Department of Communications, Energy & Natural Resources

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

Silvermines Monitoring Report - Round 2 (2015)

Final

CDM Smith

GWP consultants
earth & water resources

Document Control Sheet

Client	Department of Communications, Energy and Natural Resources			
Project	Environmental Monitoring of Former Mining Areas of Silvermines and Avoca			
Project No	95735			
Report	Monitoring Report for the Former Mining Area of Silvermines – August 2015			
Document Reference:	95735/40/DG23			
Version	**Author**	**Checked**	**Reviewed**	**Date**
1	P Barrett	R O'Carroll	R L Olsen	Dec 2015

Distribution	**Copy No.**

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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/DG22, dated September 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 Stream) and flows north through the Ballygown mining area. The river then flows west towards the Gortmore TMF which is located to the north of the river. The river is located northwest of the other main areas of previous mining activity including Shallee, Garryard and Magcobar. Streams from Shallee and Garryard drain into the Yellow Bridge River which discharges to the Kilmastulla River at the south-eastern corner of Gortmore TMF.

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

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

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

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

Gortmore TMF is some 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 24 August 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 which were in addition to the nine 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 bgl)	Screen Interval (m bgl)
TMF1(D)/SRK/01 (TMF1)	179826	173165	Yes	Yes	23	22-23
TMF2(D)/SRK/01 (TMF2)	179445	172307	Yes	Yes	18	none
BH1A-GORT-06	180181	172490	Yes	No	8.8	5.5 - 8.8
BH2A-GORT-06	180216	172855	Yes	No	10	7 - 10
BH3A-GORT-06	179835	173126	Yes	No	10	7 - 10
BH4A-GORT-06	179570	172826	Yes	No	10	7 - 10
BH5A-GORT-06	179537	172312	Yes	No	10	7 - 10
BH6A-GORT-06	179868	172212	Yes	No	10	7 - 10
BH6B-GORT-06	179867	172225	Yes	No	5	3 - 5

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

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

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

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

Exceptions applied to both monitoring wells in August 2015:

- 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.

- TMF2 borehole borehole was blocked off with silage bales and due to health and safety concerns low flow sampling was not possible. The borehole was sampled using a disposable bailer and the sample was collected after three volumes of the well (calculated as $\pi r^2 h$; r is the inner casing radius and h is the height of the water column) had been purged and the field parameters had stabilised.

Water Level

Groundwater levels were measured at the two wells and seven additional wells (Table 1) located within the TMF near its perimeter from the tailings surface, using a portable electronic water level recorder. Groundwater level data are contained in Appendix C of the Data Report and discussed in Section 6.

2.1.2 Surface Water Sampling

Twenty-eight surface water locations were sampled between 25 and 28 August 2015, as listed in Table 2 and shown on Maps 2 to 5 in Appendix A. Six samples could not be obtained because the stream bed was dry at SW18-Gort, SW19-Gort, SW7-SHAL, SW10-SHAL, SW1-GAR and SW2-GAR. A partial sample[1] could only be obtained at SW5-SHAL due to low flow conditions.

Surface water sampling was conducted consistent with the Surface Water Sampling Procedure (SOP 1-1) as detailed in the Monitoring Plan. The predetermined surface water sampling locations were located in the field using a GPS. Photographs were taken of the surface water sampling location (Appendix D of the Data Report). Samples were grab samples collected from a well-mixed portion of the water stream where possible. The sample location was approached from downstream so that the underlying sediments are not disturbed.

[1] Parameter analysis was limited to dissolved metals.

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	No - Dry	NR
SW19-GORT	GM	180097	172982	Discharge at the bottom of the decant	No - Dry	No Flow
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Flow Meter
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)	No - Dry	NR
SW2-GAR	GA	181804	171376	Drainage south of R499 road.	No - Dry	NR
SW3-GAR	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Flume
SW4-GAR	GA	181335	171404	NW oriented stream occurring west of Mogul Yard. Sample site is south of R499 road.	Yes	Flume
SW5-GAR	GA	181950	171418	Discharge from Knight Shaft	Yes	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	No measureable flow
SW9-GAR	GA	181881	171557	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of railway	Yes	Flume

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flow Meter
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	No measureable flow
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

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

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

Flow Measurements

Flow was measured at 19 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 grating covering it and at five locations the stream-bed was dry or flow was immeasurable (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 between 24 and 26 August 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

Twenty soil samples were collected between 24 and 26 August 2015, from the recently remediated Areas A and B at Gortmore TMF, at the same locations as the vegetation samples as listed in Table 3 and shown on Map 6 in Appendix A.

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

2.1.5 Field QA/QC Samples

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

Groundwater and Surface water

- Groundwater:
  - One duplicate groundwater sample was collected; and
  - One decontamination blank was collected by pouring deionised (DI) water over the YSI instrument after decontamination.
- Surface Water:
  - Three duplicate surface water samples; and
  - One decontamination blank was collected by pouring DI water over the surface water grab sampler 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. An additional filtration blank was collected in order to try to quantify any contamination caused by the filtration procedure.

Soil and Vegetation

- Soil:
  - Two duplicate soil samples were collected;
  - One decontamination blank was collected by pouring DI water over the soil sampling equipment after decontamination; and
  - One standard reference material containing known concentrations of the 22 metals were shipped blind to ALS Minerals (SRM certificate for ERA 540 is contained in Appendix G of the Data Report)
- Vegetation:

- Two duplicate vegetation samples were collected;
- One decontamination blank was collected by pouring DI water over the vegetation sampling equipment after decontamination; and
- 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 CD-281 (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).

Table 4 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
Groundwater and Surface water		
SMGD01.6	GW Duplicate	Duplicate of TMF2
SMDB01.6	GW Decontamination blank	DI water (Lennox Lab Supplies: Batch No. TE150727W) poured over YSI instrument after decon at site TMF2.
SMSD01.6	SW Duplicate	Duplicate of SW7-GAR
SMSD02.6	SW Duplicate	Duplicate of SW12-SHAL
SMSD03.6	SW Duplicate	Duplicate of SW1-SM
SMDB02.6	SW Decontamination blank	DI water (Lennox Lab Supplies. Batch No: TE150727W) poured over SW sampling beaker after final decon at site SW1-SM.
SMSR01.6	Standard Reference Material	Water ERA Lot #P240-740A.
SMSR02.6	Standard Reference Material	Water ERA Lot #P240-740A
WB01.6	Filtration blank	Deionised water (Lennox Lab Suppliers. Batch No: TE150526W)
WB02.6	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: TE150526W)
Vegetation and Soil		
SM56-V	Vegetation Duplicate	Duplicate of SM19-V
SM57-V	Vegetation Duplicate	Duplicate of SM21-V
SMDB03.6	Decontamination blank	DI water (Lennox Lab Supplies, Batch No: TE150526W) poured over shears after decon
SM56-S	Soil Duplicate	Duplicate of SM19-V
SM57-S	Soil Duplicate	Duplicate of SM21-V
SMDB04.6	Decontamination blank	DI water (Lennox Lab Supplies, Batch No: TE150526W) poured over shears after decon
SMSR03.6	Standard Reference Material	ERA 540 Lot: D082-540

2.2 Sample Handling

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

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

2.3 Sample Analysis

2.3.1 ALcontrol

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

For groundwater and surface water, analyses were performed for the following parameters: pH, conductivity, Total Dissolved Solids, ammoniacal nitrogen as N, potassium, sodium, chloride, fluoride, calcium (total and dissolved), magnesium (total and dissolved), nitrate as NO_3 and nitrite as NO_2, orthophosphate, sulphate, total alkalinity as $CaCO_3$, free cyanide, total and dissolved metals including Al, Sb, Ag, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Tl, Sn, U, V and Zn. Additionally for surface water, acidity, Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD) were analysed.

The Monitoring Plan provides details on the analytical methods, holding times and reporting limits. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. As noted in the Monitoring Plan, ALcontrol is certified for most of the analyses and the few analyses for which certifications are not available are not critical for comparison to regulatory standards.

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

2.3.2 CAL Ltd

CAL Ltd, a subsidiary of Natural Resource Management Ltd, analysed the vegetation 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.

2.3.3 ALS Minerals

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

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

Section 3

Data Quality and Usability Evaluation

3.1 Introduction

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

3.1.1 Accuracy

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

%R is calculated as follows:

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

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, DI water blanks and DI filtration blanks were generated in the field. Decontamination blanks were also generated to evaluate the sampling equipment decontamination process. Each of these types of blanks is discussed below.

3.1.4 Field QA/QC Samples

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

- Duplicate Samples: Duplicate groundwater, surface water, vegetation and soil 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 (groundwater, surface water, vegetation and soil) was cleaned, DI water was poured over 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 SMSR01.6 and SMSR02.6) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P240-740A (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 CD-281 (rye grass) were used (certificates are contained in Appendix G of the Data Report);
- One certified soil SRM was sent blind to ALS Minerals (Sample ID SMSR03.6) to evaluate laboratory accuracy. The certified SRM was ERA 540. The Certificate of Analysis is provided in Appendix G of the Data Report. The use of a blind or unknown SRM is the only method to independently verify the laboratory accuracy.

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

3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Surface water and Groundwater Duplicates

Four duplicate samples (one groundwater and three surface waters) were generated in the field and sent to ALcontrol for analysis. Table 5 provides the results of the 21 dissolved metals for the four duplicate samples and the calculated RPD between each pair of samples. Note if both the original and duplicate results were less than the limit of detection (LOD), then the RPD was zero. In addition, if one of the values was less than the LOD, the LOD value is used to calculate the RPD.

The majority of RPD values shown in Table 5 are below 50 %. The RPDs for the following parameters are good: aluminium (0.4 to 37.7%), iron (0.9 to 15.6%), barium (0.3 to 5.5%), cadmium (0 to 25.3%), chromium (3.5 to 26.6%), cobalt (1.5 to 29.4%), molybdenum (0 to 15.7%), copper (0 to 10.4%), manganese (0.6 to 5.9%), nickel (2.9 to 11.6%) and vanadium (0 to 21.8%).

