results were checked and confirmed with ALcontrol and the results were confirmed to be within their duplicate policy margin. 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

Dissolved Metal	LOD (µg/l)	TMF 2	SMGD01.5	% RPD	SW1-GAR	SMSD01.5	% RPD	SW9-SHAL	SMSD02.5	% RPD	SW2-SM-NORTH	SMSD03.5	% RPD
Aluminium	<2.9	<2.9	<2.9	0	<2.9	<2.9	0	30.6	28.1	8.5	<2.9	<2.9	0
Antimony	<0.16	0.769	0.97	-23.1	<0.16	<0.16	0	2.74	0.845	**106**	0.609	<0.16	**117**
Arsenic	<0.12	4.24	4.08	3.8	<0.12	<0.12	0	0.269	0.676	**-86.1**	0.205	0.157	26.5
Barium	<0.03	599	590	1.5	23.9	24.3	-1.7	221	211	4.6	167	168	-0.6
Cadmium	<0.1	<0.1	<0.1	0	8.66	8.07	7.1	2.07	2.12	-2.4	5.18	4.95	4.5
Chromium	<0.22	1.32	0.95	32.6	0.554	0.53	4.4	0.329	0.496	-40.5	1.33	1.07	21.7
Cobalt	<0.06	0.653	0.668	-2.3	0.519	0.505	2.7	1.66	1.62	2.4	0.072	0.072	0.0
Copper	<0.85	<0.85	<0.85	0	4.29	4.63	-7.6	13.6	12.8	6.1	<0.85	<0.85	0
Iron	<19	186	188	-1.1	<19	<19	0	40.5	43.8	-7.8	<19	<19	0
Lead	<0.02	1.3	1.38	-6.0	2.14	2.18	-1.9	285	276	3.2	1.17	1.25	-6.6
Manganese	<0.04	1110	1070	3.7	40.2	39.6	1.5	54.4	57.9	-6.2	0.243	0.277	-13.1
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	0.423	0.499	-16.5	0.585	0.553	5.6	0.371	<0.24	42.9	0.721	<0.24	**100**
Nickel	<0.15	1.59	1.58	0.6	40.3	39.8	1.2	10.5	10.1	3.9	7.54	7.18	4.9
Selenium	<0.39	<0.39	<0.39	0	<0.39	<0.39	0	<0.39	<0.39	0	<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	<0.96	0	<0.96	<0.96	0
Tin	<0.36	<0.36	<0.36	0	<0.36	<0.36	0	0.734	<0.36	**68.4**	0.794	<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	0.269	<0.24	11.4	<0.24	<0.24	0	<0.24	<0.24	0	0.272	<0.24	12.5
Zinc	<0.41	3.24	5.9	**-58.2**	5520	5400	2.2	538	512	5.0	2070	1970	5.0

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 for the first (SM17-V and SM56-V) and the second (SM40-V and SM57-V) duplicate pair which is excellent.

The highest reported value of the duplicate pair is selected for interpretive use in Section 4.

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

Total Metal	SM17-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM40-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	<0.1	<0.1	0	0.23	0.21	9.09
Cadmium	0.05	0.06	-18.2	0.04	0.04	0
Lead	0.65	0.75	-14.3	1.79	1.94	-8.04
Zinc	23.20	24.90	-7.07	25.00	25.50	-1.98

3.2.2 Decontamination Blanks

Surface Water and Groundwater

Two decontamination blanks were created by pouring water over the sampling equipment after decontamination and sent to ALcontrol for analysis. Table 7 provides the results of the 21 metals for the two 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.

Detections were observed for six dissolved metals ranging from 0.064 to 13 µg/l. Four of the metals (antimony, barium, lead, and manganese) were also detected in the DI water blank. The levels of detections in the decontamination blanks were very similar to those found in the DI water blank.

In total there were six detections of dissolved metals in the decontamination blanks. Two of these were greater than ten times the detection limit, in SMDB01.5 manganese (0.492 µg/l) and in zinc (13 µg/l). All of the detections including manganese and zinc 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 water samples (this was the last groundwater sample at Silvemines so there was no subsequent sample). The concentrations in the blanks were generally less than 10 % of the concentration in the preceding environmental samples, with the exception of dissolved zinc. The reported value for zinc in SMGD01.5 was higher than the proceeding sample (TMF2 3.24 µg/l). However the dissolved zinc concentrations within the decontamination blanks were considered to be within normal ranges for zinc because similar concentrations have been detected in the DI water blank in previous sampling rounds.

The results from the laboratory instrumentation blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory (Table 7). The parameters detected in the method blanks for both sample batches were similar to those in the field decontamination blank samples, as follows:

- One parameter detection was present in the method blank for sample batch 150206-9 that occurred in the decontamination blank for the same batch (Table 7): antimony 1.93 µg/l.
- Three detections of parameters were present in method blank for Sample Batch 150218-83 that occurred in the water blank from the same batch (Table 7): antimony 0.639 µg/l, manganese 0.072 µg/l and Molybdenum 0.278 µg/l.

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. As no dissolved zinc was detected in the DI water blanks or the laboratory method blanks and there was one instance of zinc being detected at a higher concentration in the decontamination blank when compared with the preceding sample, it is considered that low concentrations of zinc should be treated with caution as there may high bias.

Table 7 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l)

Sample Description / Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.5 (µg/l)	Water Blank WB02.5 (µg/l)	Laboratory Method Blank (µg/l)	Water: Decon blank SMDB01.5 (µg/l)	Water: Laboratory Method Blank (µg/l)	Water: Decon blank SMDB02.5 (µg/l)	Vegetation: Decon blank SMDB03.5 (µg/l)	Vegetation: Laboratory Method Blank (µg/l)
	Sample batch:	*150218-83*			*150206-9*		150207-55		
Aluminium	<2.9	<2.9	<2.9	NP	<2.9	NP	<2.9	<2.9	NP
Antimony	<0.16	<0.16	***0.585***	*0.639*	***1.12***	*1.93*	<0.16	<0.16	2.89
Arsenic	<0.12	<0.12	<0.12	NP	<0.12	NP	<0.12	<0.12	NP
Barium	<0.03	**0.151**	**0.121**	<0.03	**0.064**	<0.03	<0.03	**0.107**	<0.03
Cadmium	<0.1	<0.1	<0.1	NP	<0.1	NP	<0.1	<0.1	NP
Chromium	<0.22	**0.242**	<0.22	<0.22	<0.22	<0.22	<0.22	0.432	<0.22
Cobalt	<0.06	<0.06	**0.087**	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Copper	<0.85	<0.85	<0.85	NP	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	<19	NP	<19	NP	<19	<19	NP
Lead	<0.02	<0.02	**0.085**	<0.02	**0.071**	<0.02	<0.02	<0.02	<0.02
Manganese	<0.04	***0.05***	***0.099***	*0.072*	***0.492***	<0.04	<0.04	**0.081**	<0.04
Mercury	<0.01	<0.01	<0.01	NP	<0.01	NP	<0.01	<0.01	NP
Molybdenum	<0.24	<0.24	***0.314***	*0.278*	<0.24	*0.633*	<0.24	<0.24	0.96
Nickel	<0.15	<0.15	<0.15	NP	<0.15	<0.15	<0.15	<0.15	<0.15
Selenium	<0.39	<0.39	**0.394**	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39
Silver	<1.5	<1.5	<1.5	NP	<1.5	<1.5	<1.5	<1.5	<1.5
Thallium	<0.96	<0.96	<0.96	NP	<0.96	<0.96	<0.96	<0.96	<0.96
Tin	<0.36	<0.36	<0.36	NP	<0.36	<0.36	<0.36	<0.36	<0.36
Uranium	<1.5	<1.5	<1.5	NP	<1.5	<1.5	<1.5	<1.5	<1.5
Vanadium	<0.24	<0.24	<0.24	NP	<0.24	<0.24	<0.24	<0.24	<0.24
Zinc	<0.41	<0.41	<0.41	<0.41	**13**	<0.41	**1.43**	**1.5**	<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.

Vegetation

To assess the level of cross-contamination between vegetation samples in the field, the concentrations in decontamination blank SMDB03.5 were examined (Table 7). The detections of dissolved barium, manganese can be attributed to the concentrations in the DI water. Detections of dissolved zinc were found in the decontamination blanks but not the water blank; however dissolved zinc is commonly found in the DI water.

None of the parameters of concern for vegetation samples were detected in the decontamination blank at levels that would indicate cross-contamination of samples in the field.

3.2.3 Standard Reference Materials

SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.5 and SMSR02.5) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 8 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, molybdenum, nickel, selenium, thallium and vanadium are in good agreement with the certified value (%R ranged from 88 to 107%).

One exception was for dissolved antimony which had a % R of 120 % which was higher than the upper limit. However the other reported value for antimony was within the acceptable range and therefore the interpretation of the results are not affected. Overall, all of the results are acceptable.

Table 8 Water SRM Reported Values (µg/l) and Calculated % R

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits Lower (%)	Upper (%)	SMSR01.5 (µg/l)	% R	SMSR02.5 (µg/l)	% R
Aluminium	517	87	114	544	105	553	107
Antimony	784	87	111	943	**120**	757	97
Arsenic	135	87	111	144	107	144	107
Barium	791	91	109	789	100	797	101
Cadmium	136	88	106	120	88	130	96
Chromium	634	91	109	611	96	656	103
Cobalt	550	93	111	532	97	570	104
Copper	816	90	109	768	94	813	100
Iron	840	90	111	756	90	806	96
Lead	649	90	110	660	102	679	105
Manganese	772	92	109	774	100	803	104
Molybdenum	273	90	109	240	88	252	92
Nickel	716	91	109	660	92	696	97
Selenium	660	88	111	643	97	640	97
Silver	772	90	110	719	93	>100	-
Thallium	606	88	111	624	103	636	105
Vanadium	888	91	107	854	96	903	102
Zinc	895	91	110	847	95	889	99

Notes:
Bold indicates an exceedance in acceptance limits

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 were taken through the entire analytical system;

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

- Independent Check Standard: An independent check standard was included with every instrumental run of samples. This standard is prepared from a 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. All samples (including free cyanide) were analysed within their specified 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 1568b, a NIST 1515 and ERM CD281 samples after about every 7 samples for a total of nine analyses. The results are provided in the laboratory report in Appendix F of the Data Report (reported as CRM NIST 1568b, CRM NIST 1515 and ERM CD281). SRM NIST 1568b is a certified standard of rice flour and NIST 1515 is a certified standard for apple leaves provided by the USA National Institute of Standards & Technology. ERM CD281 is a certified reference material for rye grass which is a European Reference Material. The certificate of analysis is provided in Appendix G of the Data Report;

- Duplicates: CAL did not analyse duplicates of the field samples. However, the set of SRM NIST 1568b and NIST 1515 analyses can be used to evaluate precision; and

- Blanks: CAL performed three method blanks during the analyses of arsenic, cadmium, lead and zinc.

SRM

Table 9 provides the results of the three analyses of SRM NIST 1568b and the % R values. Table 10 provides the results of the three analyses of SRM NIST 1515 and the % R values. Table 11 provides the results of the three analyses of ERM CD-281 and the % R values. Only results for parameters where the certified value is greater than the laboratory detection limits are presented in the tables. Note that zinc was not reported for the analysis on ERM CD-281. The results were assessed for each parameter in each of the SRMs and can be summarised as follows:

- Only one of the reported arsenic values were outside of the acceptable range of 95 to 105 %R in SRM NIST 1568b.

- Two cadmium reported values were below the acceptable range in SRM NIST 1568b, two were above the acceptable range in SRM NIST 1515 and all were below the acceptable range for SRM ERM CD-281. The cadmium certified value in each of the SRMs was close to the laboratory detection limit which explains why the results have frequently fallen outside of the acceptable range due to greater uncertainty at these low concentrations.

- Three of the lead values were slightly below the acceptable range for SRM NIST 1515 and two were below acceptable range for SRM ERM CD-281. The lead certified value in each of the SRMs wasn't significantly higher than the laboratory detection limit which again could explain why the results have frequently fallen outside of the acceptable range.
- All of the zinc results (six) were considered slightly high and above outside the acceptable range of 99 to 101 %R in SRM NIST 1568b and 98 to 102 % SRM NIST 1515. These ranges are considered to be relatively narrow and therefore a high bias is not considered an issue.

Table 9 SRM NIST 1568b Reported Values and Calculated % R

Total Metal	LOD	Certified Value (mg/kg)	Certified value Acc. Range (mg/kg)	Acc. Limits (%)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R	Result 3 (mg/kg)	% R
Arsenic	0.1	0.285	0.271-0.299	95-105	0.270	95	0.260	**91**	0.270	95
Cadmium	0.01	0.0224	0.0211-0.0237	94-106	0.021	94	0.019	**85**	0.020	**89**
Zinc	0.1	19.42	19.16-19.68	99-101	20.4	**105**	21.1	**109**	20.4	**105**

Table 10 SRM NIST 1515 Reported Values and Calculated % R

Total Metal	LOD	Certified Value (mg/kg)	Certified value Acc. Range (mg/kg)	Acc. Limits (%)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R	Result 3 (mg/kg)	% R
Cadmium	0.01	0.013	0.011-0.015	85-115	0.015	115	0.018	**138**	0.017	**131**
Lead	0.01	0.47	0.446-0.494	95-105	0.360	**77**	0.360	**77**	0.35	**74**
Zinc	0.1	12.5	12.2-12.8	98-102	12.9	**103**	13.3	**106**	13.3	**106**

Table 11 SRM ERM CD-281 Reported Values and Calculated % R

Total Metal	LOD	Certified Value (mg/kg)	Certified value Acc. Range (mg/kg)	Acc. Limits (%)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R	Result 3 (mg/kg)	% R
Cadmium	0.01	0.12	0.113-0.127	94-106	0.103	**86**	0.102	**85**	0.107	**89**
Lead	0.01	1.67	1.56-1.78	93-107	1.582	95	1.464	**88**	1.52	**91**

CAL also analysed an in-house reference material (GST004 a dried ground haylage sample). The reported values are compared to historical mean and standard deviation values using a control chart. If the reported values for GST004 are outside +/- 2 standard deviations of the historical mean, corrective action is taken and all samples reanalysed. If two consecutive GST004 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.

It was concluded that SRMs are considered satisfactory for all the four parameters with results within what would be expected given the low certified values for lead and cadmium and the method uncertainties and different methodologies used by the laboratory and the SRM certified values.

Duplicates

As previously discussed, the laboratory did not perform duplicate analyses of the field samples. However, the analyses of the SRM can be considered as duplicate pairs and SRM NIST 1568b, NIST 1515 and ERM CD-281 were used to analyse precision. As shown in Table 12, the precision was good with the % RPD values ranging from 0 to 18 % for arsenic, cadmium, lead and zinc values.