The RPDs that were above 50% included arsenic for two sample pairs ranging from 55.3 to 56.3% RPD and lead for two sample pairs ranging from 56 to 163.3% RPD. Dissolved antimony (124.6 % RPD), tin (160.9 % RPD) and zinc (132 % RPD) also exceeded 50% in one sample pair (SW1-SM and SMSD03.6). ALcontrol was asked to retest the relevant parameters and issued a revised laboratory report; however, the revised results confirm a poor quality duplicate pair. 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	SMGD01.6	% RPD	SW7-GAR	SMSD01.6	% RPD	SW12-SHAL	SMSD02.6	% RPD	SW1-SM	SMSD03.6	% RPD
Aluminium	<2.9	3.14	4.6	-37.7	<2.9	<2.9	0	53.1	53.3	-0.4	8.04	8.46	-5.1
Antimony	<0.16	<0.16	<0.16	0	0.26	0.247	5.1	0.23	<0.16	35.9	0.913	0.212	**124.6**
Arsenic	<0.12	4	3.77	5.9	<0.12	<0.12	0	0.214	<0.12	**56.3**	0.353	0.2	**55.3**
Barium	<0.03	610	622	-1.9	99.7	100	-0.3	260	246	5.5	41.8	39.8	4.9
Cadmium	<0.1	<0.1	<0.1	0	0.15	0.139	7.6	<0.1	<0.1	0	0.129	<0.1	25.3
Chromium	<0.22	1.46	1.18	21.2	0.848	0.819	3.5	0.379	0.29	26.6	0.739	0.603	20.3
Cobalt	<0.06	0.595	0.604	-1.5	0.987	0.734	29.4	0.227	0.208	8.7	0.073	0.063	14.7
Copper	<0.85	<0.85	<0.85	0	0.86	0.954	-10.4	1.62	1.58	2.5	<0.85	<0.85	0
Iron	<19	212	198	6.8	26	30.4	-15.6	110	109	0.9	60.1	69.4	-14.4
Lead	<0.02	2.95	3	-1.7	0.048	0.475	**-163.3**	22.2	22.9	-3.1	0.263	0.148	**56.0**
Manganese	<0.04	1020	1040	-1.9	168	167	0.6	70	66.4	5.3	8.81	9.35	-5.9
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	0.259	0.303	-15.7	0.266	0.274	-3.0	<0.24	<0.24	0	0.855	0.782	8.9
Nickel	<0.15	1.59	1.72	-7.9	3.11	3.2	-2.9	1.19	1.06	11.6	0.766	0.794	-3.6
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	0.372	0.378	-1.6	<0.36	<0.36	0	3.89	0.422	**160.9**
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	0.27	<0.24	11.8	<0.24	<0.24	0	<0.24	<0.24	0	0.341	0.274	21.8
Zinc	<0.41	2.67	3.43	-24.9	55.2	56.1	-1.6	17.8	17.7	0.6	1.65	8.06	**-132.0**

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 (SM19-V and SM56-V) and the second (SM21-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	SM19-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM21-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	0.21	0.24	-13.3	0.09	0.07	25.0
Cadmium	0.09	0.09	0	0.04	0.04	0
Lead	3.67	4.38	-17.64	0.48	0.55	-13.59
Zinc	21.9	23.0	-4.9	21.8	25.2	-14.47

Soil Duplicates

Table 7 provides the results of the 12 metals for the two duplicate soil samples and the calculated RPD between each pair of samples. All of the RPD values are below the +/- 50 % RPD values anticipated for field samples with values ranging from 0 to 31.6 % RPD. The % RPDs for the first duplicate pair (SM19-S and SM56-S) are all below 10 % which is excellent. The majority of the % RPDs for the second duplicate pair (SM21-S and SM57-S) ranged from 0 to 14 % which is also excellent. The highest reported value of the duplicate pair is selected for interpretive use in Section 4.

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

Metal	SM19-S (mg/kg)	SM56-S (mg/kg)	% RPD	SM21-S (mg/kg)	SM57-S (mg/kg)	% RPD
Aluminium	7600	7700	-1.3	8600	8300	3.6
Arsenic	9	9	0.0	11	8	31.6
Barium	60	60	0.0	150	120	22.2
Cadmium	0.7	0.7	0.0	0.9	0.9	0.0
Chromium	18	19	-5.4	19	18	5.4
Copper	12	12	0.0	13	13	0.0
Iron	18700	18300	2.2	19500	19800	-1.5
Mercury	<1	<1	0.0	<1	<1	0.0
Manganese	900	900	0.0	2300	2000	14.0
Nickel	17	18	-5.7	20	20	0.0
Lead	23	25	-8.3	58	49	16.8
Zinc	56	61	-8.5	147	137	7.0

3.2.2 Decontamination Blanks

Surface Water and Groundwater

Two decontamination blanks were created by pouring DI water over the sampling equipment after decontamination and sent to ALcontrol for analysis. Table 8 provides the results of the 21 metals for the two decontamination blank samples, the DI water blank and filtration blank samples and the associated laboratory method blank samples. The majority of reported concentrations were below the limits of detection. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. The limits of detection ranged from 0.01 to 2.9 µg/l except for iron with a detection limit of 19 µg/l.

Detections were observed for nine dissolved metals ranging from 0.026 to 17.1 µg/l. Four of the metals (chromium, lead, manganese, and zinc) were also detected in the DI water blank. The levels of detections in the decontamination blanks were similar to those found in the DI water blank with the exception of zinc (17.1 µg/l) which was up to 15 times greater.

In total there were fifteen detections of dissolved metals in the decontamination blanks. Two of these were greater than ten times the detection limit, in SMDB01.6 zinc (7.84 µg/l) and in SMDB02.6 zinc (17.1 µg/l). All of the detections including 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.

The results from the laboratory instrumentation (method) blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory (Table 8). Each method blank is specific to the associated sample batch. The parameters detected in the method blanks for both sample batches relating to groundwater and surface water were similar to those in the field decontamination blank samples, as follows:

- One detection of a parameter was present in method blank for Sample Batch 150827-113 that occurred in the decontamination blank from the same batch (Table 8): tin 1.64 µg/l.
- Four detections of parameters were present in method blank for Sample Batch 150830-8 that occurred in the decontamination blank from the same batch (Table 8): antimony 1.79 µg/l, barium 0.04 µg/l, molybdenum 0.97 µg/l and tin 2.25 µg/l.

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. In SMDB01.6 chromium was 20% of the preceding sample; however, the reported value was lower than the detection in the DI water blank. The reported value for zinc was significantly higher than the preceding sample (TMF2 2.67 µg/l). The dissolved zinc concentrations within the decontamination blanks were considered to be within acceptable ranges for zinc because it is a common contaminant and has been detected in the DI water blank during several previous sampling events. In SMSD02.6 antimony, molybdenum and tin were detected at a higher concentration than the preceding sample; however, all three parameters were detected in the laboratory method blank. The reported values of manganese (0.15 µg/l) and chromium (0.484 µg/l) were greater than 50 % of the preceding sample. These values are similar to the concentrations recorded in the DI water blank.

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 for their intended use. Due to zinc being detected at a significantly 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 they may be an overestimation of the concentrations in the environmental sample.

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

Sample Description Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.6 (µg/l)	Water Blank WB02.6 (µg/l)	Laboratory Method Blank (µg/l)	Water: Decon blank SMDB01.6 (µg/l)	Water: Laboratory Method Blank (µg/l)	Water: Decon blank SMDB02.6 (µg/l)	Water: Laboratory Method Blank (µg/l)	Vegetation and Soil: Decon blank SMDB03.6 (µg/l)	Vegetation and Soil: Decon blank SMDB04.6 (µg/l)	Vegetation and Soil: Laboratory Method Blank (µg/l)
	Sample batch:	***150815-81***			***150827-113***		**150830-8**		**150830-11**		
Aluminium	<2.9	<2.9	<2.9	<2.90	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
Antimony	<0.16	**0.46**	<0.16	<0.16	<0.16	*0.46*	***1.37***	*1.79*	<0.16	***0.222***	*1.79*
Arsenic	<0.12	<0.12	<0.12	<0.12	<0.12	*0.13*	<0.12	<0.12	<0.12	<0.12	<0.12
Barium	<0.03	**0.059**	<0.03	<0.03	**0.089**	<0.03	***0.098***	*0.04*	***0.123***	***0.28***	*0.04*
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.22	**0.425**	**0.445**	<0.22	**0.282**	<0.22	**0.484**	<0.22	**0.257**	**0.242**	<0.22
Cobalt	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Copper	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	**1.37**	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19
Lead	<0.02	**0.041**	**0.021**	NP	**0.026**	NP	**0.108**	NP	<0.02	<0.02	<0.02
Manganese	<0.04	**0.2**	**0.729**	<0.04	**0.159**	<0.04	**0.15**	0.04	**1.96**	**0.688**	0.04
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	<0.24	**0.383**	<0.24	<0.24	<0.24	*0.54*	***1.02***	*0.97*	<0.24	<0.24	0.97
Nickel	<0.15	<0.15	**0.273**	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Selenium	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39
Silver	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Thallium	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96
Tin	<0.36	**1.22**	<0.36	<0.36	***0.421***	*1.64*	***2.25***	*2.54*	<0.36	***0.42***	*2.54*
Uranium	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Vanadium	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24
Zinc	<0.41	**1.13**	**0.617**	<0.41	**7.84**	<0.41	**17.1**	<0.41	**14**	<0.41	<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 and Soil

To assess the level of cross-contamination between vegetation and soil samples in the field, the concentrations in decontamination blank SMDB03.6 and for soil samples SMDB04.6 were examined (Table 8). The detections of dissolved chromium, manganese and zinc can be attributed to the concentrations in the DI water. Dissolved zinc is commonly found in the DI water. Detections of dissolved antimony, barium and tin were found in the decontamination blanks and also in the laboratory method blank.

None of the parameters of concern for vegetation or soil 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 SMSR01.6 and SMSR02.6) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 9 summarises the SRM results and provides the calculated %R values for the 18 requested metals.

Reported values for dissolved aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, selenium, thallium, vanadium and zinc are in good agreement with the certified value (%R ranged from 89 to 107%).

One of the reported values for dissolved antimony (85 %), molybdenum (84 %), nickel (90 %) and silver (79 %) were outside the acceptable range, however the corresponding reported values for the second SRM were within acceptable ranges and therefore the interpretation of the results are not affected. Both of the reported values for dissolved iron were low at 89 % and 87 % which fall outside of the acceptable range. This indicates that values for iron may be biased low and any use of these values should be noted with this observation.

SRM Soil

One blind SRM (ERA 540) was sent to ALS Minerals. The ALS Minerals laboratory report is provided in Appendix F of the Data Report. Table 10 summarises the SRM ERA 540 results and provides the calculated %R values for the 12 metals.

Reported values for arsenic, cadmium, mercury, nickel and lead were in excellent agreement with the certified value (%R ranged from 101 to 107 %). The reported values for chromium (115 %R), copper (114 %R), magnesium (111 %R) and zinc (115 %R) were within 20 % of the certified value and well within the acceptable range. The values for aluminium (151 %R), Barium (118 %R) and iron (192 %R) were significantly higher than the certified values. Aluminium and iron reported values in the soil samples may be biased high and any use of these values should be noted with this observation.

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

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits Lower (%)	Acceptance Limits Upper (%)	SMSR01.6 (µg/l)	% R	SMSR02.6 (µg/l)	% R
Aluminium	1810	87	114	1850	102	1840	102
Antimony	131	87	111	112	**85**	125	95
Arsenic	304	87	111	270	89	280	92
Barium	372	91	109	370	99	376	101
Cadmium	673	89	106	654	97	646	96
Chromium	483	91	109	466	96	486	101
Cobalt	747	93	111	766	103	777	104
Copper	201	91	109	200	100	189	94
Iron	1930	90	111	1710	**89**	1680	**87**
Lead	285	90	110	286	100	293	103
Manganese	1130	92	109	1210	107	1090	96
Molybdenum	140	90	109	117	**84**	129	92
Nickel	1280	91	109	1190	93	1150	**90**
Selenium	299	88	111	274	92	280	94
Silver	257	90	110	239	93	202	**79**
Thallium	567	88	111	583	103	580	102
Vanadium	252	91	107	241	96	258	102
Zinc	769	91	110	705	92	725	94

Notes:
Bold indicates an exceedance in acceptance limits

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

Metal	Certified Value (mg/kg)	Acceptance Limits (%)	Acceptance Limits (%)	SMSR03.6 (mg/kg)	% R
Aluminium	8740	53.5	146	13200	151
Arsenic	151	80.8	120	155	103
Barium	262	82.8	117	310	118
Cadmium	152	81.6	118	154	101
Chromium	117	79.4	121	135	115
Copper	68.6	80.9	119	78	114
Iron	12300	40.2	160	23600	192
Mercury	5.76	71.2	129	6	104
Magnesium	3600	76.7	123	4000	111
Nickel	315	82.2	118	330	105
Lead	254	81.5	119	271	107
Zinc	306	80.1	120	353	115

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 different standard than the calibration standards and is used as a check on the validity of the calibration standards. The acceptance criteria for this standard was method specific; and
- Replicate samples (samples tested more than once using the same method) were included at the same frequency as the AQCs.

All of the ALcontrol laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding times were exceeded for free cyanide in 27 samples by 2-7 days. Small exceedances are typically considered acceptable from a technical perspective given the conservative nature of holding times.

ALcontrol provided the associated analytical quality control samples (AQC) data. The percentage recovery results for the AQC samples that were performed with the regular environmental samples were checked against the individual lower control and upper control limits. All AQC samples run with the environmental samples were within these upper and lower control limits with the exception of total cyanide in QC 1206 which exceeded the upper limit. However, all of the corresponding environmental results were below the limit of detection which indicates no elevation during testing. In addition, several environmental samples were re-run to verify the results. 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 approximately 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 certificates of analyses are 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 two method blanks during the analyses of arsenic, cadmium, lead and zinc.

SRM

Table 11 provides the results of the three analyses of SRM NIST 1568b and the % R values. Table 12 provides the results of the three analyses of SRM NIST 1515 and the % R values. Table 13 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. 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 was outside of the acceptable range of 95 to 105 %R in SRM NIST 1568b.
- All of the reported cadmium values were within the acceptable range in SRM NIST 1568b and two were below the acceptable range in SRM NIST 1515 and 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 frequently fall 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 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 frequently fall outside of the acceptable range.
- All of the zinc results were considered slightly high and above the acceptable range of 99 to 101 %R in SRM NIST 1568b, 98 to 102 %R in SRM NIST 1515 and 96 to 104 %R in SRM ERM CD-281. These ranges are considered to be relatively narrow and therefore a high bias is not considered an issue.

Table 11 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	0.275	96	0.278	98	0.269	**94**
Cadmium	0.01	0.0224	0.0211-0.0237	94-106	0.021	94	0.023	103	0.021	94
Zinc	0.1	19.42	19.16-19.68	99-101	20.9	**108**	21.0	**108**	21.23	**109**

Table 12 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	0.017	**131**	0.015	115	0.017	**131**
Lead	0.01	0.47	0.446-0.494	95-105	0.368	**78**	0.365	**78**	0.365	**78**
Zinc	0.1	12.5	12.2-12.8	98-102	12.9	**103**	13.0	**104**	12.8	**103**

Table 13 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	0.116	97	0.103	**86**	0.108	**90**
Lead	0.01	1.67	1.56-1.78	93-107	1.469	**88**	1.496	**90**	1.564	94
Zinc	0.1	30.5	29.4-31.6	96-104	32.2	**105**	32.5	**107**	33.4	**109**

CAL also analysed an in-house reference material (GST005 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 GST005 are outside +/- 2 standard deviations of the historical mean, corrective action is taken and all samples reanalysed. If two consecutive GST005 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.

The 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, 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 14, the precision was good with the % RPD values ranging from 0 to 12.5 % for arsenic, cadmium, lead and zinc values.

Table 14 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	0.275	0.278	0.269	1.1	-2.2	-3.3
Cadmium	0.021	0.023	0.021	9.1	0.0	-9.1
Zinc	20.9	21.0	21.23	0.1	1.5	1.3
NIST 1515	**Result 1**	**Result 2**	**Result 3**			
Cadmium	0.017	0.015	0.017	-12.5	0.0	12.5
Lead	0.368	0.365	0.365	-0.8	-0.8	0.0
Zinc	12.9	13.0	12.8	0.7	-0.3	-1.0

Total Metal	SRM Results (mg/kg)			%RPD (1 vs 2)	%RPD (1 vs 3)	%RPD (2 vs 3)
ERM CD-281	**Result 1**	**Result 2**	**Result 3**			
Cadmium	0.116	0.103	0.108	-11.9	-7.1	4.7
Lead	1.469	1.496	1.564	1.8	6.3	4.4
Zinc	32.2	32.5	33.4	1.2	3.7	2.5

Blanks

As previously discussed, CAL performed two method blanks (for arsenic, cadmium, lead and zinc). All zinc results were below reporting limits (non-detects). Two detections were reported for arsenic (0.004 and 0.004 mg/kg), cadmium (0.001 and 0.002 mg/kg) and lead (0.025 and 0.021 mg/kg) which were all below the critical value of 0.1 mg/kg and were therefore considered acceptable. If the critical value is exceeded, the lab considers investigating potential contamination.

3.3.3 ALS Minerals

ALS Minerals provided the results for the following samples:

- SRMs: ALS Minerals analysed two in-house standard reference materials (GEOMS-03 and OGGeo08);
- Duplicates: ALS Minerals analysed a duplicate of one of the field samples; and
- Blanks: ALS Minerals performed one method blank during the analyses.

SRM

ALS Minerals analysed two in-house standard reference materials GEOMS-03 and OGGeo08 and the results are contained in Appendix F of the Data Report. ALS Minerals provided a target range (upper and lower bound) for each metal and standard. All reported values for both SRMs were within the target range therefore the analytical results are accurate and acceptable to use.

Duplicates

The following Table 15 provides the reported values for the duplicate soil samples performed by ALS Minerals and the resulting RPD for the sample pair. All the RPD values are very low and ranged from 0 to 15.4 % RPD which is well within the acceptable range for laboratory duplicates.

Table 15 Laboratory Duplicate Reported Values for Soils (mg/kg) and % RPD

Sample Description	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
SM19-S Original	7,800	10	60	0.6	19	12	1,9300	<1	1,070	18	24	58
SM19-S-Duplicate	7,600	9	60	0.7	18	12	1,8700	<1	1,040	17	23	56
% RPD	2.6	10.5	0	-15.4	5.4	0	3.2	0	2.8	5.7	4.3	3.5

Blanks

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

3.4 Summary of Data Checks

3.4.1 Field physico-chemical Versus Laboratory Data

Table 16 summarises the field and laboratory results for pH and conductivity and provides the calculated %RPD values between the two samples. Note that pH measurements in the laboratory were taken from the unpreserved sample and therefore the results do not affect the results of samples from preserved bottles (e.g. metals).

The RPDs between laboratory and field conductivity were less than 22 % which is good. The RPDs between laboratory and field pH were also good at less than 17 %. For SW12-Shal, the %RPD was higher at 35.8%. The result was confirmed with ALcontrol and the difference is believed to be due to the unstable reading obtained in the field. Recordings of pH in the field are typically lower than the laboratory due to some carbon dioxide degassing during transport or within the laboratory itself. With the exception of SW12-SHAL, 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 16 Field physico-chemical data and Laboratory Reported Values and Calculated % RPD

	pH	pH	% RPD	Conductivity @ 20 deg.C	Specific Cond. @ 25 deg.C	% RPD
	Lab	Field		Lab	Field	
Sample Description	(pH Units)			(mS/cm)		
DS SHAL	7.16	7.24	-1.1	0.246	0.274	-10.8
SW10 - GORT - DISCHARGE	8.05	7.62	5.5	2.13	2.397	-11.8
SW10 - GORT - DS	8.07	7.83	3.0	0.494	0.552	-11.1
SW10 - GORT - US	8.11	7.41	9.0	0.479	0.55	-13.8
SW10-GAR	8.17	8.12	0.6	0.864	0.963	-10.8
SW12-GAR	7.75	7.5	3.3	0.412	0.37	10.7
SW12-GORT-DISCHARGE	8.03	7.18	11.2	1.91	2.008	-5.0
SW12-GORT-DS	8.26	7.91	4.3	0.537	0.58	-7.7
SW12-SHAL	6.09	4.24*	35.8	0.0349	0.038	-8.5
SW14-GORT	8.19	7.94	3.1	0.478	0.521	-8.6
SW17 - GORT	7.8	7.5	3.9	0.391	0.441	-12.0
SW1-SHAL	7.58	7.26	4.3	0.146	0.163	-11.0
SW1-SM	7.85	7.4	5.9	0.131	0.147	-11.5
SW2-SM-NORTH	8.11	7.37	9.6	0.447	0.509	-13.0
SW2-SM-SOUTH	7.81	6.97	11.4	0.455	0.512	-11.8
SW3-GAR	8.14	8.06	1.0	0.784	0.91	-14.9
SW3-SM	7.86	7.42	5.8	0.124	0.137	-10.0
SW4-GAR	7.78	7.04	10.0	0.264	0.283	-6.9
SW4-SHAL	7.3	6.35	13.9	0.119	0.147	-21.1
SW4-SM-GA	7.94	7.3	8.4	0.167	0.187	-11.3
SW5-GAR	7.55	6.57	13.9	0.373	0.431	-14.4
SW6-MAG	7.78	7.63	1.9	0.513	0.541	-5.3