Table 12 SRM Reported Values and Calculated % RPD

Total Metal	SRM Results (mg/kg)			%RPD (1 vs 2)	%RPD (1 vs 3)	%RPD (2 vs 3)
NIST 1568b	**Result 1**	**Result 2**	**Result 3**			
Arsenic	0.270	0.260	0.270	-3.8	0	3.8
Cadmium	0.021	0.019	0.020	-10.0	-4.9	5.1
Zinc	20.4	21.1	20.4	3.4	0	-3.4
NIST 1515	**Result 1**	**Result 2**	**Result 3**			
Cadmium	0.015	0.018	0.017	18.2	12.5	-5.7
Lead	0.360	0.360	0.35	0	-2.8	-2.8
Zinc	12.9	13.3	13.3	3.1	3.1	0
ERM CD-281	**Result 1**	**Result 2**	**Result 3**			
Cadmium	0.103	0.102	0.107	-1.0	3.8	4.8
Lead	1.582	1.464	1.52	-7.7	-4.0	3.8

Blanks

As previously discussed, CAL performed three method blanks (for arsenic, cadmium, lead and zinc). If the detections were less than the critical value determined by the laboratory for each parameter, then they are not considered to be significant. All zinc results were below reporting limits (non-detects). Arsenic had one detection of 0.004 mg/kg and cadmium had one detection of 0.001 mg/kg which were below the critical value of 0.1 mg/kg. There were three detections of lead ranging from 0.003 to 0.004 mg/kg, which were also below the critical value of 0.1 mg/kg and therefore could indicate carryover in the laboratory. All reported values were below the critical values and were therefore considered acceptable.

3.4 Summary of Data Checks

3.4.1 Field physico-chemical Versus Laboratory Data

Table 13 summarises the field and laboratory results for pH and conductivity and provides the calculated %RPD values. The RPDs between laboratory and field conductivity was less than 18 % which is very good. The RPDs between laboratory and field pH were also good at less than 24 % which is very good. For SW12-Shal the %RPD was higher at nearly 50%, the result was confirmed with ALcontrol and the difference is believed to be due to the unstable reading obtained in the field. The field pH and conductivity are more representative of actual conditions and are used for interpretive purposes. Overall the RPDs between the field and laboratory data are considered satisfactory.

Table 13 Field physico-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
SW12-SHAL	6.61	3.99*	49.4	0.0459	0.05	-8.6
SW1-SHAL	7.74	7.58	2.1	0.176	0.195	-10.2
SW4-SHAL	7.85	6.82	14.0	0.13	0.145	-10.9
SW5-SHAL	6.68	5.6	17.6	0.266	0.31	-15.3
SW6-SHAL	6.95	6.44	7.6	0.129	0.147	-13.0
SW9-SHAL	7.75	7.29	6.1	0.162	0.179	-10.0
DS SHAL	7.70	7.69	0.1	0.462	0.518	-11.4
SW10-GAR	7.78	8.19	-5.1	0.867	0.954	-9.6
SW12-GAR	7.55	8.14	-7.5	0.885	0.967	-8.9
SW4-GAR	7.39	8	-7.9	0.141	0.143	-1.4
SW3-GAR	7.79	8.32	-6.6	0.824	0.938	-12.9
SW5-GAR	7.34	7.43	-1.2	0.788	0.847	-7.2
SW7-GAR	7.38	8.17	-10.2	0.731	0.824	-12.0
SW8-GAR	7.61	7.92	-4.0	1.4	1.52	-8.2
SW9-GAR	7.74	8.17	-5.4	1.48	1.567	-5.7
SW17-GORT	8.00	7.6	5.1	0.366	0.411	-11.6
SW18-GORT	7.89	6.88	13.7	0.637	0.72	-12.2
SW19-GORT	7.87	7.64	3.0	0.7	0.801	-13.5
SW10-GORT-Disc.	7.83	7.42	5.4	0.878	1.003	-13.3
SW10-GORT-DS	8.15	7.72	5.4	0.454	0.515	-12.6
SW10-GORT-US	8.07	7.95	1.5	0.438	0.497	-12.6
SW12-GORT-Disc.	7.78	7.12	8.9	1.03	1.154	-11.4
SW12-GORT-DS	8.02	7.72	3.8	0.459	0.531	-14.5
SW14-GORT	8.03	7.74	3.7	0.425	0.48	-12.2
SW1-GAR	7.31	7.3	0.1	1.39	1.615	-15.0
SW1-SM	7.73	7.38	4.6	0.144	0.157	-8.6
SW2-GAR	7.15	7.25	-1.4	0.984	1.117	-12.7
SW2-SM North	8.07	9.2	-13.1	0.467	0.541	-14.7
SW2-SM South	7.72	7.06	8.9	0.45	0.54	-18.2
SW3-SM	8.01	7.17	11.1	0.165	0.194	-16.2
SW4-SM-GA	8.16	6.42	23.9	0.268	0.312	-15.2
SW6-MAG	7.59	7.2	5.3	0.464	0.529	-13.1
TMF1	7.88	7.43	5.9	0.427	0.458	-7.0
TMF2	7.71	7.07	8.7	0.471	0.509	-7.8

Notes:
Bold indicates an exceedance in acceptance limits
* pH value had trouble stabilising 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:

$$(\Sigma(\text{Cations x charge}) - \Sigma(\text{Anions x charge}))/ (\Sigma(\text{Cations x charge}) + \Sigma(\text{Anions x charge})) \text{ x } 100\%$$

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:

$$(\text{TDS-Calc} – \text{TDS-Meas})/\text{TDS-Meas x } 100\%$$

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 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. 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). The SW12-Shal measured TDS value was very low (<10 mg/l) and was checked and confirmed ALcontrol, however it should be treated with caution given the mass balance % difference of 117%.

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
DS-Shal	320	332	-0.1	-0.6	-3.6	Missing cations
SW10-GAR	686	708	-0.1	-0.6	-3.2	Missing cations
SW10-GORT-DISC.	716	770	-1.5	-6.6	-7.0	Missing cations
SW10-GORT-DS	295	308	-0.9	-8.5	-4.3	Missing cations
SW10-GORT-U/S	279	303	-0.5	-5.0	-7.8	Missing cations
SW12-GAR	713	723	0.3	1.4	-1.4	Missing anions
SW12-GORT-DISC.	814	878	-2.1	-7.9	-7.3	Missing cations
SW12-GORT-DS	296	303	-0.9	-8.0	-2.3	Missing cations
SW12-SHAL	22	<10	0.0	1.4	**117**	Too many cations
SW14-GORT	276	280	-0.6	-5.8	-1.4	Missing cations
SW17-GORT	224	253	-0.6	-7.5	**-11.3**	Missing cations
SW18-GORT	482	496	-0.8	-5.4	-2.8	Missing cations
SW19-GORT	551	587	-0.8	-4.6	-6.1	Missing cations
SW1-GAR	1261	1430	0.3	0.6	**-11.8**	Missing anions
SW1-SHAL	104	95	-0.2	-5.4	9.6	Too many anions
SW1-SM	77	121	-0.1	-2.6	**-36.3**	Missing cations
SW2-GAR	810	890	-0.9	-3.4	-9.0	Missing cations
SW2-SM-NORTH	300	318	-0.1	-1.2	-5.6	Missing cations
SW2-SM-SOUTH	301	279	-0.2	-1.4	8.0	Too many anions
SW3-GAR	662	722	-0.8	-3.7	-8.3	Missing cations
SW3-SM	102	102	-0.2	-4.2	0.3	Too many anions
SW4-GAR	67	64	0.0	-2.0	4.7	Too many anions
SW4-SHAL	72	60	-0.2	-8.1	**20.2**	Too many anions
SW4-SM-GA	168	186	-0.2	-2.7	-9.5	Missing cations
SW5-GAR	610	656	-0.7	-3.5	-6.9	Missing cations
SW5-SHAL	187	148	-0.1	-1.8	**26.1**	Too many anions
SW6-MAG	339	345	0.0	-0.4	-1.7	Missing cations
SW6--SHAL	74	60	-0.1	-3.9	**22.9**	Too many anions
SW7-GAR	562	654	-0.8	-4.3	**-14.1**	Missing cations
SW8-GAR	1185	1390	-1.0	-2.8	**-14.8**	Missing cations
SW9-GAR	1242	1400	-0.8	-2.1	**-11.3**	Missing cations
SW9-SHAL	91	87	-0.2	-5.4	4.8	Too many anions
TMF 1	244	216	-0.3	-3.0	**12.8**	Too many anions
TMF 2	271	275	-0.5	-4.2	-1.5	Missing 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 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 was SW12-SHAL with a ratio of 2.3 for SC/TDS-Calc and 5 for SC/TDS-Meas and had the lowest measured conductivity and TDS. At these low levels, the relationships are less accurate.

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=0.98) 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)
DS-Shal	SW	518	320	332	1.6	1.6
SW10-GAR	SW	954	686	708	1.4	1.3
SW10-GORT-DISC.	SW	1003	716	770	1.4	1.3
SW10-GORT-DS	SW	515	295	308	1.7	1.7
SW10-GORT-US	SW	497	279	303	1.8	1.6
SW12-GAR	SW	967	713	723	1.4	1.3
SW12-GORT-DISC.	SW	1150	814	878	1.4	1.3
SW12-GORT-DS	SW	531	296	303	1.8	1.8
SW12-SHAL	SW	50	22	<10	2.3	5.0
SW14-GORT	SW	480	276	280	1.7	1.7
SW17-GORT	SW	411	224	253	1.8	1.6
SW18-GORT	SW	720	482	496	1.5	1.5
SW19-GORT	SW	801	551	587	1.5	1.4
SW1-GAR	SW	1615	1260	1430	1.3	1.1
SW1-SHAL	SW	195	104	95	1.9	2.1
SW1-SM	SW	157	77	121	2.0	1.3
SW2-GAR	SW	1117	810	890	1.4	1.3
SW2-SM-NORTH	SW	541	300	318	1.8	1.7
SW2-SM-SOUTH	SW	540	301	279	1.8	1.9
SW3-GAR	SW	938	662	722	1.4	1.3
SW3-SM	SW	194	102	102	1.9	1.9
SW4-GAR	SW	143	67	64	2.1	2.2
SW4-SHAL	SW	145	72	60	2.0	2.4
SW4-SM-GA	SW	312	168	186	1.9	1.7
SW5-GAR	SW	847	610	656	1.4	1.3
SW5-SHAL	SW	310	187	148	1.7	2.1
SW6-MAG	SW	529	339	345	1.6	1.5
SW6--SHAL	SW	147	74	60	2.0	2.5
SW7-GAR	SW	824	562	654	1.5	1.3
SW8-GAR	SW	1520	1190	1390	1.3	1.1
SW9-GAR	SW	1570	1240	1400	1.3	1.1
SW9-SHAL	SW	179	91	87	2.0	2.1
TMF 1	GW	458	244	216	1.9	2.1
TMF 2	GW	509	271	275	1.9	1.9

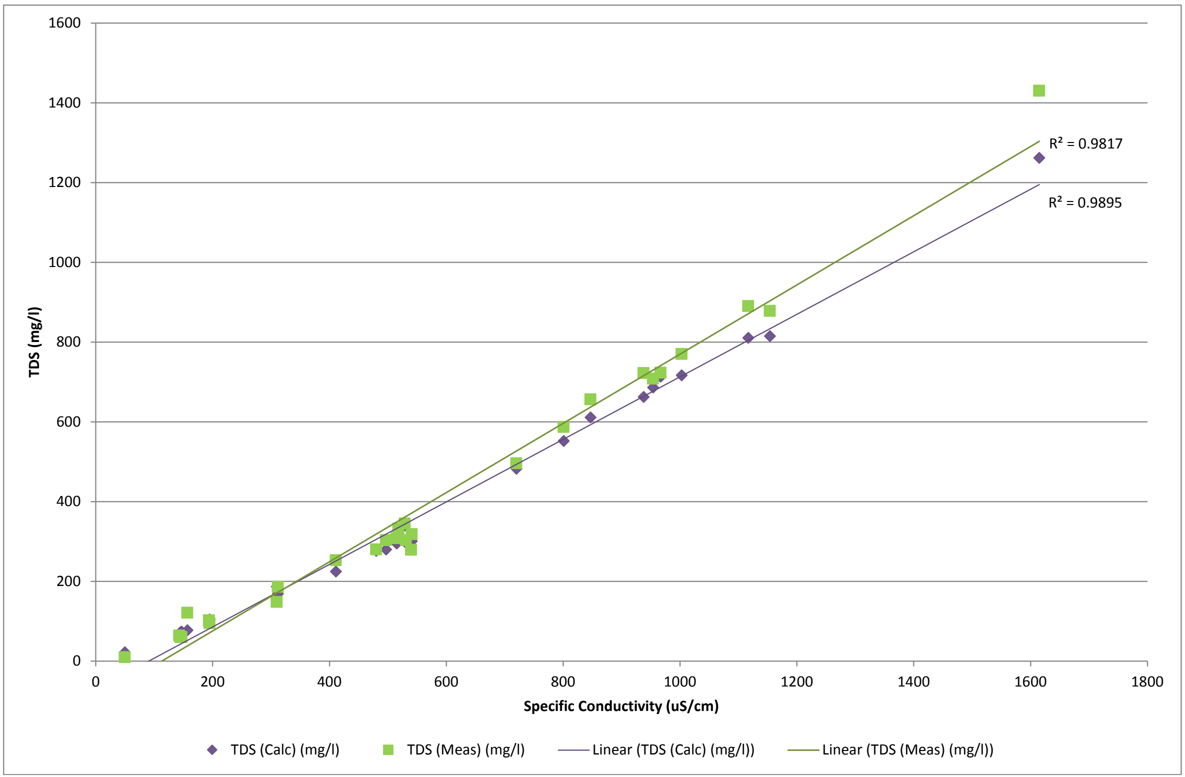

Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

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 should be less than the total metals because they are a portion of the total concentration. This was checked for some of the key metals; cadmium, lead, nickel and zinc, by calculating the ratio of total and dissolved metals to evaluate if the concentrations were distinguishable. Table B-1 in Appendix B shows the full tabulation of results.

The total metals were generally equal to the dissolved metals, indicating that the majority of the cadmium, nickel and zinc present were dissolved. The total concentrations were significantly higher than the dissolved concentrations for lead, showing the majority of lead was total lead. The total suspended solids for these samples ranged from <2 to 8 mg/l.

Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater, surface water and vegetation 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 metals 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	0.755	0.97	0.863
Arsenic	<0.12	2	2	3.65	4.24	3.95
Barium	<0.03	2	2	139	599	369
Cadmium	<0.1	2	0	0.05	0.05	-
Chromium	<0.22	2	2	0.717	1.32	1.02
Cobalt	<0.06	2	2	0.233	0.668	0.450
Copper	<0.85	2	0	0.425	0.425	-
Iron	<19	2	2	186	199	193
Lead	<0.02	2	1	0.01	1.38	-
Manganese	<0.04	2	2	86.5	1110	598
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	2	0.393	0.499	0.446
Nickel	<0.15	2	2	0.772	1.59	1.18
Selenium	<0.39	2	0	0.195	0.195	-
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	1	0.12	0.269	-
Zinc	<0.41	2	1	0.205	5.9	-

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

Dissolved barium (599 µg/l) and manganese (1,110 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 4.24 µg/l. Detections of dissolved chromium and lead were detected at slightly more elevated concentrations in TMF2 compared with 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 15 discharge/ drainage samples and Table 18 provides a summary of the reported results of the 17 river and stream samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metals 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	15	3	1.45	49.2	6.59	13.8
Antimony	<0.16	15	11	0.08	4.75	1.90	1.64
Arsenic	<0.12	15	11	0.06	0.862	0.289	0.211
Barium	<0.03	15	15	12.9	244	79.9	88.0
Cadmium	<0.1	15	14	0.05	69.2	14.6	18.8
Chromium	<0.22	15	14	0.11	1.88	0.671	0.484
Cobalt	<0.06	15	15	0.072	4.66	1.17	1.51
Copper	<0.85	15	13	0.425	16.2	4.13	4.09
Iron	<19	15	5	9.5	64.8	19.9	18.0
Lead	<0.02	15	14	0.01	363	38.5	98.1
Manganese	<0.04	15	15	0.277	382	123	130
Mercury	<0.01	15	0	0.005	0.005	-	-
Molybdenum	<0.24	15	10	0.12	1.38	0.582	0.443
Nickel	<0.15	15	15	1.43	62.5	25.1	23.2
Selenium	<0.39	15	4	0.195	1.15	0.339	0.281
Silver	<1.5	15	0	0.75	0.75	-	-
Thallium	<0.96	15	8	0.48	5.81	1.74	1.71
Tin	<0.36	15	7	0.18	2.3	0.707	0.707
Uranium	<1.5	15	0	0.75	0.75	-	-
Vanadium	<0.24	15	2	0.12	0.482	0.177	-
Zinc	<0.41	15	15	22.6	21400	6690	7140

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

SW12-GAR had the highest concentrations of dissolved nickel (62.5 µg/l). The highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 363 µg/l. SW2-GAR had the highest concentration of zinc with a value of 21,400 µg/l.