Sample Description	pH Lab	pH Field	% RPD	Conductivity @ 20 deg.C Lab	Specific Cond. @ 25 deg.C Field	% RPD
	(pH Units)			(mS/cm)		
SW6-SHAL	6.87	5.96	14.2	0.134	0.152	-12.6
SW7-GAR	8.02	7.39	8.2	0.607	0.69	-12.8
SW8-GAR	7.66	7.09	7.7	1.52	1.689	-10.5
SW9-GAR	7.23	7.3	-1.0	0.994	1.109	-10.9
SW9-SHAL	7.66	6.89	10.6	0.142	0.159	-11.3
TMF 1	8.18	6.95	16.3	0.406	0.452	-10.7
TMF 2	7.74	6.83	12.5	0.456	0.496	-8.4

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:

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

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

The mass balance was calculated using the following relationship:

(TDS-Calc – TDS-Meas)/TDS-Meas x 100%

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

By evaluating both the mass balance and charge balance, conclusions can be drawn about the accuracy and completeness of the analysis. The possible mass balance and charge balance combinations and the corresponding interpretations are shown in Table 17.

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 all values with the exception of SW12-Shal (46.9 %) were less than 20 % which overall is very good considering the complex nature of some of the samples with high metal concentrations. Note that an accurate mass balance calculation at SW12-SHAL is difficult due to a very low TDS value. The fact that the mass balance values are mostly negative suggests that either one or more parameters were under-reported by the analytical laboratory and/or one or more parameters present within the samples were not analysed (e.g. silica).

Table 17 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	166	198	-0.1	-2.3	**-16.0**	Missing cations
SW10 - GORT - DISCHARGE	2154	2450	3.5	4.9	**-12.1**	Missing anions
SW10 - GORT - DS	326	353	-0.4	-3.0	-7.6	Missing cations
SW10 - GORT - US	323	345	-0.2	-1.7	-6.4	Missing cations
SW10-GAR	662	732	-0.5	-2.0	-9.6	Missing cations
SW12-GAR	317	342	1.0	9.6	-7.2	Missing anions
SW12-GORT-DISCHARGE	1644	1890	0.3	0.5	**-13.0**	Missing anions
SW12-GORT-DS	346	406	-0.1	-0.9	**-14.7**	Missing cations
SW12-SHAL	19	13	0.0	-2.9	**46.9**	Too many anions
SW14-GORT	308	351	0.0	0.4	**-12.3**	Missing anions
SW17 - GORT	255	261	-0.2	-2.1	-2.2	Missing cations
SW1-SHAL	88	102	0.0	-1.2	**-14.2**	Missing cations
SW1-SM	74	80	-0.1	-4.9	-6.9	Missing cations
SW2-SM-NORTH	286	294	-0.5	-4.9	-2.6	Missing cations
SW2-SM-SOUTH	294	306	0.0	0.3	-4.0	Missing anions
SW3-GAR	593	683	-1.0	-4.9	**-13.2**	Missing cations
SW3-SM	65	80	0.1	4.4	**-18.3**	Missing anions
SW4-GAR	161	176	-0.2	-4.0	-8.4	Missing cations
SW4-SHAL	66	62	-0.1	-2.7	6.7	Too many anions
SW4-SM-GA	96	109	-0.1	-1.6	**-12.4**	Missing cations
SW5-GAR	259	290	0.0	-0.1	**-10.8**	Missing cations
SW6-MAG	347	430	-0.2	-1.5	**-19.2**	Missing cations
SW6-SHAL	79	75	-0.1	-4.9	4.9	Too many anions
SW7-GAR	455	508	1.0	6.2	**-10.3**	Missing anions
SW8-GAR	1379	1510	3.0	6.7	-8.7	Missing anions
SW9-GAR	825	963	0.3	1.2	**-14.3**	Missing anions
SW9-SHAL	89	91	-0.2	-4.7	-2.1	Missing cations
TMF 1	244	250	-0.2	-1.8	-2.6	Missing cations
TMF 2	268	264	-0.1	-1.1	1.5	Too many anions

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 18 are within the range for natural waters and therefore the analyses are considered reliable. Two exceptions are SW12-SHAL with a ratio of 2.0 for SC/TDS-Calc and 2.9 for SC/TDS-Meas and SW4-SHAL with a ratio of 2.2 for SC/TDS-Calc and 2.4 for SC/TDS-

Meas. Measured conductivity and TDS at both sites (particularly SW12-SHAL) were low and 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 18 Comparison of Specific Conductivity to Total Dissolved Solids (SC/TDS) Ratio

Sample Description	Sample Type	Specific Conductance	TDS (Calc)	TDS (Meas)	Ratio	
		(uS/cm)	(mg/l)	(mg/l)	SC/ TDS (Calc)	SC/ TDS (Meas)
DS SHAL	SW	274	166	198	1.6	1.4
SW10 - GORT - DISCHARGE	SW	2397	2154	2450	1.1	1.0
SW10 - GORT - DS	SW	552	326	353	1.7	1.6
SW10 - GORT - US	SW	550	323	345	1.7	1.6
SW10-GAR	SW	963	662	732	1.5	1.3
SW12-GAR	SW	370	317	342	1.2	1.1
SW12-GORT-DISCHARGE	SW	2008	1644	1890	1.2	1.1
SW12-GORT-DS	SW	580	346	406	1.7	1.4
SW12-SHAL	SW	38	19	13	2.0	2.9
SW14-GORT	SW	521	308	351	1.7	1.5
SW17 - GORT	SW	441	255	261	1.7	1.7
SW1-SHAL	SW	163	88	102	1.9	1.6
SW1-SM	SW	147	74	80	2.0	1.8
SW2-SM-NORTH	SW	509	286	294	1.8	1.7
SW2-SM-SOUTH	SW	512	294	306	1.7	1.7
SW3-GAR	SW	910	593	683	1.5	1.3
SW3-SM	SW	137	65	80	2.1	1.7
SW4-GAR	SW	283	161	176	1.8	1.6
SW4-SHAL	SW	147	66	62	2.2	2.4
SW4-SM-GA	SW	187	96	109	2.0	1.7
SW5-GAR	SW	431	259	290	1.7	1.5
SW6-MAG	SW	541	347	430	1.6	1.3
SW6-SHAL	SW	152	79	75	1.9	2.0
SW7-GAR	SW	690	455	508	1.5	1.4
SW8-GAR	SW	1689	1379	1510	1.2	1.1
SW9-GAR	SW	1109	825	963	1.3	1.2
SW9-SHAL	SW	159	89	91	1.8	1.7
TMF 1	GW	452	244	250	1.9	1.8
TMF 2	GW	496	268	264	1.9	1.9

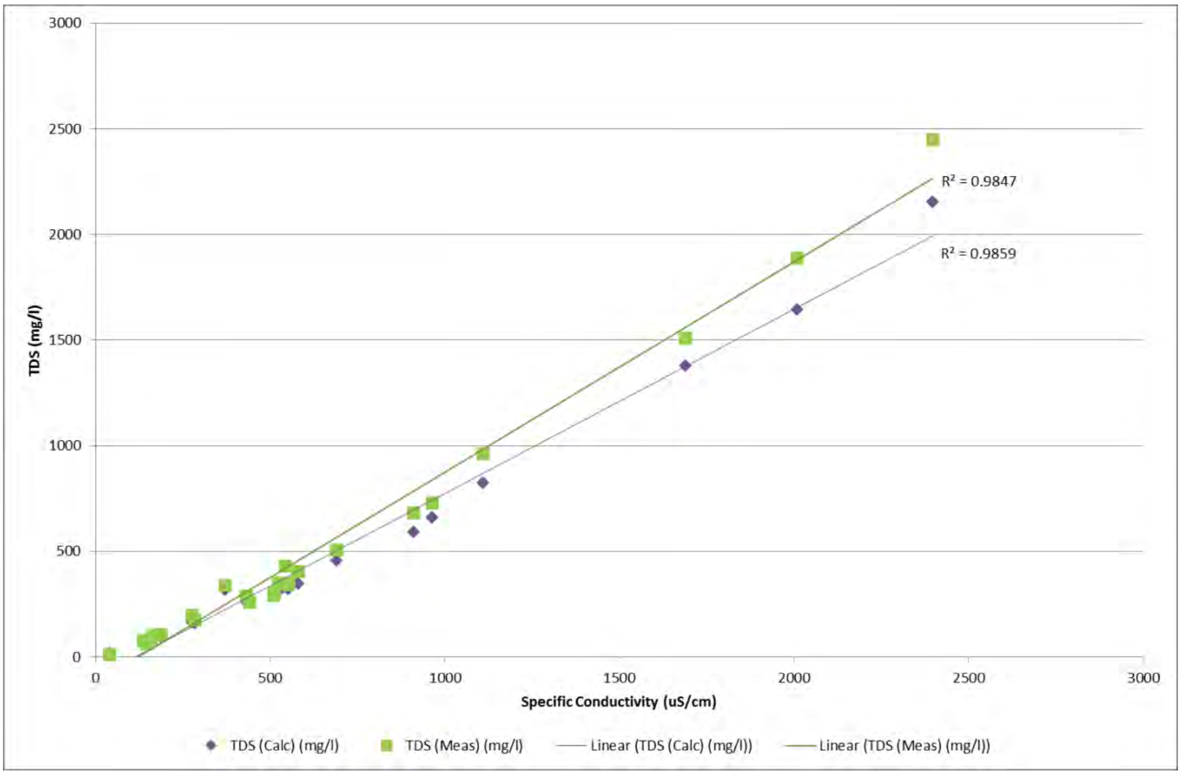

Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

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 different. Table B-1 in Appendix B shows the full tabulation of results.

The total metals were generally equal or close 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 107 mg/l.

Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater, surface water, vegetation and soil and a comparison of the analytical results against selected assessment criteria. An analysis of loading and time trends is provided in Section 5 and groundwater levels are discussed in Section 6.