Rivers and Streams

Table 18 Summary of Dissolved Metal Concentrations in Rivers and Streams

Dissolved Metal	LOD (µg/l)	Numbe r	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	17	11	1.45	39.5	9.42	12.1
Antimony	<0.16	17	13	0.08	6.23	2.15	1.960
Arsenic	<0.12	17	12	0.06	0.676	0.255	0.183
Barium	<0.03	17	17	24.3	336	148	89.8
Cadmium	<0.1	17	15	0.05	25.9	4.34	7.73
Chromium	<0.22	17	16	0.11	1.2	0.661	0.324
Cobalt	<0.06	17	14	0.03	5.19	0.815	1.28
Copper	<0.85	17	11	0.425	18.3	4.51	5.41
Iron	<19	17	10	9.5	79.4	23.77	17.7
Lead	<0.02	17	16	0.01	285	34.8	81.8
Manganese	<0.04	17	17	2.88	773	93.5	180
Mercury	<0.01	17	0	0.005	0.005	-	-
Molybdenum	<0.24	17	11	0.12	1.39	0.504	0.449
Nickel	<0.15	17	17	0.475	56.4	11.6	16.4
Selenium	<0.39	17	2	0.195	2.35	0.334	0.522
Silver	<1.5	17	0	0.75	0.75	-	-
Thallium	<0.96	17	1	0.48	1.15	0.519	0.162
Tin	<0.36	17	7	0.18	3.5	0.774	0.961
Uranium	<1.5	17	0	0.75	0.75	-	-
Vanadium	<0.24	17	6	0.12	0.334	0.187	0.085
Zinc	<0.41	17	17	0.682	10200	1850	3310

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 dissolved zinc than the rest of the rivers and streams sampled in the Silvermines area (1.55 and 0.682 µg/l, respectively). SW17-Gort has background concentrations of manganese (46.5 µg/l) and barium (186 µg/l).

SW3-Gar (downstream of Garryard) had the highest concentrations of dissolved cadmium (25.9 µg/l) and zinc (10,200 µg/l). SW5-Shal (downstream of the drum dump) had the highest concentrations of dissolved nickel (56.4 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). 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 duplicate pair was used.

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

	Arsenic	Cadmium	Lead	Zinc
Number	20	20	20	20
LOD	<0.1	<0.01	<0.01	<0.1
Detections	8	20	20	20
Minimum	0.05	0.03	0.36	21.7
Maximum	0.481	0.15	2.49	35.9
Mean	0.12	0.06	0.99	27.2
SDEV	0.117	0.030	0.759	3.80

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

There were eight detections of arsenic above the detection limit of <0.1. The highest arsenic concentration of 0.481 mg/kg was in SM33-V. The highest lead (2.49 mg/kg) was also in SM33-V. The highest cadmium (0.15 mg/kg) and highest zinc (35.9 mg/kg) concentrations were in vegetation sample SM01-V. SM01-V and SM33-V are located at the edge of the capped area (see Map 6 in Appendix A).

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 20. 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 20).

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 20. The appropriate ecological assessment criteria are highlighted in bold in Table 20.

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

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

Table 20 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; 30 µg/l 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

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 20 and Table 21).

Table 21 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 Livestock Drinking Water Assessment Criteria

There are currently no Irish or European guidelines for the quality of drinking water for livestock. Recommendations for levels of toxic substances in drinking water for livestock are available from the US National Academy of Sciences (1972). Table 19 summarises the recommended levels for metals where limits have been established, and for total dissolved solids, sulphate and fluoride.

Table 22 Assessment Criteria for Livestock Drinking Water Quality

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

Parameter	Unit	Parametric Value	Source	Comment
Mercury	µg/l	10	NAS 1972	
Selenium	µg/l	50	NAS 1972	
Vanadium	µg/l	100	NAS 1972	
Zinc	µg/l	24,000	NAS 1972	
Total Dissolved Solids (TDS)	mg/l	1,000	NAS 1972	<1,000 mg/l Relatively low level of salinity. Excellent for all classes of livestock. 1,000-3,000 mg/l Satisfactory for livestock. May cause temporary and mild diarrhea in livestock not accustomed to them.
Fluoride	mg/l	2	NAS 1972	
Sulphate	mg/l	500	Higgins *et. al.* 2008	<500 mg/l for calves <1,000 mg/l for adults

Notes
NAS is National Academy of Science

4.2.3 Vegetation Assessment Criteria

The European Communities (Undesirable Substances in Feedingstuffs) Regulations 2003 (S.I. 317 of 2003) transpose the Directive 2002/32/EC on Undesirable Substances in Animal Feed into Irish law and are in place to control the metal content in animal feed. The EU Directive was last updated on 29 September 2006. Table 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)

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

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

The maximum content is actually the "Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12 %". For cadmium and lead, the Directive states that the extraction be "performed with nitric acid (5 % w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency." The 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).

4.3 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 surface water analytical results was made against the relevant assessment criteria for livestock drinking water as described in Section 4.2. Table B-3 in **Appendix B** highlights the exceedances of the assessment criteria. Where there was an exceedance of the livestock assessment criteria, the result is highlighted in green.

A comparison of the vegetation 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 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.

Groundwater, surface water and vegetation 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 7.25. The specific conductance ranged from 0.458 to 0.509 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 2.8 to 13.2 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, barium and manganese exceeded the assessment criteria in groundwater samples, 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 139 µg/l and TMF2 had a result of 599 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1 had a result of 86.5 µg/l and TMF2 had a result of 1,110 µg/l which also exceeded the ecological health criteria of 1,100 µg/l. Note that manganese is not important criteria for human health (see Section 4.2.1).

4.3.2 Surface Water Assessment

The pH in surface waters in the Silvermines mining area was found to range from 3.99 to 9.2, with an average of 7.39. There was one exceedance of the assessment criteria for pH at SW12-Shal (3.99 pH) which was below the acceptable range for human health of 6.5 to 9.5 pH and for ecological health 4.5 to 9 pH. Low acidity results were detected at twenty-six locations which ranged from 5.48 to 27.40 mg/l (as HCl) with the highest acidity at SW2-GAR. The conductivity ranged from 0.05 to 1.62 mS/cm with an average of 0.66 mS/cm, with no exceedances of the human health criteria (2.5 mS/cm).

Nutrients in surface water were generally considered acceptable with a few exceptions where the ecological assessment criteria were exceeded for ammonia. The ammonia ecological assessment criteria (0.14 mg/l) was exceeded at SW4-SM-GA which had a concentration of 0.209 mg/l. SW4-SM-GA also had elevated ortho-phosphate at 0.0496 mg/l but it was below the ecological assessment criteria of 0.075 mg/l.

Fluoride results were elevated above the ecological assessment criteria (0.5 mg/l) ranging from 1.09 to 2.45 mg/l at ten locations. Both the ecological and human health (1.5 mg/l) criteria were exceeded at eight locations.

Sulphate exceeded the criteria for human health (250 mg/l) at all of the discharge and drainage locations in the Garryard area, with the exception of SW4-Gar (14.7 mg/l) and the criteria was exceeded at four locations in the Gortmore area. The sulphate results that exceeded the criteria ranged from 279 to 897 mg/l, with an average of 471 mg/l. The highest sulphate result was from SW1-Gar with 897 mg/l.

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. Table 24 provides a summary of the reported values for rivers and streams at the upstream and downstream locations at the different mining areas that exceeded the relevant ecological and human health assessment criteria for dissolved metals. For the locations refer to the maps in Appendix A.

The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with high results even at upstream locations SW1-SM (47.3 µg/l) and SW17-Gort (186 µg/l), and is not discussed further. Dissolved arsenic was detected at the majority of surface water locations but was significantly below both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria, with the highest concentration of 0.862 µg/l at SW6-Shal.

In the Ballygown area (Map 5 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. Upstream at SW1-SM there were no exceedances of the ecological or human health criteria (except barium). The southern adit and northern adit SW2-SM discharges to the Silvermines stream and had cadmium (5.45 and 5.18 µg/l) and zinc (2140 and 2070 µg/l) above the ecological assessment criteria of 0.9 µg/l for cadmium and 100 µg/l for zinc. Downstream on the Silvermines stream at SW4-SM-GA, dissolved zinc was also above the ecological assessment criteria with a concentration of 244 µg/l.

Table 24 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

	Sample Description	Sample Location	Date Sampled / Units	Ammoniacal Nitrogen as N	Fluoride	Sulphate	Antimony (diss.filt)	Cadmium (diss.filt)	Cobalt (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Nickel (diss.filt)	Zinc (diss.filt)
				mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
			Ecological Criteria	**0.14**	**0.5**	**-**	**-**	**0.9**	**5.1**	**7.2**	**1100**	**20**	**100**
			Human Health Criteria	**0.3**	**1.5**	**250**	**5**	**5**	**-**	**10**	**50**	**20**	**-**
Ballygown	SW1-SM	Upstream	06/02/2015	<2	<0.5	5.7	1.31	<0.1	<0.06	<0.02	7.34	0.475	1.55
	SW3-SM	DS (underground workings)	06/02/2015	<2	<0.5	7.3	<0.16	0.24	<0.06	0.99	2.88	0.887	83.7
	SW4-SM-Ga	Downstream (all)	06/02/2015	0.209	<0.5	12.8	4.44	0.641	<0.06	1.36	3.69	1.6	244
Magcobar	SW6-Mag	Downstream	05/02/2015	<2	<0.5	209	2.31	1.75	0.752	0.032	65.2	11.5	921
Garryard	SW1-GAR	Upstream	04/02/2015	<2	1.09	897	<0.16	8.66	0.519	2.18	40.2	40.3	5520
	SW3-GAR	Downstream (all)	04/02/2015	<2	1.99	348	0.673	25.9	1.77	2.06	193	34.2	10200
Shallee	SW4-SHAL	Upstream	05/02/2015	<2	<0.5	3.4	6.2	0.543	0.231	1.08	45.7	5.19	87.9
	SW5-SHAL	DS (drum dump)	05/02/2015	<2	1.61	103	2.66	21.3	5.19	27.4	773	56.4	9320
	SW9-SHAL	Downstream	05/02/2015	<2	<0.5	18.9	2.74	2.12	1.66	285	57.9	10.5	538
	SW1-SHAL	Downstream (all)	05/02/2015	<2	<0.5	21.7	2.14	2.14	1.56	209	80.5	10.3	548
Garryard/ Shallee	DS SHAL	Downstream of SW3-GAR and SW1-SHAL	05/02/2015	<2	<0.5	136	1.42	7.97	0.911	38.7	87.7	15	3230
Gortmore	SW17-GORT	Upstream	03/02/2015	<2	<0.5	12.9	0.942	<0.1	0.127	0.029	46.5	0.903	0.682
	SW12-GORT-DS	Downstream (TMF)	03/02/2015	<2	<0.5	45.4	1.23	0.616	0.192	2.11	40	2.32	261
	SW14-GORT	Downstream (TMF and Yellow River)	03/02/2015	<2	<0.5	38.8	0.599	0.563	0.17	1.74	36.8	2.09	233

Notes:

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Metals are dissolved

SW6-Mag downstream of the Magcobar area also had dissolved cadmium (1.75 µg/l) and zinc (921 µg/l) above the ecological assessment criteria.

At Gortmore TMF (Map 2 of **Appendix A**), dissolved cadmium, lead and zinc, exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. The concentration of dissolved cadmium exceeded the ecological assessment criterion of 0.9 µg/l with values ranging from 1.07 to 1.31 µg/l at SW18-Gort and SW19-Gort. Lead exceeded the ecological assessment criteria (7.2 µg/l) at SW18-Gort with a concentration of 7.66 µg/l. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at SW12-Gort-Disc with a concentration of 217 µg/l. Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at all of the drainages and discharges ranging from 583 to 895 µg/l. The concentration of zinc increased on the Kilmastulla River from 0.682 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 261 µg/l at SW12-Gort-DS and 233 µg/l at SW14-Gort. SW14-Gort is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The loading from these areas are discussed in Section 5.

At Shallee (Map 3 of **Appendix A**), dissolved lead exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations with the (exception of the upstream location SW4-Shal) with concentrations ranging from 27.4 to 363 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 1.08 µg/l (below both the assessment criteria). With the exception of SW12-Shal (stone lined drainage channel) and SW4-Shal, dissolved zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 223 to 9,320 µg/l. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all Shallee locations except SW4-Shal, with results ranging from 57.9 to 773 µg/l. SW5-Shal concentrations exceeded the ecological health criteria for dissolved cobalt of 5.1 µg/l (5.19 µg/l) and both the ecological and human health criteria for dissolved nickel of 20 µg/l (56.4 µg/l). SW5-Shal concentrations also exceeded both the ecological (0.9 µg/l) and human health criteria (5 µg/l) for dissolved cadmium with a value of 21.3 µg/l. Dissolved cadmium decreased further downstream to 2.12 and 2.14 µg/l at SW9-Shal and SW1-Shal, respectively, which still exceed the ecological health criteria.

DS-Shal is located on the Yellow River downstream of all the discharges from the Shallee and Garryard areas and located upstream of the confluence with the Kilmastulla River in the Gortmore area. The dissolved lead exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria with a concentration of 38.7 µg/l. The dissolved zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 3,230 µg/l. DS-Shal also exceeded both the ecological (0.9 µg/l) and human health criteria (5 µg/l) for dissolved cadmium with a value of 7.97 µg/l.

In the Garryard area (Map 4 of **Appendix A**), some of the highest concentrations of dissolved metals were observed. Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l, ranging from 184 to 21,400 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 8.37 to 69.2 µg/l) with one exception, SW4-GAR (0.958 µg/l) that only exceeded the ecological criteria. Dissolved lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at two locations; SW4-Gar with a concentration of 19.7 µg/l and SW2-Gar with 152 µg/l. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at all locations ranging from 20.5 to 62.5 µg/l, again with the exception of SW4-Gar (2.42 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 eight locations, with results ranging from 56.1 to 382 µg/l. Dissolved zinc exceeded the ecological assessment criteria (100 µg/l) at all locations with ranging in concentration from 184 and 21,400 µg/l.