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

4.1 Statistical Summary of Analytical Results

4.1.1 Groundwater Sample Results

Table 19 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 19 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	2	4.6	6.73	5.67
Antimony	<0.16	2	1	0.08	0.298	-
Arsenic	<0.12	2	2	3.71	4	3.86
Barium	<0.03	2	2	158	622	390
Cadmium	<0.1	2	0	0.05	0.05	-
Chromium	<0.22	2	2	1.2	1.46	1.33
Cobalt	<0.06	2	2	0.51	0.60	0.56
Copper	<0.85	2	0	0.425	0.425	-
Iron	<19	2	2	162	212	187
Lead	<0.02	2	2	0.08	3	1.54
Manganese	<0.04	2	2	85.1	1040	563
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	2	0.3	0.45	0.38
Nickel	<0.15	2	2	1.47	1.72	1.60
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	1	0.18	0.528	-
Uranium	<1.5	2	0	0.75	0.75	-
Vanadium	<0.24	2	2	0.27	0.284	0.28
Zinc	<0.41	2	2	1.95	3.43	2.69

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

Dissolved barium (622 µg/l), iron (212 µg/l) and manganese (1,040 µg/l) were found in the highest concentrations in TMF2 (downgradient of the TMF), which were significantly higher than the concentrations in TMF1 (upgradient of the TMF). Dissolved arsenic was detected in both wells with the highest concentration at TMF2 of 4 µg/l. Detections of dissolved aluminium, chromium, lead and zinc were detected at slightly more elevated concentrations in TMF2 compared to 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 20 provides a summary of the reported results of the 12 discharge/ drainage samples and Table 21 provides a summary of the reported results of the 16 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 20 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	12	4	1.45	53.3	7.66	14.8
Antimony	<0.16	12	10	0.08	1.21	0.54	0.40
Arsenic	<0.12	12	11	0.06	4.62	1.06	1.66
Barium	<0.03	12	12	12.8	260	96.3	85.9
Cadmium	<0.1	12	10	0.05	56.1	7.92	15.6
Chromium	<0.22	12	12	0.379	1.94	0.97	0.49
Cobalt	<0.06	12	12	0.097	3.31	1.31	1.14
Copper	<0.85	12	10	0.425	10.8	4.29	3.06
Iron	<19	12	9	9.5	110	48.9	39
Lead	<0.02	12	12	0.073	211	22.7	59.7
Manganese	<0.04	12	12	0.252	1540	324	458
Mercury	<0.01	12	0	0.005	0.005	-	-
Molybdenum	<0.24	12	10	0.12	1.55	0.64	0.46
Nickel	<0.15	12	12	1.19	49.7	12.8	13.8
Selenium	<0.39	12	9	0.195	0.644	0.27	0.15
Silver	<1.5	12	0	0.75	0.75	-	-
Thallium	<0.96	12	4	0.48	6.3	1.54	1.88
Tin	<0.36	12	6	0.18	1.63	0.52	0.5
Uranium	<1.5	12	0	0.75	0.75	-	-
Vanadium	<0.24	12	5	0.12	0.474	0.23	0.14
Zinc	<0.41	12	12	17.8	12200	2790	4190

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

SW8-GAR had the highest concentrations of dissolved nickel (49.7 µg/l) and zinc (12,200 µg/l). The highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 211 µg/l.

Rivers and Streams

Table 21 Summary of Dissolved Metal Concentrations in Rivers and Streams

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2.9	16	10	1.45	47.8	9.12	13.3
Antimony	<0.16	16	14	0.08	1.25	0.522	0.33
Arsenic	<0.12	16	16	0.213	4.52	1.00	1.31
Barium	<0.03	16	16	34.6	301	155	86.7
Cadmium	<0.1	16	12	0.05	7.11	1.25	2.17
Chromium	<0.22	16	16	0.42	1.41	0.84	0.313
Cobalt	<0.06	16	16	0.06	7.84	0.859	1.89
Copper	<0.85	16	13	0.425	12.1	3.76	3.76
Iron	<19	16	14	9.5	247	68.8	61.6
Lead	<0.02	16	16	0.11	149	21	44.3
Manganese	<0.04	16	16	4.17	1530	144	374
Mercury	<0.01	16	1	0.005	0.011	0.005	-
Molybdenum	<0.24	16	13	0.12	1.89	0.55	0.476
Nickel	<0.15	16	16	0.794	20.3	5.16	5.13
Selenium	<0.39	16	4	0.195	0.491	0.257	0.113
Silver	<1.5	16	0	0.75	0.75	-	-
Thallium	<0.96	16	1	0.48	2.07	0.579	-
Tin	<0.36	16	9	0.18	3.89	0.779	0.948
Uranium	<1.5	16	0	0.75	0.75	-	-
Vanadium	<0.24	16	5	0.12	0.345	0.184	0.1
Zinc	<0.41	16	16	5.9	2520	378	679

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

SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc than the rest of the rivers and streams sampled in the Silvermines area (8.06 and 5.9µg/l, respectively). SW17-Gort has background concentrations of manganese (53.2 µg/l) and barium (260 µg/l).

SW5-Shal (downstream of Garryard) had the highest concentrations of cadmium (7.11 µg/l), Manganese (77.4 µg/l), nickel (20.3 µg/l) and zinc (2,520 µg/l). Note that very low flow at SW5-Shal was observed at the time of sampling. SW9-Shal (downstream of field shaft) had the highest concentrations of lead (149 µg/l).

4.1.3 Vegetation Sample Results

Table 22 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 22 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	17	20	20	20
Minimum	0.050	0.026	0.469	16.285
Maximum	1.444	0.152	7.219	38.247
Mean	0.311	0.060	2.438	26.076
SDEV	0.316	0.028	1.94	5.46

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

There were 17 detections of arsenic above the detection limit of <0.1. The highest arsenic concentration of 1.444 mg/kg was in SM01-V which exceeded the no effect level for digestion in wildlife (0.621 mg/kg). The highest cadmium (0.152 mg/kg) was also in SM01-V. The highest lead (7.219 mg/kg) and highest zinc (38.2 mg/kg) concentrations were in vegetation sample SM28-V and SM13-V which are located at the edge of the capped area (see Map 6 in Appendix A).

4.1.4 Soil Sample Results

Table 23 provides a summary of the results of the 20 soil samples from the recently remediated Areas A and B at Gortmore TMF. Included in this table are the mean, median, minimum, maximum, and standard deviation (SDEV). Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The values were calculated by using the highest result from the duplicate pair where applicable.

Table 23 Summary of Soil Concentrations (mg/kg) at Gortmore TMF

Metal	Count	Detections	Min	Max	Mean	SDEV	Median	Median in Irish soil *
Aluminium	20	20	5200	9500	6830	1932	7250	34800
Arsenic	20	20	5	12	8.75	2.00	9	7.3
Barium	20	20	40	150	71	30.9	60	230
Cadmium	20	14	0.025	0.9	0.419	0.314	0.5	0.33
Chromium	20	20	14	21	17.3	2.30	17.5	43
Copper	20	20	9	16	12.3	1.95	13	16.2
Iron	20	20	14900	22900	18370	2123	17950	18700
Mercury	20	6	0.5	1	0.625	0.222	0.5	0.09
Manganese	20	20	373	1180	803.3	227	742.5	462
Nickel	20	20	10	23	17.4	3.56	18	17.5
Lead	20	20	20	58	28.5	8.48	26	24.8
Zinc	20	20	40	147	59.1	22.6	58	62.6

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

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

The highest arsenic concentration (12 mg/kg) was found in sample SM15-S which is located close to the centre of sampling area A and the highest lead (58 mg/kg) and zinc concentration (147 mg/kg) was in soil sample SM21-S which is located on the northern edge of sampling area B. These values were higher than the Irish median values. Many of values for cadmium were <0.5 mg/kg; however, 13 locations had values just at or above the detection limit. The majority of values for mercury were <1 mg/kg with 9 values just at the detection limit of 1 mg/kg.

4.2 Assessment Criteria

4.2.1 Groundwater and Surface Water Assessment Criteria

To assess the analytical results of the groundwater and surface water samples, assessment criteria have been selected to screen reported values against for both ecological and human health. To assess ecological criteria, the environmental quality standards (EQS) from the European Communities Environmental Objectives (Surface Water) Regulations, 2009 (S.I. 272 of 2009) and amendments were utilised, as shown in Table 24. 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 24).

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 24. The appropriate ecological assessment criteria are highlighted in bold in Table 24.

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

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 24 and Table 25).

Table 24 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

Table 25 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 26 summarises the recommended levels for metals where limits have been established, and for total dissolved solids, sulphate and fluoride.

Table 26 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)
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	

Parameter	Unit	Parametric Value	Source	Comment
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 27 summarises the maximum content in feedingstuff for arsenic, cadmium and lead applicable to the vegetation samples collected. No values are available for zinc.

Table 27 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 27 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 27 is for digestion by wildlife (whitetail deer) taken from the Oak Ridge National Laboratory (Sample *et al.*, 1996).

4.2.4 Soil Assessment Criteria

The Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 (S.I. No. 148 of 1998) sets maximum values for concentrations of heavy metals in soil designed to set specifications for soils that may receive sewage sludge. These maximum values have been widely used as threshold or indicator values of soil quality. Table 28 summarises the maximum values for concentrations of heavy metals in soil.

Additional comparisons are made to screening levels or thresholds to indicate the concentrations at which metals in soils may have adverse effects (phytotoxicity) on the vegetation, wildlife or grazing cattle and sheep. Table 28 summarises the screening level and threshold values and the information sources.

Table 28 Assessment Criteria for Soil (mg/kg)

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

Notes:
1. Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 (S.I. No. 148 of 1998);
2. USEPA (2005); 3. Efroymson *et al.* (1997); 4. Ford (2004).

4.3 Comparison to Assessment Criteria

A comparison of the groundwater and surface water analytical results was performed 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, soil 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 6.89. The specific conductance ranged from 0.452 to 0.496 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 to 15 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 (upgradient) had a result of 158 µg/l and TMF2 (downgradient) had a result of 622 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1 had a result of 85.1 µg/l and TMF2 had a result of 1,040 µg/l. As well, iron exceeded the human health criteria (200 µg/l) with a concentration of 212 µg/l. Note that manganese and iron are 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 ranged from 4.24 to 8.12, with an average of 7.20. There were two exceedances of the assessment criteria for pH at SW12-Shal (6.09 pH) and SW4-Shal (6.35 pH) which were below the acceptable range for human health of 6.5 to 9.5 pH. Low acidity results were detected at nine locations which ranged from 5.48 to 9.13 mg/l (as HCl) with the highest acidity at SW9-Gar. The conductivity ranged from 0.04 to 2.4 mS/cm with an average of 0.61 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-Shal which had a concentration of 0.208 mg/l and at SW3-SM which had a concentration of 0.22 mg/l. Low levels of ortho-phosphate were recorded at 8 locations ranging from 0.02 to 0.07 mg/l with the highest concentration at SW17-Gort.

Fluoride results were below the detection limit (0.5 mg/l) at all river/stream sampling locations. However, both the ecological (0.5 mg/l) and human health (1.5 mg/l) criteria were exceeded at two drainage locations with values ranging from 2.34 mg/l (SW9-Gar) to 2.51 mg/l (SW8-Gar).

Sulphate exceeded the criteria for human health (250 mg/l) at both wetland discharges in the Gortmore area and three of the discharge and drainage locations in the Garryard area. As well, the human health criteria was exceeded at SW3-Gar (283 mg/l). The sulphate results that exceeded the criteria ranged from 283 to 1360 mg/l, with an average of 706 mg/l. The highest sulphate result was from SW10-Gort-Disc.

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 29 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 (41.8 µg/l) and SW17-Gort (260 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 4.62 µg/l at SW2-SM-South.

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 discharge to the Silvermines stream and had cadmium (4.14 and 4.32 µg/l) and zinc (1540 and 1560 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 125 µg/l.

SW6-Mag downstream of the Magcobar area also had dissolved zinc (361 µg/l) above the ecological assessment criteria.

Table 29 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

	Sample Description	Sample Location	Date Sampled	Ammoniacal Nitrogen as N	pH (field)	Sulphate	Cadmium (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Nickel (diss.filt)	Zinc (diss.filt)
			Units	mg/l		mg/l	µg/l	µg/l	µg/l	µg/l	µg/l
			Ecological Criteria	**0.14**	**4.5 to 9**	**-**	**0.9**	**7.2**	**1100**	**20**	**100**
			Human Health Criteria	**0.3**	**6.5 to 9.5**	**250**	**5**	**10**	**50**	**20**	**-**
Ballygown	SW1-SM	Upstream	28/08/2015	<0.2	7.4	2.9	0.129	0.263	8.81	0.766	13.8
	SW3-SM	DS (underground workings)	28/08/2015	0.22	7.42	<2	<0.1	0.84	6.75	0.884	23.7
	SW4-SM-Ga	Downstream (all)	28/08/2015	<0.2	7.3	5	0.19	1.98	4.17	1.37	125
Magcobar	SW6-Mag	Downstream	25/08/2015	<0.2	7.63	199	0.796	0.345	6.88	5.17	361
Garryard	SW1-GAR	Upstream	No flow	-	-	-	-	-	-	-	-
	SW3-GAR	Downstream (all)	26/08/2015	<0.2	8.06	283	6.15	2.57	105	9.05	1510
Shallee	SW4-SHAL	Upstream	27/08/2015	0.208	6.35	3.6	0.278	1.47	251	4.37	56.9
	SW5-SHAL	DS (drum dump)	27/08/2015	-	-	-	7.11	17.5	77.4	20.3	2520
	SW9-SHAL	Downstream	27/08/2015	<0.2	6.89	15	1.01	149	37.5	7.94	231
	SW1-SHAL	Downstream (all)	27/08/2015	<0.2	7.26	16	0.96	107	36.5	7.51	234
Garryard/ Shallee	DS SHAL	Downstream of SW3-GAR and SW1-SHAL	27/08/2015	<0.2	7.24	60.3	1.23	49.8	35	4.65	393
Gortmore	SW17-GORT	Upstream	25/08/2015	<0.2	7.5	12	<0.1	0.11	53.2	1.34	5.9
	SW12-GORT-DS	Downstream (TMF)	25/08/2015	<0.2	7.91	70.2	0.127	1.37	39	2.37	58.8
	SW14-GORT	Downstream (TMF and Yellow River)	25/08/2015	<0.2	7.94	55.4	0.106	1.19	38.6	2.03	51.1

Notes:

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Metals are dissolved

At Gortmore TMF (Map 2 of **Appendix A**), dissolved zinc exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. Concentrations of dissolved lead and nickel were detected at all sampling locations but were significantly lower than the assessment criteria. Dissolved manganese exceeded the human health assessment criterion of 50 µg/l but was below the ecological assessment criterion of 1100 µg/l at three locations; SW17-Gort (53.2 µg/l), SW12-Gort-Disc. (910 µg/l) and SW10-Gort-Disc. (349 µg/l). Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the two wetland discharges at Gortmore TMF with concentrations ranging from 169 µg/l at SW12-Gort-Disc to 252 µg/l at SW10-Gort-Disc. The concentration of zinc increased on the Kilmastulla River from 5.9 µg/l at the upstream location SW17-Gort, to 58.8 µg/l at the downstream location SW12-Gort-DS, which is lower than the ecological assessment criteria. This location 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. Note the pond discharges (SW18-Gort and SW19-Gort) were dry at the time of sampling.

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 17.5 to 211 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 1.47 µg/l (below both assessment criterion). 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 153 to 2,520 µg/l. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at three Shallee locations with values ranging from 70 µg/l (SW12-Shal) to 251 µg/l (SW4-Shal). SW5-Shal exceeded the ecological and human health criteria for dissolved nickel of 20 µg/l (20.3 µg/l). With the exception of SW12-Shal and SW4-Shal, dissolved cadmium exceeded the ecological criteria (0.9 µg/l) at all locations. SW5-Shal (7.11 µg/l) exceeded both the ecological and human health criteria (5 µg/l). Dissolved cadmium decreased further downstream to 1.01 µg/l and 0.96 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 49.8 µg/l. The dissolved zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 393 µg/l. DS-Shal also exceeded the ecological criteria (0.9 µg/l) for dissolved cadmium with a value of 1.23 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 374 to 12,200 µg/l. However, SW7-Gar (discharge from wetlands) had a dissolved zinc concentration of 56.1 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 5.73 to 56.1 µg/l) with the exception of three locations; SW4-GAR (1.64 µg/l) and SW5-Gar (3.56 µg/l) that only exceeded the ecological criteria and SW7-Gar which was below the assessment criterion. Dissolved lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at SW9-Gar (14.6 µg/l) and only the ecological assessment criteria at SW12-Gar (8.35 µg/l) and SW5-Gar (7.42 µg/l). Nickel was above both the ecological and human health assessment criteria of 20 µg/l at SW8-Gar (49.7 µg/l) and SW9-Gar (30.6 µg/l) which are both downgradient locations. Dissolved manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all locations with the exception of SW4-Gar (1,530 µg/l) and SW8-Gar (1,540) which also exceeded the ecological assessment criteria. At SW4-Gar the human health criteria for iron and the ecological assessment criteria for cobalt was also exceeded with values of 247 µg/l and 7.84 µg/l respectively.

4.3.3 Livestock Water Quality Assessment

Recommendations for levels of toxic substances in drinking water for livestock are provided in Table 26. 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 211 µg/l and the sampling location on the stream SW9-Shal which is just downstream of the Field Shaft had concentration of 149 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). Note the pond discharges (SW18-Gort and SW19-Gort) were dry at the time of sampling.

- No exceedances of the livestock threshold values for any metals were found;
- The recommended value for total dissolved solids (TDS) is 1,000 mg/l, and the TDS values at SW10-Gort-Disc and SW12-Gort-Disc were 2,450 and 1,890 respectively. However, levels of TDS between 1,000 and 3,000 mg/l are considered very satisfactory for all classes of livestock especially when they are accustomed to these levels; and
- The maximum recommended sulphate levels for calves is 500 mg/l and for adults is 1,000 mg/l. The sulphate values at SW10-Gort-Disc and SW12-Gort-Disc exceeded the recommended value with 1,360 and 978 mg/l respectively. The guidelines for sulphates in water are not well defined but high concentrations cause diarrhoea; however, at the levels found in the waterbodies at Gortmore TMF it is likely that livestock are accustomed to them also. 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.

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 27.

The measured concentrations in the vegetation were all below both the no effect and low effect levels provided in Table 27, except for arsenic at SM01-V (1.44 mg/kg) which exceeded the no effect levels but was below the low effect level of 6.21 mg/kg for digestion in wildlife.

4.3.5 Soil Assessment

Table B-5 in Appendix B highlights the exceedances of the assessment criteria for soil. In general, the measured soil concentrations are below the screening levels for arsenic, cadmium, copper, nickel, lead and zinc shown in Table 28 that may have adverse effects on the vegetation or mammals. The measured soil concentrations are all below the threshold reference values (TRVs) for grazing sheep and cattle provided in Table 28. These values consider that in many cases the grazing animals consume the plant leaves and roots containing soil.

The reported values for arsenic in SM15-S and SM21-S were 12 and 11 mg/kg respectively, which were slightly above the ORNL benchmark concentration of 10 mg/kg, there were 6 other locations where the reported value was 10 mg/kg. The reported values for zinc concentrations were at or above the ORNL benchmark concentration of 50 mg/kg in 13 samples. SM21-S had a reported value of 147 mg/kg which exceeds the Eco-SSL recommended value of 79 mg/kg. All reported values were lower than the maximum values for concentrations of zinc of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998.

The reported value for lead in SM21-S (58 mg/kg) exceeded maximum values for concentrations of lead of 50 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998.

Section 5

Flows, Loads and Trend Analysis

5.1 Surface Water Flows

No river flow gauging stations are present within the Silvermines mining area. The nearest gauge on the Kilmastulla River is Coole (EPA station 25044) which is 10 km downstream. The flow record from 1 April to 31 August 2015 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >8 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 0.7 m^3/s. The recorded flow at the Coole gauging station showed that for May high flows existed and were at or above the calculated 5%-ile (high flow) of 4.68 m^3/s on several occasions after rainfall. The flow during this period shows a flashy response to rainfall. The highest recorded flow in the monitoring period was on 5 May 2015 with a mean daily flow of 8 m^3/s. From mid-June to August the flows were low with a baseline of 0.34 m^3/s which is below the 95%-ile (low flow) of 0.38 m^3/s. Overall flows were relatively high in April and May and low during the remainder of the monitoring period.