4.3.3 Livestock Water Quality Assessment

Recommendations for levels of toxic substances in drinking water for livestock are provided in Table 22. A limit of 100 µg/l is recommended for lead in drinking water for livestock by the National Academy of Sciences (1972). However lead is accumulative and problems may begin at threshold value of 50 µg/l. The Field Shaft (SW6-Shal) had a concentration of dissolved lead of 363 µg/l and the sampling location on the stream SW9-Shal which is just downstream of the Field Shaft had concentration of 285 µg/l. Therefore it is recommended that livestock should be prevented from drinking water in the stream in the Shallee mining area.

The water quality results for all of the ponds and streams sampled at Gortmore TMF were also assessed against the recommendations for levels of toxic substances in drinking water for livestock from the National Academy of Sciences (1972). No exceedances of the livestock threshold values for any metals, total dissolved solids or sulphate were found. Therefore it is considered that the streams and ponds on top of the Gortmore TMF are safe for livestock but they should be continued to be monitored as there has been minor exceedances of the thresholds for TDS and sulphate in the past.

4.3.4 Vegetation Assessment

Table B-4 in Appendix B highlights the exceedances of the assessment criteria for vegetation. 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 all below both the no effect and low effect levels provided in Table 23.

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 10 October 2014 to 31 March 2015 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >14 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 3.26 m^3/s. The recorded flow at the Coole gauging station showed that high flows were equal to or greater than the calculated 5%ile (high flow) of 8.58 m^3/s on nine occasions throughout the monitoring period. The flow during this period shows a flashy response to rainfall. The highest recorded flow in the monitoring period was on 14 November 2014 with a mean daily flow of 14.9 m^3/s. Overall flows were high during the monitoring period with a sustained medium-high flow in December and January.

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 of the Kilmastulla River at the location just downstream of the Gortmore TMF which was 0.16 m^3/s. It is estimated that the flows would have been greater than the 95%-ile in the Silvermines mining area for the entire monitoring period. The EPA tool for ungauged catchments was used to calculate the 5%-ile flow (high flow) which was 4.36 m^3/s and the flows were likely greater than this on several occasions throughout the monitoring period.

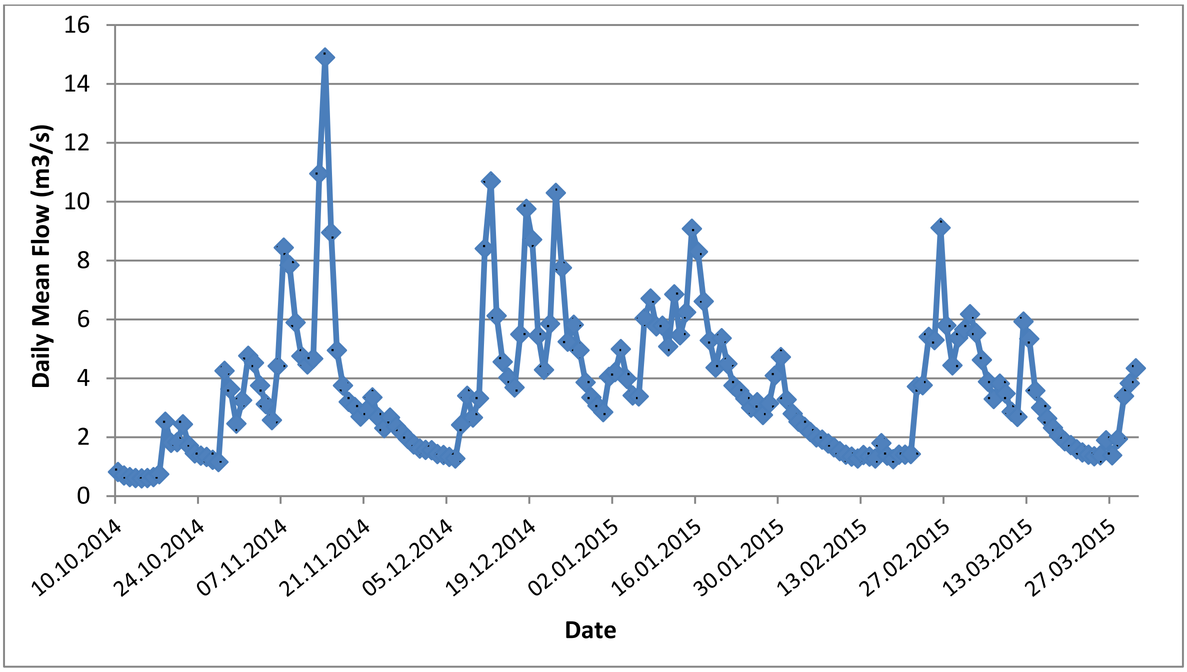

Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 10 Oct 2014 to 31 Mar 2015

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 February 2015 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 February 2015

Site Name	Flow l/s	Date
SW10-GORT Discharge	7.22	03/02/2015
SW12-GORT Discharge	9.63	03/02/2015
SW19-Gort	2.04	03/02/2015
SW10-GAR	16.8	04/02/2015
SW12-GAR	0.48	04/02/2015
SW3-GAR	32.2	04/02/2015
SW4-GAR	6.35	04/02/2015
SW5-GAR	Flow immeasurable (grating)	04/02/2015
SW7-GAR	0.81	04/02/2015
SW8-GAR	0.44	04/02/2015
SW9-GAR	1.09	04/02/2015
DS-SHAL	60.6	05/02/2015
SW12-SHAL	2.28	05/02/2015
SW1-SHAL	9.90	05/02/2015
SW4-SHAL	0.08	05/02/2015
SW5-SHAL	0.85	05/02/2015
SW6-SHAL	5.08	05/02/2015
SW7-SHAL	No flow	05/02/2015
SW9-SHAL	10.9	05/02/2015
SW10-SHAL	No flow	05/02/2015
SW1-SM	18.3	06/02/2015
SW3-SM	30.2	06/02/2015
SW2-SM-North	0.02	06/02/2015
SW2-SM-South	1.93	06/02/2015
SW4-SM-GA	46.7	06/02/2015

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.

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
SW10-GORT Discharge	3/2/2015	7.22	7.42	448000	4630	0.199	0.12	0.095	0.06	47.1	29.4	7.08	4.42	895	558
SW12-GORT Discharge	3/2/2015	9.63	7.12	440000	5920	0.49	0.41	0.01	0.01	217	181	7.28	6.06	597	497
SW19-Gort	3/2/2015	2.04	7.64	333000	1350	1.07	0.19	1.08	0.19	8.43	1.48	5.44	0.96	729	128
SW10-GAR	4/2/2015	16.8	8.19	351000	11900	30.1	43.7	1.21	1.76	148	215	40.9	59.4	13000	18900
SW12-GAR	4/2/2015	0.48	8.14	364000	340	26.2	1.09	0.322	0.01	372	15.5	62.5	2.61	13900	580
SW3-GAR	4/2/2015	32.2	8.32	348000	23100	25.9	72.1	2.06	5.73	193	537	34.2	95.1	10200	28400
SW4-GAR	4/2/2015	6.35	8	14700	4390	0.958	0.53	19.7	10.8	42.3	23.2	2.42	1.33	184	101
SW7-GAR	4/2/2015	0.81	8.17	340000	569	8.37	0.58	0.369	0.03	56.1	3.91	20.5	1.43	5610	391
SW8-GAR	4/2/2015	0.44	7.92	729000	302	20.3	0.77	0.91	0.03	280	10.7	45.9	1.75	15600	595
SW9-GAR	4/2/2015	1.09	8.17	804000	770	23.7	2.23	2.42	0.23	107	10.1	40.8	3.84	11000	1040
DS-SHAL	5/2/2015	60.6	7.69	136000	40200	7.97	41.7	38.7	202	87.7	459	15	78.5	3230	16900
SW12-SHAL	5/2/2015	2.28	3.99	1000	785	0.05	0.01	45.2	8.89	68.5	13.5	1.43	0.28	22.6	4.45
SW1-SHAL	5/2/2015	9.90	7.58	21700	6490	2.14	1.83	209	179	80.5	68.9	10.3	8.81	548	469
SW4-SHAL	5/2/2015	0.08	6.82	3400	44.2	0.543	0	1.08	0.01	45.7	0.3	5.19	0.03	87.9	0.57
SW5-SHAL	5/2/2015	0.85	5.6	103000	411	21.3	1.56	27.4	2.01	773	56.7	56.4	4.14	9320	684
SW6-SHAL	5/2/2015	5.08	6.44	12000	2820	1.16	0.51	363	159	65.3	28.6	8.1	3.55	223	97.8
SW9-SHAL	5/2/2015	10.9	7.29	18900	6850	2.12	1.99	285	268	57.9	54.4	10.5	9.86	538	505
SW1-SM	6/2/2015	18.3	7.38	5700	11700	0.05	0.08	0.01	0.02	7.34	11.6	0.475	0.75	1.55	2.46
SW3-SM	6/2/2015	30.2	7.17	7300	18700	0.24	0.63	0.99	2.58	2.88	7.51	0.887	2.31	83.7	218
SW2-SM-North	6/2/2015	0.02	9.2	31000	15.9	5.18	0.01	1.25	0	0.277	0	7.54	0.01	2070	3.58
SW2-SM-South	6/2/2015	1.93	7.06	32200	1180	5.45	0.91	1.11	0.18	1.02	0.17	7.5	1.25	2140	356
SW4-SM-GA	6/2/2015	46.7	6.42	12800	25900	0.641	2.59	1.36	5.49	3.69	14.9	1.6	6.45	244	984

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

The dissolved metal with the highest mass loading was zinc ranging from 0.57 to 28,400 g/day with an average of 3,250 g/day overall. The largest mass load of zinc was 28,400 g/day at SW3-GAR which is located in a stream containing the SW10-GAR discharge (18,900 g/day) and the western part of the Mogul yard. This shows an apparent increase in zinc loadings from the discharge at the tailings lagoon (SW10-GAR) to SW3-GAR which is located further downstream, which is due to an increase in flow. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 2.46 g/day, which increases to 218 g/day downstream of the mine workings (SW3-SM). The southern and northern adits (SW2-SM) also contribute 356 g/day and 3.58 g/day respectively of dissolved zinc to the stream. Further downstream the calculated mass load at SW4-SM-GA was 984 g/day, which indicates that there was likely another source of zinc load. The Silvermines stream contributes this load to the Kilmastulla River.

The highest load of dissolved lead was from the SW9-Shal downstream of the Shallee mining area with a calculated value of 268 g/day. SW9-Shal is located immediately west of the southernmost Shallee tailings impoundment and downstream of Field Shaft. The dissolved lead loading from Field Shaft (SW6-Shal) was 159 g/day. This indicates that the discharge from the Field Shaft is not the only contributor of lead load to the stream. The majority of the stream has been surveyed between the main road and Knights Shaft (where accessible) and no other inputs of surface water were observed. Further downstream at SW1-Shal the dissolved lead load decreases to 179 g/day.

DS-Shal is located downstream of both the Shallee and Garryard mining areas. The dissolved lead load increases from 179 g/day at SW1-Shal to 202 g/day at DS-Shal. The stream from the Garryard area only contributes 5.73 g/day of dissolved lead therefore the increase could be from diffuse flow from a tailings impoundment at Shallee. The dissolved zinc load at DS-Shal is 16,900 g/day which is an increase from the Shallee area (SW1-Shal – 469 g/day). This indicates that the main source of zinc load is from the stream emerging from the Garryard area with 28,400 g/day, which also indicates there is some loss in the zinc load.

Of the two wetland discharges at Gortmore TMF, SW10-Gort-Discharge had the highest loading of dissolved zinc at 558 g/day and SW12-Gort-Discharge had 497 g/day of zinc. Discharges from the Garryard and Shallee area (DS-Shal – 16,900 g/day) therefore provided the greatest mass loads of dissolved zinc to the Kilmastulla River.

5.3 Trend Analysis

5.3.1 Historical Trends

This section discusses concentration time trends for select locations including the main discharges (SW2-SM South, SW6-SHAL, SW10-GAR, SW10-Gort-Disc and SW12-Gort-Disc) and SW14-Gort which is the most downstream sampling location on the Kilmastulla River. The Mann-Kendall test was performed on the surface water data. The Mann-Kendall test is a non-parametric test that is well suited to use in water quality data analysis. The Mann-Kendall test was performed for dissolved cadmium, lead, manganese, nickel and zinc.

The Mann-Kendall test results in the identification of a trend (if one exists) and the probability of that trend being real. Table 27 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 27 Reporting the Mann-Kendall Results

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

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

Trend analysis was conducted for all the available data since November 2006. The Mann-Kendall test results are presented in Table 28 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 28 Mann-Kendall Trend Analysis of data from November 2006 to February 2015

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. cadmium	10	0.1052	-15	No Trend
	Diss. lead	9	0.2647	-7	No Trend
	Diss. manganese	10	0.0021	-33	Decreasing
	Diss. nickel	10	0.2648	-8	No Trend
	Diss. zinc	10	0.3938	4	No Trend
SW10-Gort-discharge	Diss. cadmium	7	0.1838	-7	No Trend
	Diss. lead	5	0.4032	-2	No Trend
	Diss. manganese	7	0.3819	3	No Trend
	Diss. nickel	7	0.0177	-15	Decreasing
	Diss. zinc	7	0.1148	-9	No Trend
SW12-Gort-discharge	Diss. cadmium	5	0.1103	6	No Trend
	Diss. lead	5	0.0432	-8	Decreasing
	Diss. manganese	6	0.3536	-3	No Trend
	Diss. nickel	6	0.1298	-7	No Trend
	Diss. zinc	6	0.3536	3	No Trend
SW6-Shal	Diss. cadmium	8	0.4508	-2	No Trend
	Diss. lead	8	0.5480	0	No Trend
	Diss. manganese	8	0.1932	-8	No Trend
	Diss. nickel	8	0.4508	-2	No Trend
	Diss. zinc	8	0.3553	-4	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	6	0.3536	3	No Trend
	Diss. lead	7	0.3819	7	No Trend
	Diss. manganese	7	0.2740	5	No Trend
	Diss. nickel	7	0.3819	3	No Trend
	Diss. zinc	7	0.500	1	No Trend

The results of the Mann-Kendall analysis show that dissolved manganese concentrations are decreasing at SW10-Gar. Dissolved nickel and dissolved lead concentrations are also decreasing in the SW10-Gort discharge and SW12-Gort discharge respectively. No other statistically significant trends were observed in the data that were analysed.

5.3.2 Seasonal Trends

Table 29 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling events in April 2013 (R1), March 2014 (R3) and February 2015 (R5) and the low flow sampling event in August 2013 (R2) and September 2014 (R4). As can be observed from Table 29, the concentrations of dissolved cadmium, manganese and zinc are generally at similar concentrations in both low flow and high flow conditions.

Table 29 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in the Main Discharges and on the most downstream location on the Kilmastulla River for the period 2013-2015

Site Description	Round & 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
	R3 11/03/2014	3	5.18	1.34	1.1	0.29	1.86	0.48	1940	503
	R4 25/09/2014	1.1	4.65	0.44	0.912	0.09	0.563	0.05	1750	166
	R5 06/02/2015	1.93	5.45	0.907	1.11	0.185	1.02	0.17	2140	356
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
	R3 05/03/2014	2.208	1.29	0.25	477	91	97.9	18.7	252	48.1
	R4 22/09/2014	4.3	0.799	0.3	320	119	85.5	31.8	221	82.1
	R5 05/02/2015	5.08	1.16	0.508	363	159.2	65.3	28.6	223	97.8
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
	R3 06/03/2014	50.7	24.8	109	2.06	9.03	226	990	9320	40800
	R4 23/09/2014	3.1	21.7	5.81	8.51	2.28	255	68.3	7150	1920
	R5 04/02/2015	16.8	30.1	43.7	1.21	1.76	148	215.1	13000	18893
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
	R3 13/03/2014	6	0.328	0.17	0.276	0.14	91.5	47.4	1040	539
	R4 25/09/2014	1.7	0.5	0.07	0.137	0.02	308	45.2	301	44.2
	R5 03/02/2015	7.22	0.199	0.12	0.095	0.059	47.1	29.4	895	558.5
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
	R3 13/03/2014	7.826	0.462	0.31	0.061	0.04	269	182	585	396
	R4 25/09/2014	2.6	0.5	0.11	0.022	0.0	453	102	124	27.9
	R5 03/02/2015	9.63	0.5	0.41	0.01	0.008	217	181	597	497
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	-
	R3 13/03/2014	-	0.542	-	2.21	-	50.7	-	245	-
	R4 25/09/2014	-	0.145	-	2.9	-	105	-	102	-
	R5 03/02/2015	-	0.563	-	1.74	-	36.8	-	233	-

Notes
- is not measured / calculated

However in some cases the concentrations were significantly lower during low flow conditions, particularly in August 2013. An example includes dissolved zinc in the SW10-Gort-Disc and SW12-Gort-Disc discharges, where values of dissolved zinc in these discharges ranged from 99.9-301 µg/l in low flow to 597-1,040 µg/l in high flow. This difference in the 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 during high flows with reported values of 108 µg/l in April 2013, 245 µg/l in March 2014 and 233 µg/l in February 2015. Concentrations were significantly lower than the assessment criterion in August 2013 with a value of 42.1 µg/l. This was not the case in September 2014 during low flow as dissolved zinc was detected at 102 µg/l, which is likely due to the high concentration of dissolved zinc in SW10-GAR (7,150 µg/l).

Table 29 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August 2013 and September 2014 due to the low flow conditions.

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 30 displays the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevations outside the TMF decreased from 48.95 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.49 m OD 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. The groundwater elevations at TMF1 and TMF2 are similar to the elevations measured on 12/3/2014 and between 0.56 and 0.41 metres higher than the elevations measured in autumn (24/9/2014).

Within the tailings area, measured water levels were in the range of 1.7 to 3.7 m below the top of the tailings surface. 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 48.69 to 54.23 m OD. These groundwater elevations are similar to the elevations measured during high flow (12/3/2014) which ranged from 48.69 to 54.24 m OD and between 0.1 to 1.2 metres higher than the elevations measured during low flow (24/9/2014).

Table 30 Measures Groundwater Levels February 2015

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	02/02/2015	11:55	0.05	0.64	48.95
TMF2		02/02/2015	15:15	1.51	1.97	46.49
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	02/02/2015	16:35	2.67	3.32	53.09
BH2A-GORT-06		02/02/2015	16:45	2.74	3.27	53.02
BH3A-GORT-06		02/02/2015	17:10	7.91	8.24	48.69
BH4A-GORT-06		02/02/2015	16:55	3.67	4.19	52.49
BH5A-GORT-06		02/02/2015	16:25	2.89	3.32	53.32
BH6A-GORT-06		02/02/2015	16:05	5.21	5.90	50.87
BH6B-GORT-06		02/02/2015	16:15	1.72	2.44	54.23

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

Section 7

Summary and Recommendations

7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in February 2015 and water levels were measured in seven additional monitoring wells. Thirty-two surface water locations were sampled and analysed in February 2015 with flows measured at 22 of the locations. Twenty vegetation samples were collected and analysed in February 2015. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QA/QC samples and laboratory reports were also reviewed. Overall the data quality is considered acceptable and the data can be used to compare to the assessment criteria and for evaluation of loads.

Statistical summaries of the analytical results for 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 had exceedances of the assessment criteria for dissolved barium and manganese, with higher concentrations in the downgradient monitoring well TMF2 (599 and 1,110 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.

- Surface water locations 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 (1.55 and 0.682 µg/l, respectively), which are both below the ecological assessment criteria of 100 µg/l.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. For example, SW12-GAR had the highest concentrations of dissolved nickel (62.5 µg/l) and manganese (372 µg/l). Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l, ranging from 184 to 21,400 µg/l. The majority of locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for dissolved cadmium (ranging from 8.37 to 69.2 µg/l). Dissolved nickel was above both the ecological and human health assessment criteria of 20 µg/l at the majority of locations in Garryard (ranging from 20.5 to 62.5 µg/l).

- At Shallee dissolved lead exceeded the both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations, except SW4-Shal upstream. The highest concentration was from the Field Shaft discharge (SW6-Shal) at 363 µg/l.

- Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the majority of the drainages and discharges ranging from 22.6 to 21,400 µg/l. The concentration of zinc increased on the Kilmastulla River from 0.682 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 261 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee. The concentration at DS-Shal on the Yellow River tributary was significantly higher at 3,230 µg/l.

- The dissolved metal with the highest mass loading was zinc, ranging from 0.57 to 28,400 g/day with an average of 3,250 g/day overall. The largest mass load of zinc was SW3-GAR of 28,400 g/day which is the stream containing the SW10-GAR discharge and the western part of the Mogul yard. The highest load of dissolved lead was from the SW9-Shal downstream of the Shallee mining area with a calculated value of 268 g/day.
- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated lead levels (>50 µg/l).
- No measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium, lead and zinc exceeded the Maximum Content standards or the no effect and low effect levels.

7.2 Recommendations for the Monitoring Programme

Based on the data analysis and above conclusions no recommendations are made at this time. However, it is intended that as an additional item of work all of the data and evaluations for the three year monitoring programme will be reviewed and summarised after the sixth round of sampling and recommendations for the monitoring programme will be made at that stage.

Section 8

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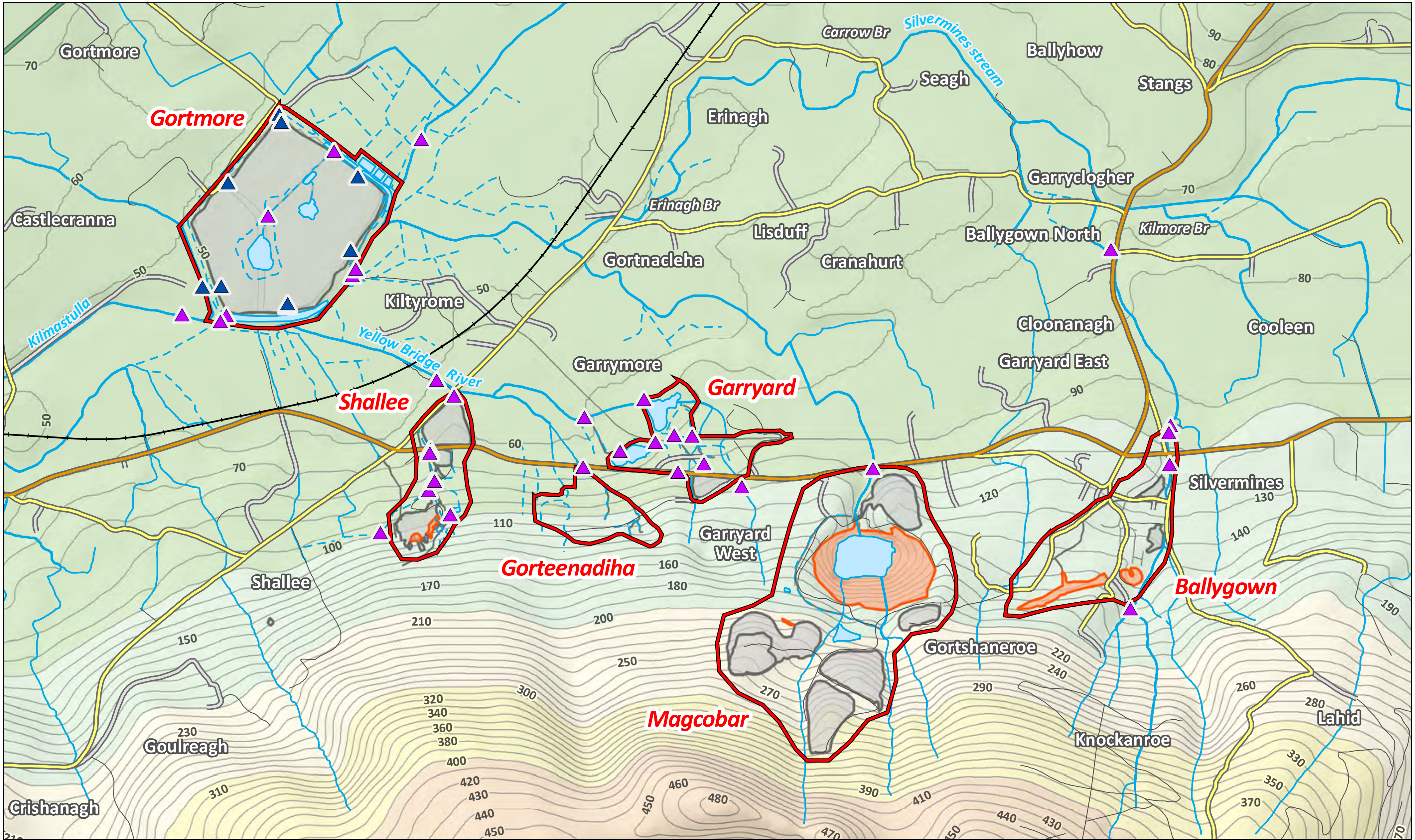
Appendix A

Figures

CDM Smith



Map 1 - Silvermines - Overview

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CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater

- Rivers
- Streams
- Pond / Wetland / Pit Lake

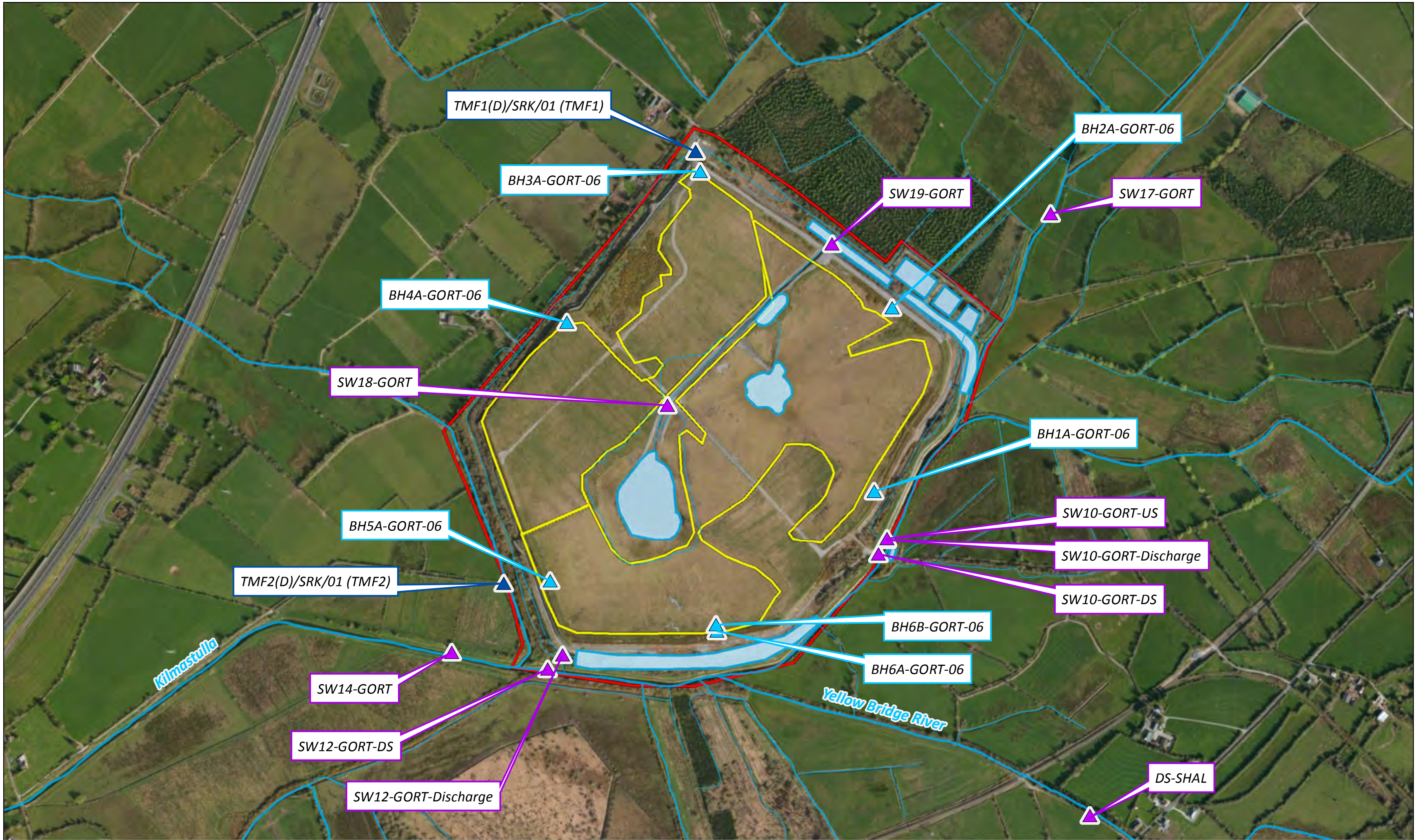
Mines

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

Scale is 1:25,000

0 250 500 1,000 m

N S W E



Map 2 - Silvermines - Gortmore TMF

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Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater
- Groundwater (Levels only)
- Rivers
- Streams
- Pond / Wetland