The flows in the Kilmastulla River in the Silvermines mining area are expected to be lower than that recorded at the EPA Station 10 km downstream, as many small tributaries drain from the surrounding mountains between the mining area and the gauging station. The EPA tool for ungauged catchments was utilised to estimate the 95%-ile flow (low flow) of the Kilmastulla River at the location just downstream of the Gortmore TMF which was 0.16 m^3/s. It is estimated that the flows would have been close to the 95%-ile low flow in the Silvermines mining area in June, July and August. The EPA tool for ungauged catchments was used to calculate the 5%-ile flow (high flow) which was 4.36 m^3/s as the flows were likely greater than this on several occasions in May.

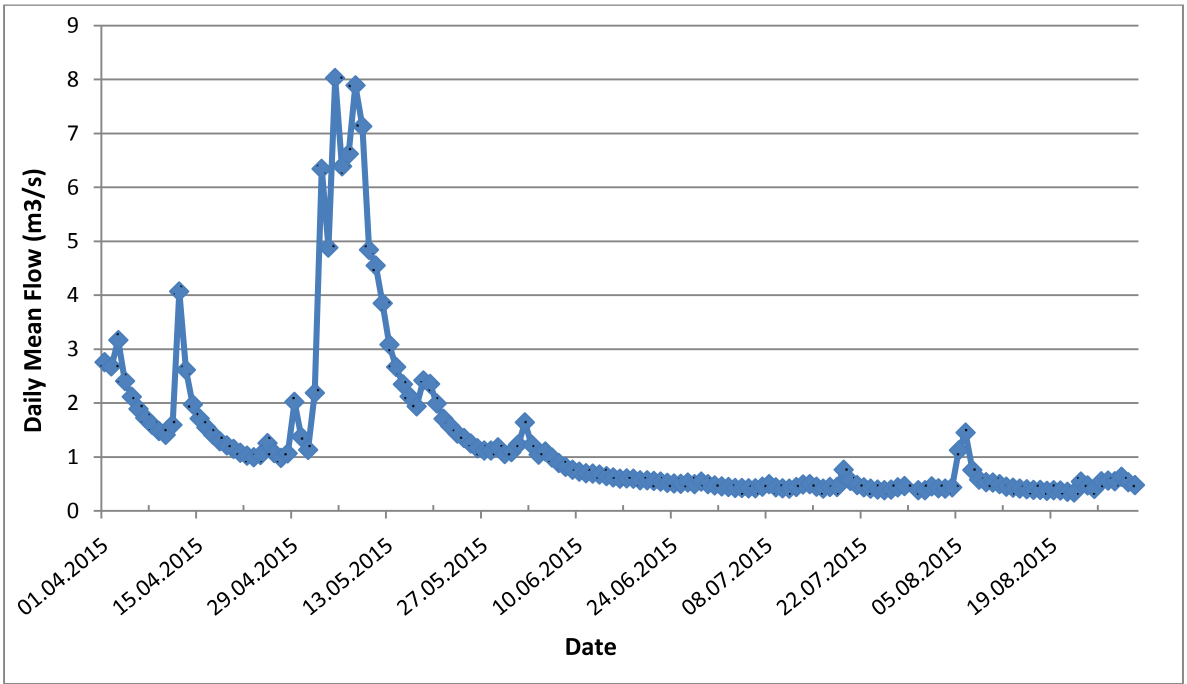

Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 Apr to 31 Aug 2015

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 30 presents a summary of the results from the flow measured in August 2015 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 30 Surface Water Flow Value Measured in August 2015

Site Name	Flow l/s	Date
SW10-GORT Discharge	0.13	25/08/2015
SW12-GORT Discharge	1.86	25/08/2015
SW19-Gort	No flow	24/08/2015
SW10-GAR	4.4	26/08/2015
SW12-GAR	2.47	26/08/2015
SW3-GAR	11.1	26/08/2015
SW4-GAR	0.10	25/08/2015
SW5-GAR	Flow immeasurable (grating)	26/08/2015
SW7-GAR	0.22	26/08/2015
SW8-GAR	Flow immeasurable	26/08/2015
SW9-GAR	1.58	26/08/2015
DS-SHAL	33.9	27/08/2015
SW10-SHAL	No flow	27/08/2015
SW12-SHAL	4.85	27/08/2015
SW1-SHAL	10.34	27/08/2015
SW4-SHAL	0.01	27/08/2015
SW5-SHAL	Flow immeasurable	27/08/2015
SW6-SHAL	3.76	27/08/2015
SW7-SHAL	No flow	27/08/2015
SW9-SHAL	10.9	27/08/2015
SW1-SM	24.9	28/08/2015
SW3-SM	30.3	28/08/2015
SW2-SM-North	0.02	28/08/2015
SW2-SM-South	1.03	28/08/2015
SW4-SM-GA	45.7	28/08/2015

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 31 aid with the interpretation of the loading of sulphate and dissolved cadmium, lead, manganese, nickel and zinc to rivers.

Table 31 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 - DISC.	25/08/2015	0.13	7.62	1360000	14800	0.05	0	0.21	0	349	3.79	9.29	0.1	252	2.73
SW12-GORT-DISC.	25/08/2015	1.86	7.18	978000	157000	0.106	0.02	0.073	0.01	910	146	7.21	1.16	169	27.1
SW4-GAR	25/08/2015	0.10	7.04	41300	353	1.64	0.01	1.41	0.01	1530	13.1	10.8	0.09	374	3.2
SW10-GAR	26/08/2015	4.4	8.12	330000	124000	12	4.52	3.98	1.5	141	53.1	12.9	4.86	2590	976
SW12-GAR	26/08/2015	2.47	7.5	167000	35600	7.98	1.7	8.35	1.78	230	49	11.7	2.49	2800	597
SW3-GAR	26/08/2015	11.1	8.06	283000	272000	6.15	5.91	2.57	2.47	105	101	9.05	8.7	1510	1450
SW7-GAR	26/08/2015	0.22	7.39	182000	3410	0.15	0	0.475	0.01	168	3.14	3.2	0.06	56.1	1.05
SW9-GAR	26/08/2015	1.58	7.09	533000	72500	56.1	7.63	14.6	1.99	371	50.5	30.6	4.16	10800	1470
DS SHAL	27/08/2015	33.92	7.24	60300	177000	1.23	3.6	49.8	146	35	103	4.65	13.6	393	1150
SW12-SHAL	27/08/2015	4.85	6.09	1000	419	0.05	0.02	22.9	9.6	70	29.3	1.19	0.5	17.8	7.46
SW1-SHAL	27/08/2015	10.3	7.26	16000	14300	0.96	0.86	107	95.6	36.5	32.6	7.51	6.71	234	209
SW4-SHAL	27/08/2015	0.01	6.35	3600	3.82	0.278	0	1.47	0	251	0.27	4.37	0	56.9	0.06
SW6-SHAL	27/08/2015	3.76	5.96	13400	4360	0.903	0.29	211	68.6	46.4	15.1	7.85	2.55	153	49.8
SW9-SHAL	27/08/2015	10.87	6.89	15000	14100	1.01	0.95	149	140	37.5	35.2	7.94	7.46	231	217
SW1-SM	28/08/2015	24.92	7.4	2900	6240	0.129	0.28	0.263	0.57	9.35	20.1	0.794	1.71	8.06	17.4
SW2-SM-NORTH	28/08/2015	0.02	7.37	27500	48.2	4.14	0.01	1.47	0	0.252	0	6.14	0.01	1540	2.7
SW2-SM-SOUTH	28/08/2015	1.0	6.97	27800	2480	4.32	0.39	0.856	0.08	0.547	0.05	6.3	0.56	1560	139
SW3-SM	28/08/2015	30.3	7.42	1000	2620	0.05	0.13	0.84	2.2	6.75	17.7	0.884	2.32	23.7	62.1
SW4-SM-GA	28/08/2015	45.7	7.3	5000	19700	0.19	0.75	1.98	7.82	4.17	16.5	1.37	5.41	125	494

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 0.06 to 1,470 g/day with an average of 361 g/day overall. The largest mass load of zinc was 1,470 g/day at SW9-GAR which is located downgradient of the Garryard Facility. Note the sample was taken directly after heavy rainfall. SW10-Gar (the discharge from the tailings lagoon) had a smaller loading of 976 g/day zinc. Further downstream at SW3-Gar which is located in a stream containing the SW10-Gar discharge and the western part of the Mogul yard, there was an apparent increase in zinc loading to 1,450 g/day. The stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 17.4 g/day, which increases to 62.1 g/day downstream of the mine workings (SW3-SM). The southern and northern adits (SW2-SM) also contribute 139 g/day and 2.7 g/day respectively of dissolved zinc to the stream. Further downstream the calculated mass load at SW4-SM-GA was 494 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 DS-Shal located downstream of both the Shallee and Garryard mining areas. The dissolved lead load increases from 95.6 g/day at SW1-Shal to 146 g/day at DS-Shal. The stream from the Garryard area only contributes 2.47 g/day of dissolved lead and therefore the increase could be from diffuse flow from a tailings impoundment at Shallee. The dissolved zinc load at DS-Shal is 1,150 g/day which is an increase from the Shallee area (SW1-Shal – 209 g/day). This indicates that the main source of zinc load is from the stream emerging from the Garryard area with 1,450 g/day, which also indicates there is some loss in the zinc load.

Upstream of SW1-Shal the dissolved lead load was 140 g/day at SW9-Shal which is located immediately east of the southernmost Shallee tailings impoundment and downstream of Field Shaft. The dissolved lead loading from Field Shaft (SW6-Shal) was 68.6 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 Field Shaft (where accessible) and no other inputs of surface water were observed.