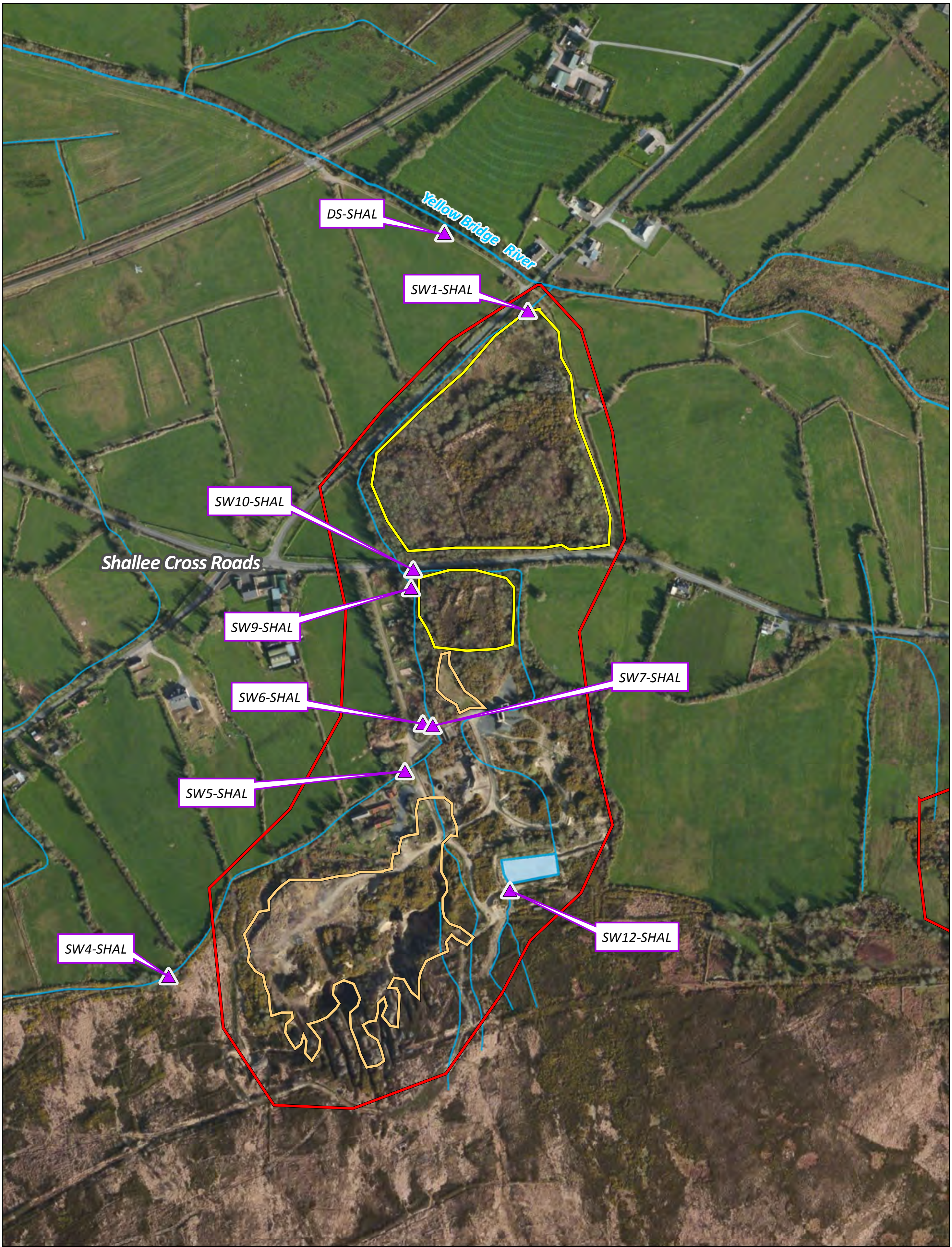
Mines

- Mining Area

Scale is 1:10,000

0 125 250 500 m

N W E S



Map 3 - Silvermines - Shallee South

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Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

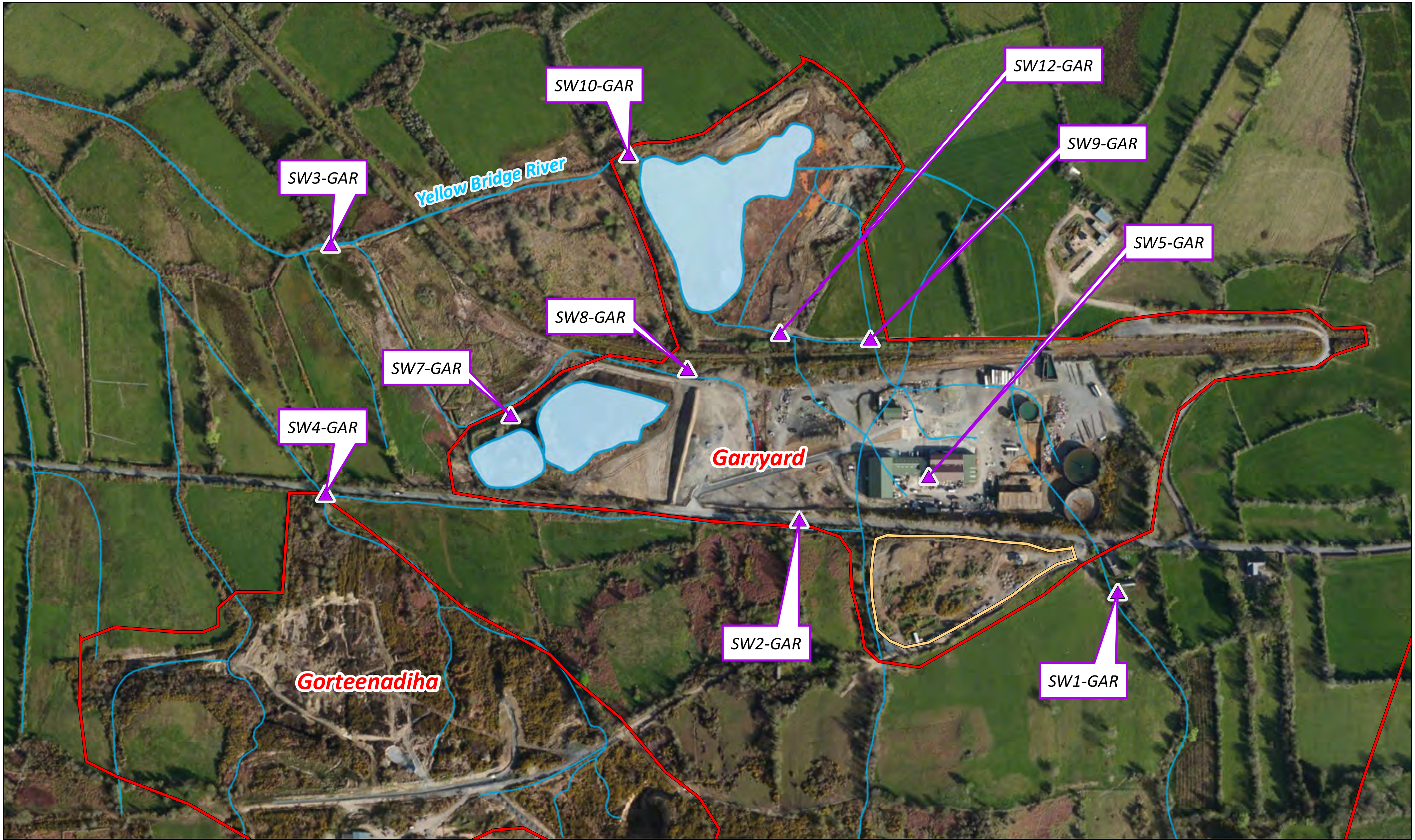
Pond / Wetland

Mines

Mining Area

Tailings / Tailings Pond

Spoil Heap / Waste Drum Dump



Map 4 - Silvermines - Garryard

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Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

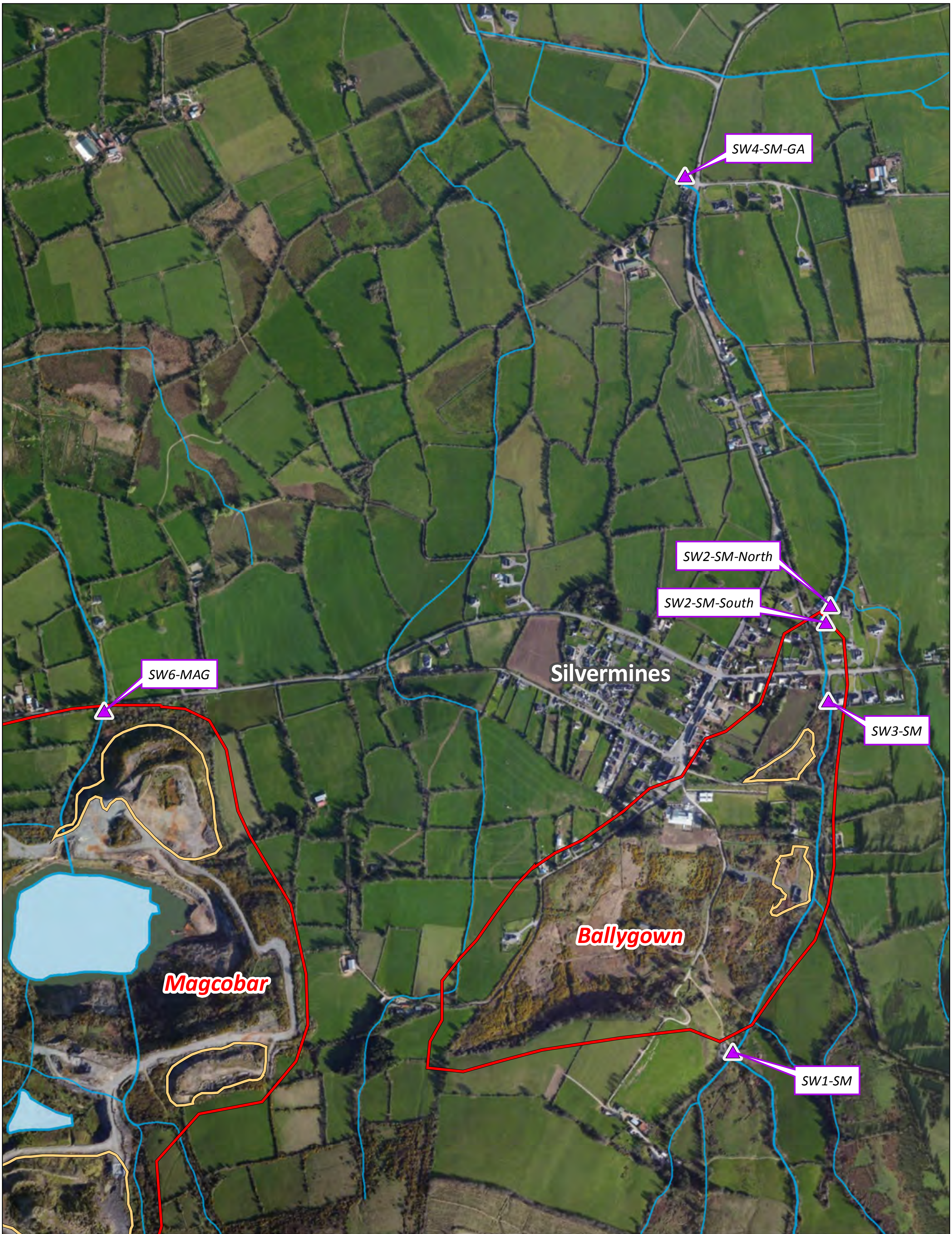
Mining Areas

Stockpile Dump

Scale is 1:5,000

0 50 100 200 m

N W E S



Map 5 - Silvermines - Magcobar and Ballygown

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Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

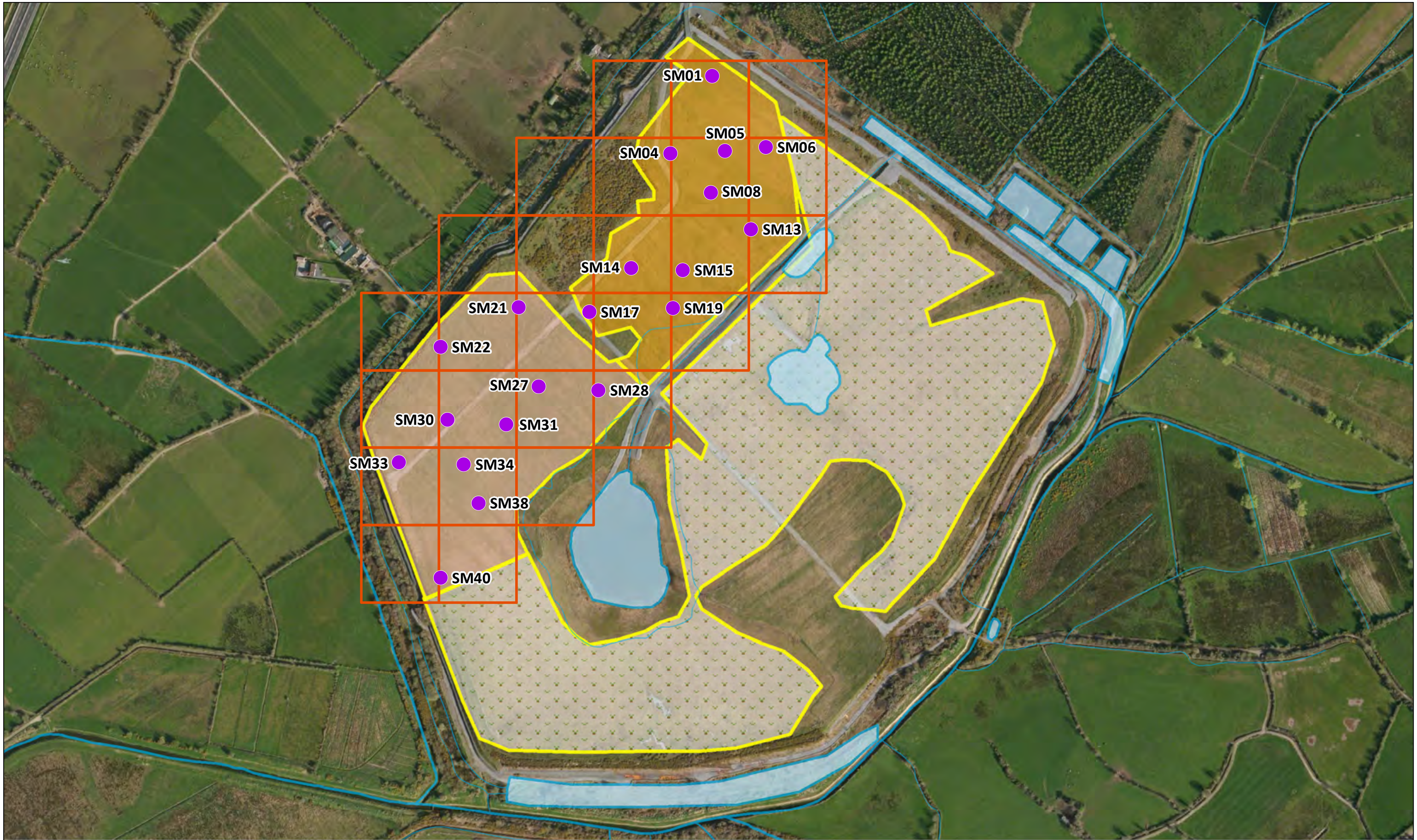
Mining Area

Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:10,000

0 100 200 m



Map 6 - Silvermines - Gortmore - Vegetation

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Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Areas A and B *(vegetation samples)*

Grid *(1 ha)*

Sampling Areas

Sampling Area A

Sampling Area B

Sampling Area GS1 to GS3

Rivers

Streams

Pond / Wetland / Pit Lake

Scale is 1:6,500

0 50 100 200 m

N W E S

Appendix B

Analytical Data Tables and Assessment Criteria

CDM Smith

Table B-1 Comparison of Total versus Dissolved Metals R5

Sample Description	Date Sampled	Suspended solids, Total	Cadmium (tot.unfilt)	Cadmium (diss.filt)	Ratio diss to total Cadmium	Lead (tot.unfilt)	Lead (diss.filt)	Ratio diss to total Lead	Nickel (tot.unfilt)	Nickel (diss.filt)	Ratio diss to total Nickel	Zinc (tot.unfilt)	Zinc (diss.filt)	Ratio diss to total Zinc
	Units	mg/l	µg/l	µg/l		µg/l	µg/l		µg/l	µg/l		µg/l	µg/l	
TMF 1	02/02/2015	-	*0.25*	*0.05*	0.2	1.49	*0.01*	0.0	*0.25*	0.772	3.1	*1.5*	*0.205*	0.1
TMF 2	02/02/2015	-	*0.25*	*0.05*	0.2	24.5	1.3	0.1	3.35	1.59	0.5	9.45	3.24	0.3
DISC.	03/02/2015	<2	*0.25*	0.199	0.8	*0.25*	0.095	0.4	8.3	7.08	0.9	1160	895	0.8
DS	03/02/2015	5	*0.25*	0.121	0.5	5.76	0.298	0.1	2.88	1.62	0.6	86.8	64.2	0.7
U/S	03/02/2015	5.5	*0.25*	0.103	0.4	3.47	0.324	0.1	4.02	1.46	0.4	50.7	45.8	0.9
DISC.	03/02/2015	2	0.6	0.49	0.8	*0.25*	*0.01*	0.0	11.4	7.28	0.6	739	597	0.8
DS	03/02/2015	4.5	0.741	0.616	0.8	8.59	2.11	0.2	3.18	2.32	0.7	310	261	0.8
SW14-GORT	03/02/2015	4.5	0.525	0.563	1.1	5.86	1.74	0.3	3.38	2.09	0.6	252	233	0.9
SW17-GORT	03/02/2015	8	*0.25*	*0.05*	0.2	0.512	0.029	0.1	*0.25*	0.903	3.6	*1.5*	0.682	0.5
SW18-GORT	03/02/2015	<2	1.45	1.31	0.9	14.8	7.66	0.5	4.3	4.45	1.0	662	583	0.9
SW19-GORT	03/02/2015	<2	0.992	1.07	1.1	3.03	1.08	0.4	4.85	5.44	1.1	856	729	0.9
SW10-GAR	04/02/2015	<2	36.2	30.1	0.8	4.18	1.21	0.3	50.2	40.9	0.8	12800	13000	1.0
SW12-GAR	04/02/2015	<2	28.7	26.2	0.9	7.16	0.322	0.0	73.4	62.5	0.9	15200	13900	0.9
SW1-GAR	04/02/2015	2	8.66	8.66	1.0	12.7	2.14	0.2	56.1	40.3	0.7	6590	5520	0.8
SW2-GAR	04/02/2015	3.5	73.3	69.2	0.9	285	152	0.5	76	55.3	0.7	24400	21400	0.9
SW3-GAR	04/02/2015	2.5	28	25.9	0.9	7.18	2.06	0.3	48.1	34.2	0.7	12400	10200	0.8
SW4-GAR	04/02/2015	<2	0.987	0.958	1.0	23.7	19.7	0.8	4.39	2.42	0.6	274	184	0.7
SW5-GAR	04/02/2015	<2	30.4	25.6	0.8	5.08	0.153	0.0	78.6	61.6	0.8	16400	12600	0.8
SW7-GAR	04/02/2015	<2	10.5	8.37	0.8	1.05	0.369	0.4	27.2	20.5	0.8	7080	5610	0.8
SW8-GAR	04/02/2015	<2	20.1	20.3	1.0	2.17	0.91	0.4	65.8	45.9	0.7	17600	15600	0.9
SW9-GAR	04/02/2015	<2	29.3	23.7	0.8	5.91	2.42	0.4	56.7	40.8	0.7	14000	11000	0.8
DS-Shal	05/02/2015	<2	9.06	7.97	0.9	59.2	38.7	0.7	16.4	15	0.9	3310	3230	1.0
SW12-SHAL	05/02/2015	<2	*0.25*	*0.05*	0.2	51.1	45.2	0.9	1.18	1.43	1.2	24.9	22.6	0.9
SW1-SHAL	05/02/2015	<2	2.08	2.14	1.0	242	209	0.9	11.7	10.3	0.9	640	548	0.9
SW4-SHAL	05/02/2015	<2	0.57	0.543	1.0	2.3	1.08	0.5	5.93	5.19	0.9	106	87.9	0.8
SW5-SHAL	05/02/2015	4	27.2	21.3	0.8	135	27.4	0.2	78.9	56.4	0.7	12500	9320	0.7
SW6-MAG	05/02/2015	<2	2.13	1.75	0.8	5.57	0.032	0.0	14.5	11.5	0.8	1070	921	0.9
SW6--SHAL	05/02/2015	<2	1.5	1.16	0.8	432	363	0.8	11.4	8.1	0.7	286	223	0.8
SW9-SHAL	05/02/2015	<2	2.34	2.07	0.9	323	285	0.9	11.9	10.5	0.9	638	538	0.8
SW1-SM	06/02/2015	<2	*0.25*	*0.05*	0.2	*0.25*	*0.01*	0.0	*0.25*	0.475	1.9	*1.5*	1.55	1.0
NORTH	06/02/2015	<2	6.36	5.18	0.8	1.6	1.17	0.7	9.75	7.54	0.8	2280	2070	0.9
SOUTH	06/02/2015	<2	6.01	5.45	0.9	1.48	1.11	0.8	10.8	7.5	0.7	2540	2140	0.8
SW3-SM	06/02/2015	<2	*0.25*	0.24	1.0	2.13	0.99	0.5	1.69	0.887	0.5	125	83.7	0.7
SW4-SM-GA	06/02/2015	<2	0.795	0.641	0.8	2.5	1.36	0.5	3.28	1.6	0.5	351	244	0.7

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

Table B-2 Comparison of Groundwater and Surface Water Results to Assessment Criteria R5

Sample Description	Type	Area	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	-
TMF 1	GW	GM	02/02/2015	-	217	265	0.1	13.5	-	0.458	0.025	216	0.25	0.15	0.025	7.4	7.43	0.01	13.2	10.6	-
TMF 2	GW	GM	02/02/2015	-	250	305	0.1	18	-	0.509	0.025	275	0.25	0.15	0.025	1.6	7.07	0.01	2.8	10.6	-
SW1-SM	River/Stream	BG	06/02/2015	2	50	61	0.1	12.4	3.5	0.157	0.025	121	0.25	2.13	0.025	90.4	7.38	0.0277	5.7	6.66	1
SW3-SM	River/Stream	BG	06/02/2015	5.48	75	92	0.1	12.2	3.5	0.194	0.025	102	0.25	2.21	0.025	95.2	7.17	0.01	7.3	7.03	1
SW2-SM-SOUTH	Discharge	BG	06/02/2015	11	235	287	0.1	13.8	3.5	0.54	0.025	279	0.25	6.31	0.025	55.6	7.06	0.01	32.2	8.2	1
SW2-SM-NORTH	Discharge	BG	06/02/2015	9.13	235	287	0.1	13.9	3.5	0.541	0.025	318	0.25	6.17	0.025	72.6	9.2	0.01	31	7.53	1
SW4-SM-GA	River/Stream	BG	06/02/2015	5.48	125	153	0.209	14.8	3.5	0.312	0.025	186	0.25	5.94	0.025	90	6.42	0.0496	12.8	8.77	1
SW6-MAG	River/Stream	Mag	05/02/2015	2	41	50	0.1	10.3	7.51	0.529	0.025	345	0.25	1.27	0.025	81	7.2	0.01	209	5.86	1
SW18-GORT	Drainage	GM	03/02/2015	5.48	90	110	0.1	16.3	3.5	0.72	0.025	496	0.25	0.15	0.025	96.1	6.88	0.01	279	7.3	1
SW19-GORT	Drainage	GM	03/02/2015	2	85	104	0.1	16.6	3.5	0.801	0.025	587	0.25	0.15	0.025	97	7.64	0.01	333	7.46	1
SW17-GORT	River/Stream	GM	03/02/2015	5.48	135	165	0.1	34.9	16.5	0.411	0.025	253	0.25	21.5	0.074	92.7	7.6	0.03	12.9	17.8	8
SW10-GORT-US	River/Stream	GM	03/02/2015	9.13	195	238	0.1	24.8	13.6	0.497	0.025	303	0.25	15.9	0.025	92.5	7.95	0.0202	26.8	12.7	5.5
SW10-GORT-DISC.	Discharge	GM	03/02/2015	5.48	110	134	0.1	15	11.2	1.003	0.025	770	0.25	0.459	0.025	78	7.42	0.01	448	6.74	1
SW10-GORT-DS	River/Stream	GM	03/02/2015	5.48	195	238	0.1	25.6	10	1.154	0.025	308	0.25	15.5	0.025	65.1	7.72	0.01	42.8	12.3	5
SW12-GORT-DISC.	Discharge	GM	03/02/2015	11	205	250	0.1	20.3	16.8	1.154	0.025	878	0.25	19	0.064	65.1	7.12	0.01	440	9.48	2
SW12-GORT-DS	River/Stream	GM	03/02/2015	5.48	195	238	0.1	24.8	11.5	0.531	0.025	303	0.25	14.4	0.025	93.8	7.72	0.01	45.4	12.1	4.5
SW14-GORT	River/Stream	GM	03/02/2015	5.48	180	220	0.1	23.6	13.4	0.48	0.025	280	0.25	14.9	0.025	94.9	7.74	0.0222	38.8	12	4.5
SW1-GAR	River/Stream	GAR	04/02/2015	5.48	50	61	0.1	12	3.5	1.615	0.025	1430	1.09	0.822	0.025	98.3	7.3	0.01	897	6.84	2
SW2-GAR	Drainage	GAR	04/02/2015	27.4	85	104	0.1	43.6	3.5	1.117	0.025	890	2.13	3.28	0.025	65.3	7.25	0.01	486	25	3.5
SW4-GAR	River/Stream	GAR	04/02/2015	5.48	27	33	0.1	12.6	3.5	0.143	0.025	64	0.25	1.22	0.025	98.2	8	0.01	14.7	7.14	1
SW5-GAR	Discharge	GAR	04/02/2015	16.4	185	226	0.1	13	3.5	0.847	0.025	656	2.45	0.411	0.025	61	7.43	0.01	309	7.75	1
SW7-GAR	Drainage	GAR	04/02/2015	9.13	85	104	0.1	19.6	3.5	0.824	0.025	654	1.14	0.826	0.025	94.9	8.17	0.01	340	10.7	1
SW12-GAR	Drainage	GAR	04/02/2015	9.13	190	232	0.1	13.7	3.5	0.967	0.025	723	2.22	0.646	0.025	96.5	8.14	0.01	364	7.81	1
SW8-GAR	Drainage	GAR	04/02/2015	16.4	165	201	0.1	18.4	3.5	1.52	0.025	1390	2.33	1.54	0.025	87.3	7.92	0.01	729	10.4	1
SW9-GAR	Drainage	GAR	04/02/2015	16.4	145	177	0.1	15.3	3.5	1.567	0.025	1400	2.05	2.09	0.025	97.2	8.17	0.01	804	8.67	1
SW10-GAR	Discharge	GAR	04/02/2015	7.3	185	226	0.1	13.9	3.5	0.954	0.025	708	1.75	1.52	0.025	97.9	8.19	0.01	351	7.64	1
SW3-GAR	River/Stream	GAR	04/02/2015	12.8	180	220	0.1	15	3.5	0.938	0.025	722	1.99	1.88	0.025	101.9	8.32	0.01	348	8.54	2.5
SW4-SHAL	River/Stream	ShS	05/02/2015	2	50	61	0.1	13.5	3.5	0.145	0.025	60	0.25	0.81	0.025	63.3	6.82	0.01	3.4	7.29	1
SW5-SHAL	River/Stream	ShS	05/02/2015	11	22.5	27	0.1	11.9	3.5	0.31	0.025	148	1.61	1.36	0.025	79.9	5.6	0.01	103	6.73	4
SW6-SHAL	Discharge	ShS	05/02/2015	2	41	50	0.551	11	3.5	0.147	0.025	60	0.25	1.55	0.025	47.1	6.44	0.01	12	6.17	1
SW12-SHAL	Drainage	ShS	05/02/2015	5.48	2.5	3	0.1	10.4	3.5	0.05	0.025	5	0.25	0.507	0.025	77.3	3.99	0.01	1	5.82	1
SW9-SHAL	River/Stream	ShS	05/02/2015	5.48	50	61	0.1	11.2	3.5	0.179	0.025	87	0.25	1.53	0.025	79.6	7.29	0.01	18.9	5.91	1
SW1-SHAL	River/Stream	ShS	05/02/2015	2	60	73	0.1	11.2	3.5	0.195	0.025	95	0.25	1.41	0.025	78.2	7.58	0.01	21.7	6.47	1
DS-Shal	River/Stream	ShS	05/02/2015	7.3	115	140	0.1	13.3	3.5	0.518	0.025	332	0.25	1.22	0.025	79.1	7.69	0.01	136	7.57	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 R5

Sample Description	Type	Area	Date Sampled Units	Aluminium (diss.filt) µg/l	Antimony (diss.filt) µg/l	Arsenic (diss.filt) µg/l	Barium (diss.filt) µg/l	Cadmium (diss.filt) µg/l	Chromium (diss.filt) µg/l	Cobalt (diss.filt) µg/l	Copper (diss.filt) µg/l	Iron (diss.filt) µg/l	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Mercury (diss.filt) µg/l	Molybdenum (diss.filt) µg/l	Nickel (diss.filt) µg/l	Selenium (diss.filt) µg/l	Silver (diss.filt) µg/l	Thallium (diss.filt) µg/l	Tin (diss.filt) µg/l	Uranium (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) 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**	**-**	**-**	**-**	**-**	**-**	**-**
TMF 1	GW	GM	02/02/2015	*1.45*	0.755	3.65	139	*0.05*	0.717	0.233	*0.425*	199	*0.01*	86.5	*0.005*	0.393	0.772	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	*0.205*
TMF 2	GW	GM	02/02/2015	*1.45*	0.97	4.24	599	*0.05*	1.32	0.668	*0.425*	186	1.38	1110	*0.005*	0.499	1.59	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.269	5.9
SW1-SM	River/Stream	BG	06/02/2015	*1.45*	1.31	0.191	47.3	*0.05*	0.633	*0.03*	*0.425*	*9.5*	*0.01*	7.34	*0.005*	0.808	0.475	*0.195*	*0.75*	*0.48*	1.47	*0.75*	*0.12*	1.55
SW3-SM	River/Stream	BG	06/02/2015	*1.45*	*0.08*	*0.06*	61.2	0.24	0.612	*0.03*	*0.425*	*9.5*	0.99	2.88	*0.005*	*0.12*	0.887	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	83.7
SW2-SM-SOUTH	Discharge	BG	06/02/2015	*1.45*	*0.08*	0.217	148	5.45	1.88	0.095	*0.425*	*9.5*	1.11	1.02	*0.005*	*0.12*	7.5	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.482	2140
SW2-SM-NORTH	Discharge	BG	06/02/2015	*1.45*	0.609	0.205	168	5.18	1.33	0.072	*0.425*	*9.5*	1.25	0.277	*0.005*	0.721	7.54	*0.195*	*0.75*	*0.48*	0.794	*0.75*	0.272	2070
SW4-SM-GA	River/Stream	BG	06/02/2015	*1.45*	4.44	0.446	119	0.641	1.2	*0.03*	*0.425*	*9.5*	1.36	3.69	*0.005*	1.3	1.6	2.35	*0.75*	*0.48*	*0.18*	*0.75*	0.318	244
SW6-MAG	River/Stream	Mag	05/02/2015	6.86	2.31	*0.06*	39.7	1.75	*0.11*	0.752	6.69	*9.5*	0.032	65.2	*0.005*	1.05	11.5	*0.195*	*0.75*	*0.48*	1.33	*0.75*	*0.12*	921
SW18-GORT	Drainage	GM	03/02/2015	*1.45*	3.63	0.349	13.3	1.31	0.552	0.153	3.56	*9.5*	7.66	10.7	*0.005*	*0.12*	4.45	*0.195*	*0.75*	4.92	*0.18*	*0.75*	*0.12*	583
SW19-GORT	Drainage	GM	03/02/2015	*1.45*	4.75	0.379	14.1	1.07	0.357	0.115	2.6	*9.5*	1.08	8.43	*0.005*	0.727	5.44	0.502	*0.75*	5.81	1.08	*0.75*	*0.12*	729
SW17-GORT	River/Stream	GM	03/02/2015	5.12	0.942	0.404	186	*0.05*	0.575	0.127	*0.425*	30.6	0.029	46.5	*0.005*	*0.12*	0.903	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.284	0.682
SW10-GORT-US	River/Stream	GM	03/02/2015	10.1	3.4	0.446	142	0.103	0.869	0.108	*0.425*	30	0.324	33.3	*0.005*	0.327	1.46	0.402	*0.75*	*0.48*	0.8	*0.75*	0.246	45.8
SW10-GORT-DISC.	Discharge	GM	03/02/2015	*1.45*	1.99	0.189	12.9	0.199	0.281	0.137	1.76	*9.5*	0.095	47.1	*0.005*	*0.12*	7.08	*0.195*	*0.75*	2.01	*0.18*	*0.75*	*0.12*	895
SW10-GORT-DS	River/Stream	GM	03/02/2015	6.53	6.23	0.423	138	0.121	1.19	0.117	*0.425*	23.1	0.298	34.1	*0.005*	0.42	1.62	*0.195*	*0.75*	*0.48*	1.03	*0.75*	0.253	64.2
SW12-GORT-DISC.	Discharge	GM	03/02/2015	*1.45*	0.772	0.296	194	0.49	1.1	0.469	1.84	20.8	*0.01*	217	*0.005*	*0.12*	7.28	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.344	597
SW12-GORT-DS	River/Stream	GM	03/02/2015	*1.45*	1.23	0.355	153	0.616	0.959	0.192	1.06	24	2.11	40	*0.005*	*0.12*	2.32	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.334	261
SW14-GORT	River/Stream	GM	03/02/2015	3.41	0.599	0.339	148	0.563	0.856	0.17	1	34.1	1.74	36.8	*0.005*	*0.12*	2.09	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.284	233
SW1-GAR	River/Stream	GAR	04/02/2015	*1.45*	*0.08*	*0.06*	24.3	8.66	0.554	0.519	4.63	*9.5*	2.18	40.2	*0.005*	0.585	40.3	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	5520
SW2-GAR	Drainage	GAR	04/02/2015	*1.45*	*0.08*	*0.06*	20.5	69.2	0.318	1.1	9.59	*9.5*	152	86.3	*0.005*	*0.12*	55.3	*0.195*	*0.75*	2.11	*0.18*	*0.75*	*0.12*	21400
SW4-GAR	River/Stream	GAR	04/02/2015	4.17	*0.08*	0.132	204	0.958	0.522	0.453	7.19	30.1	19.7	42.3	*0.005*	*0.12*	2.42	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	184
SW5-GAR	Discharge	GAR	04/02/2015	*1.45*	2.82	0.434	21.3	25.6	*0.11*	4.66	4.9	*9.5*	0.153	382	*0.005*	0.965	61.6	*0.195*	*0.75*	1.86	0.958	*0.75*	*0.12*	12600
SW7-GAR	Drainage	GAR	04/02/2015	*1.45*	*0.08*	0.365	65.3	8.37	0.372	0.209	2.71	*9.5*	0.369	56.1	*0.005*	0.724	20.5	1.15	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	5610
SW12-GAR	Drainage	GAR	04/02/2015	*1.45*	3.6	*0.06*	21.4	26.2	0.512	4.44	5.17	*9.5*	0.322	372	*0.005*	0.542	62.5	*0.195*	*0.75*	*0.48*	0.467	*0.75*	*0.12*	13900
SW8-GAR	Drainage	GAR	04/02/2015	*1.45*	2.63	0.392	14.4	20.3	0.884	0.889	2.26	64.8	0.91	280	*0.005*	1.34	45.9	0.718	*0.75*	3.44	2.3	*0.75*	*0.12*	15600
SW9-GAR	Drainage	GAR	04/02/2015	*1.45*	1.44	0.403	14.9	23.7	1.07	0.896	5.36	38	2.42	107	*0.005*	1.38	40.8	0.57	*0.75*	1.39	1.26	*0.75*	0.242	11000
SW10-GAR	Discharge	GAR	04/02/2015	3.13	4.49	*0.06*	23.1	30.1	0.503	2.07	4.01	*9.5*	1.21	148	*0.005*	0.972	40.9	*0.195*	*0.75*	1.19	2.07	*0.75*	*0.12*	13000
SW3-GAR	River/Stream	GAR	04/02/2015	*1.45*	0.673	0.224	28.5	25.9	1.13	1.77	2.72	*9.5*	2.06	193	*0.005*	0.26	34.2	*0.195*	*0.75*	1.15	*0.18*	*0.75*	0.253	10200
SW4-SHAL	River/Stream	ShS	05/02/2015	2.96	6.2	*0.06*	336	0.543	0.398	0.231	1.02	*9.5*	1.08	45.7	*0.005*	1.39	5.19	*0.195*	*0.75*	*0.48*	3.5	*0.75*	*0.12*	87.9
SW5-SHAL	River/Stream	ShS	05/02/2015	39.5	2.66	0.202	283	21.3	0.408	5.19	18.3	23.3	27.4	773	*0.005*	1.09	56.4	*0.195*	*0.75*	*0.48*	2.49	*0.75*	*0.12*	9320
SW6-SHAL	Discharge	ShS	05/02/2015	29.1	0.668	0.862	223	1.16	0.392	1.86	16.2	52.1	363	65.3	*0.005*	0.504	8.1	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	223
SW12-SHAL	Drainage	ShS	05/02/2015	49.2	0.895	*0.06*	244	*0.05*	0.411	0.364	1.11	28.4	45.2	68.5	*0.005*	0.26	1.43	*0.195*	*0.75*	*0.48*	0.411	*0.75*	*0.12*	22.6
SW9-SHAL	River/Stream	ShS	05/02/2015	30.6	2.74	0.676	221	2.12	0.496	1.66	13.6	40.5	285	57.9	*0.005*	0.371	10.5	*0.195*	*0.75*	*0.48*	0.734	*0.75*	*0.12*	538
SW1-SHAL	River/Stream	ShS	05/02/2015	31.7	2.14	0.201	221	2.14	0.234	1.56	10.5	79.4	209	80.5	*0.005*	*0.12*	10.3	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	548
DS-Shal	River/Stream	ShS	05/02/2015	10.5	1.42	*0.06*	164	7.97	0.494	0.911	7.43	22.4	38.7	87.7	*0.005*	0.254	15	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	3230

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 Surface Water Results to Assessment Criteria for Livestock Drinking Water R5

Sample Description	Area	Type	Date Sampled	Dissolved solids, Total	Fluoride	Sulphate	Aluminium (diss.filt)	Arsenic (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Lead (diss.filt)	Mercury (diss.filt)	Selenium (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Livestock Criteria				1000	2	500	5000	200	50	1000	1000	500	100	10	50	100	24000
SW1-SM	River/Stream	BG	06/02/2015	121	*0.25*	5.7	*1.45*	0.191	*0.05*	0.633	*0.03*	*0.425*	*0.01*	*0.005*	*0.195*	*0.12*	1.55
SW3-SM	River/Stream	BG	06/02/2015	102	*0.25*	7.3	*1.45*	*0.06*	0.24	0.612	*0.03*	*0.425*	0.99	*0.005*	*0.195*	*0.12*	83.7
SW2-SM-NORTH	Discharge	BG	06/02/2015	318	*0.25*	31	*1.45*	0.205	5.18	1.33	0.072	*0.425*	1.25	*0.005*	*0.195*	0.272	2070
SW2-SM-SOUTH	Discharge	BG	06/02/2015	279	*0.25*	32.2	*1.45*	0.217	5.45	1.88	0.095	*0.425*	1.11	*0.005*	*0.195*	0.482	2140
SW4-SM-GA	River/Stream	BG	06/02/2015	186	*0.25*	12.8	*1.45*	0.446	0.641	1.2	*0.03*	*0.425*	1.36	*0.005*	2.35	0.318	244
SW6-MAG	River/Stream	Mag	05/02/2015	345	*0.25*	209	6.86	*0.06*	1.75	*0.11*	0.752	6.69	0.032	*0.005*	*0.195*	*0.12*	921
SW18-GORT	Drainage	GM	03/02/2015	496	*0.25*	279	*1.45*	0.349	1.31	0.552	0.153	3.56	7.66	*0.005*	*0.195*	*0.12*	583
SW19-GORT	Drainage	GM	03/02/2015	587	*0.25*	333	*1.45*	0.379	1.07	0.357	0.115	2.6	1.08	*0.005*	0.502	*0.12*	729
SW17-GORT	River/Stream	GM	03/02/2015	253	*0.25*	12.9	5.12	0.404	*0.05*	0.575	0.127	*0.425*	0.029	*0.005*	*0.195*	0.284	0.682
SW10-GORT-US	River/Stream	GM	03/02/2015	303	*0.25*	26.8	10.1	0.446	0.103	0.869	0.108	*0.425*	0.324	*0.005*	0.402	0.246	45.8
SW10-GORT-DISC.	Discharge	GM	03/02/2015	770	*0.25*	448	*1.45*	0.189	0.199	0.281	0.137	1.76	0.095	*0.005*	*0.195*	*0.12*	895
SW10-GORT-DS	River/Stream	GM	03/02/2015	308	*0.25*	42.8	6.53	0.423	0.121	1.19	0.117	*0.425*	0.298	*0.005*	*0.195*	0.253	64.2
SW12-GORT-DISC.	Discharge	GM	03/02/2015	878	*0.25*	440	*1.45*	0.296	0.49	1.1	0.469	1.84	*0.01*	*0.005*	*0.195*	0.344	597
SW12-GORT-DS	River/Stream	GM	03/02/2015	303	*0.25*	45.4	*1.45*	0.355	0.616	0.959	0.192	1.06	2.11	*0.005*	*0.195*	0.334	261
SW14-GORT	River/Stream	GM	03/02/2015	280	*0.25*	38.8	3.41	0.339	0.563	0.856	0.17	1	1.74	*0.005*	*0.195*	0.284	233
SW1-GAR	River/Stream	GAR	04/02/2015	1430	1.09	897	*1.45*	*0.06*	8.66	0.554	0.519	4.63	2.18	*0.005*	*0.195*	*0.12*	5520
SW2-GAR	Drainage	GAR	04/02/2015	890	2.13	486	*1.45*	*0.06*	69.2	0.318	1.1	9.59	152	*0.005*	*0.195*	*0.12*	21400
SW4-GAR	River/Stream	GAR	04/02/2015	64	*0.25*	14.7	4.17	0.132	0.958	0.522	0.453	7.19	19.7	*0.005*	*0.195*	*0.12*	184
SW5-GAR	Discharge	GAR	04/02/2015	656	2.45	309	*1.45*	0.434	25.6	*0.11*	4.66	4.9	0.153	*0.005*	*0.195*	*0.12*	12600
SW7-GAR	Drainage	GAR	04/02/2015	654	1.14	340	*1.45*	0.365	8.37	0.372	0.209	2.71	0.369	*0.005*	1.15	*0.12*	5610
SW12-GAR	Drainage	GAR	04/02/2015	723	2.22	364	*1.45*	*0.06*	26.2	0.512	4.44	5.17	0.322	*0.005*	*0.195*	*0.12*	13900
SW8-GAR	Drainage	GAR	04/02/2015	1390	2.33	729	*1.45*	0.392	20.3	0.884	0.889	2.26	0.91	*0.005*	0.718	*0.12*	15600
SW9-GAR	Drainage	GAR	04/02/2015	1400	2.05	804	*1.45*	0.403	23.7	1.07	0.896	5.36	2.42	*0.005*	0.57	0.242	11000
SW10-GAR	Discharge	GAR	04/02/2015	708	1.75	351	3.13	*0.06*	30.1	0.503	2.07	4.01	1.21	*0.005*	*0.195*	*0.12*	13000
SW3-GAR	River/Stream	GAR	04/02/2015	722	1.99	348	*1.45*	0.224	25.9	1.13	1.77	2.72	2.06	*0.005*	*0.195*	0.253	10200
SW4-SHAL	River/Stream	ShS	05/02/2015	60	*0.25*	3.4	2.96	*0.06*	0.543	0.398	0.231	1.02	1.08	*0.005*	*0.195*	*0.12*	87.9
SW5-SHAL	River/Stream	ShS	05/02/2015	148	1.61	103	39.5	0.202	21.3	0.408	5.19	18.3	27.4	*0.005*	*0.195*	*0.12*	9320
SW6-SHAL	Discharge	ShS	05/02/2015	60	*0.25*	12	29.1	0.862	1.16	0.392	1.86	16.2	363	*0.005*	*0.195*	*0.12*	223
SW12-SHAL	Drainage	ShS	05/02/2015	*5*	*0.25*	*1*	49.2	*0.06*	*0.05*	0.411	0.364	1.11	45.2	*0.005*	*0.195*	*0.12*	22.6
SW9-SHAL	River/Stream	ShS	05/02/2015	87	*0.25*	18.9	30.6	0.676	2.12	0.496	1.66	13.6	285	*0.005*	*0.195*	*0.12*	538
SW1-SHAL	River/Stream	ShS	05/02/2015	95	*0.25*	21.7	31.7	0.201	2.14	0.234	1.56	10.5	209	*0.005*	*0.195*	*0.12*	548
DS-Shal	River/Stream	ShS	05/02/2015	332	*0.25*	136	10.5	*0.06*	7.97	0.494	0.911	7.43	38.7	*0.005*	*0.195*	*0.12*	3230

xx Exceeds Livestock Assessment Criteria

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 R5

	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	0.23	0.152	1.7	35.88
SM04-V	0.11	0.089	0.6	29.34
SM05-V	*0.05*	0.041	0.4	23.97
SM06-V	*0.05*	0.063	0.6	27.69
SM08-V	*0.05*	0.037	0.4	23.97
SM13-V	0.17	0.052	2.4	26.71
SM14-V	0.10	0.087	0.8	28.12
SM15-V	*0.05*	0.056	0.7	26.95
SM17-V	*0.05*	0.054	0.8	24.87
SM19-V	*0.05*	0.054	0.4	24.19
SM21-V	*0.05*	0.068	0.4	32.15
SM22-V	0.33	0.106	2.4	28.32
SM27-V	*0.050*	0.060	0.8	29.86
SM28-V	*0.05*	0.044	0.4	27.64
SM30-V	*0.05*	0.032	0.4	25.86
SM31-V	*0.05*	0.032	0.4	24.59
SM33-V	0.48	0.098	2.5	34.78
SM34-V	0.11	0.057	1.3	21.72
SM38-V	*0.05*	0.033	0.46	22.12
SM40-V	0.225	0.042	1.94	25.51

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