Of the two wetland discharges at Gortmore TMF, SW12-Gort-Discharge had the highest loading of dissolved zinc at 27.1 g/day and SW10-Gort-Discharge had 2.73 g/day of zinc. Discharges from the Garryard and Shallee area (DS-Shal – 1,150 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 32 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 32 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 33 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 33 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	11	0.3481	-6	No Trend
	Diss. lead	10	0.3927	-4	No Trend
	Diss. manganese	11	0.0255	-26	Decreasing
	Diss. nickel	11	0.2655	-9	No Trend
	Diss. zinc	11	0.1736	13	No Trend
SW10-Gort-discharge	Diss. cadmium	8	0.0673	-13	Likely Decreasing
	Diss. lead	6	0.5	1	No Trend
	Diss. manganese	8	0.1328	10	No Trend
	Diss. nickel	8	0.0868	-12	Likely Decreasing
	Diss. zinc	8	0.0539	-14	Likely Decreasing
SW12-Gort-discharge	Diss. cadmium	6	0.2262	5	No Trend
	Diss. lead	6	0.3536	-3	No Trend
	Diss. manganese	7	0.5	1	No Trend
	Diss. nickel	7	0.1148	-9	No Trend
	Diss. zinc	7	0.5	1	No Trend
SW6-Shal	Diss. cadmium	9	0.3772	-4	No Trend
	Diss. lead	9	0.3772	-4	No Trend
	Diss. manganese	9	0.0589	-16	Likely Decreasing
	Diss. nickel	9	0.2328	-8	No Trend
	Diss. zinc	9	0.1257	-12	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	7	0.5	1	No Trend
	Diss. lead	8	n/a	n/a	Not Calculated
	Diss. manganese	8	0.4508	2	No Trend
	Diss. nickel	8	n/a	n/a	Not Calculated
	Diss. zinc	8	0.3553	-4	No Trend

Not Calculated: Insufficient statistical evidence of a significant trend.

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The results of the Mann-Kendall analysis show that dissolved manganese concentrations are decreasing at SW10-Gar. At SW10-Gort-discharge dissolved cadmium, nickel and zinc are likely decreasing. Note that additional samples are required to confirm this trend. In the Shallee mining area dissolved manganese is likely decreasing at the field shaft (SW6-Shal). No other statistically significant trends were observed in the data that were analysed.

5.3.2 Seasonal Trends

Table 34 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), September 2014 (R4) and August 2015 (R6).

Table 34 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
	R6 28/08/2015	1	4.32	0.39	0.856	0.08	0.547	0.05	1560	139
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
	R6 27/08/2015	3.76	0.903	0.29	211	68.6	46.4	15.1	153	49.8
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
	R6 26/08/2015	4.4	12	4.52	3.98	1.5	141	53.1	2590	976
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
	R6 25/08/2015	0.13	0.05	0	0.21	0	349	3.79	252	2.73
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
	R6 25/08/2015	1.86	0.106	0.02	0.073	0.01	910	146	169	27.1
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	-
	R6 25/08/2015	-	0.106	-	1.19	-	38.6	-	51.1	-

Notes
- is not measured / calculated

As can be seen from Table 34 the concentrations of dissolved cadmium, lead, manganese and zinc are generally at similar concentrations in both low flow and high flow conditions. 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 (42.1 µg/l) and August 2015 (51.1 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 34 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August 2013, September 2014 and August 2015 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 35 displays the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevations outside the TMF decreased from 48.29 m Ordnance Datum (OD) at the upgradient location TMF1 to 45.85 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 0.003, however the level of the river is unknown. The groundwater elevations at TMF1 and TMF2 are similar to the elevations measured on 24/9/2014 and between 0.66 and 0.64 metres lower than the elevations measured in spring (2/2/2015).

Within the tailings area, measured water levels were in the range of 2.93 to 4.15 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 48.54 to 53.02 m OD. These groundwater elevations are similar to the elevations measured during low flow (24/9/2014) which ranged from 48.54 to 53.02 m OD and between 0.15 to 1.2 metres lower than the elevations measured during high flow (2/2/2015).

Table 35 Measures Groundwater Levels August 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	24/8/2015	11:00	0.71	1.3	48.29
TMF2		24/8/2015	12:45	2.15	2.61	45.85
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	24/8/2015	15:25	3.29	3.94	52.47
BH2A-GORT-06		24/8/2015	15:10	3.40	3.93	52.36
BH3A-GORT-06		24/8/2015	14:50	8.06	8.39	48.54
BH4A-GORT-06		24/8/2015	16:05	4.00	4.52	52.16
BH5A-GORT-06		24/8/2015	15:55	4.15	4.58	52.06
BH6A-GORT-06		24/8/2015	15:35	5.17	5.86	50.91
BH6B-GORT-06		24/8/2015	15:40	2.93	3.65	53.02

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

Section 7

Summary and Recommendations

7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in August 2015 and water levels were measured in seven additional monitoring wells. Twenty-eight surface water locations were sampled and analysed in August 2015 with flows measured at 19 of the locations. Twenty vegetation samples and twenty soil samples were collected and analysed in August 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 exceeded the assessment criteria for dissolved barium and manganese, with higher concentrations in the downgradient monitoring well TMF2 (622 and 1,040 µg/l, respectively). Dissolved barium exceeded the ecological health criteria and dissolved manganese exceeded the human health criteria in both monitoring wells. Dissolved iron also exceeded the human health criteria of 200 µg/l with a value of 212 µg/l at TMF2. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- Surface water locations SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc than the rest of the rivers and streams sampled in the Silvermines area (5.9 and 8.06 µg/l, respectively), which are both well below the ecological assessment criteria of 100 µg/l.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. For example, SW9-Gar, located downgradient of the Garryard facility had the highest concentrations of dissolved cadmium (56.1 µg/l) and lead (14.6 µg/l). Each location in Garryard (374 to 12,200 µg/l) exceeded the dissolved zinc ecological assessment criteria of 100 µg/l with the exception of SW7-Gar (56.1 µg/l). The majority of locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium. The human health criteria of 50 µg/l for manganese was exceeded at all locations with values ranging from 63.9 to 1,540 µg/l. SW4-Gar and SW8-Gar also exceeded the ecological assessment criteria for manganese (1,100 µg/l).

- At Shallee dissolved lead exceeded 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 211 µg/l.

- Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the majority of the drainages and discharges ranging from 17.8 to 12,200 µg/l at SW8-Gar. The concentration of zinc increased on the Kilmastulla River from 5.9 µg/l at the upstream location SW17-Gort to 58.8 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 393 µg/l.
- The dissolved metal with the highest mass loading was zinc, ranging from 0.06 to 1,470 g/day with an average of 361 g/day overall. The largest mass load of zinc was 1,470 g/day at SW9-GAR which is downgradient of the Garryard facility. The highest load of dissolved lead was from DS-Shal (146 g/day) which is located downstream of the Shallee and Garryard mining areas. Measured flows ranged from 0.01 to 45.7 l/s with an average of 9.87 l/s overall.
- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated lead levels (>50 µg/l).
- No measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium, lead and zinc exceeded the Maximum Content standards. The concentration of arsenic at SM01-V (1.44 mg/kg) exceeded the no effect level (0.621 mg/kg) for digestion in wildlife.

7.2 Recommendations for the Monitoring Programme

Recommendations for future monitoring at the former Silvermines mining site as well as a review of the monitoring which has been undertaken from 2013-2015 will be presented in a summary report due December 2015.

Section 8

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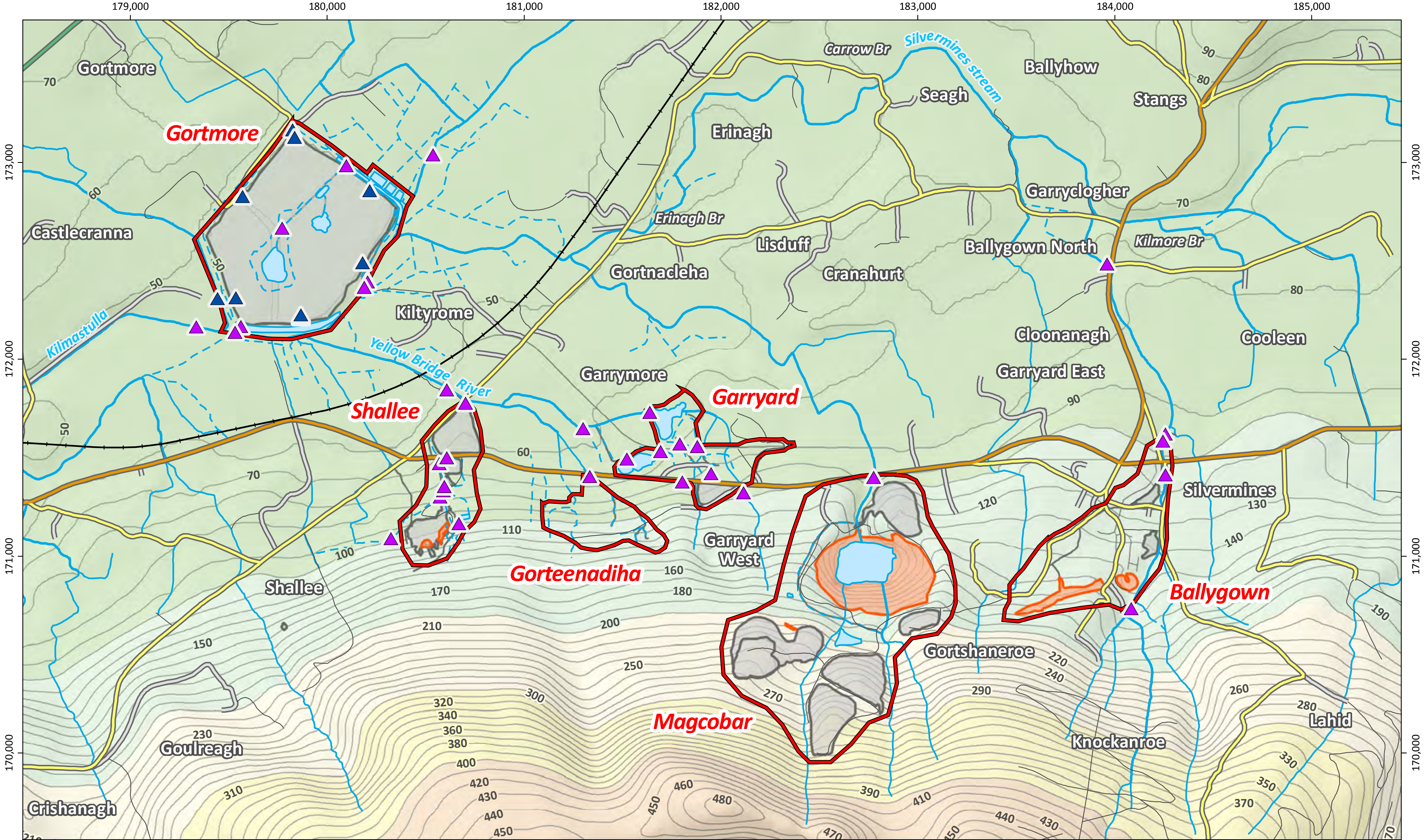
Appendix A

Figures



Map 1 - Silvermines - Overview

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CDM Smith

Legend

Sampling Locations
- Surface water
- Groundwater

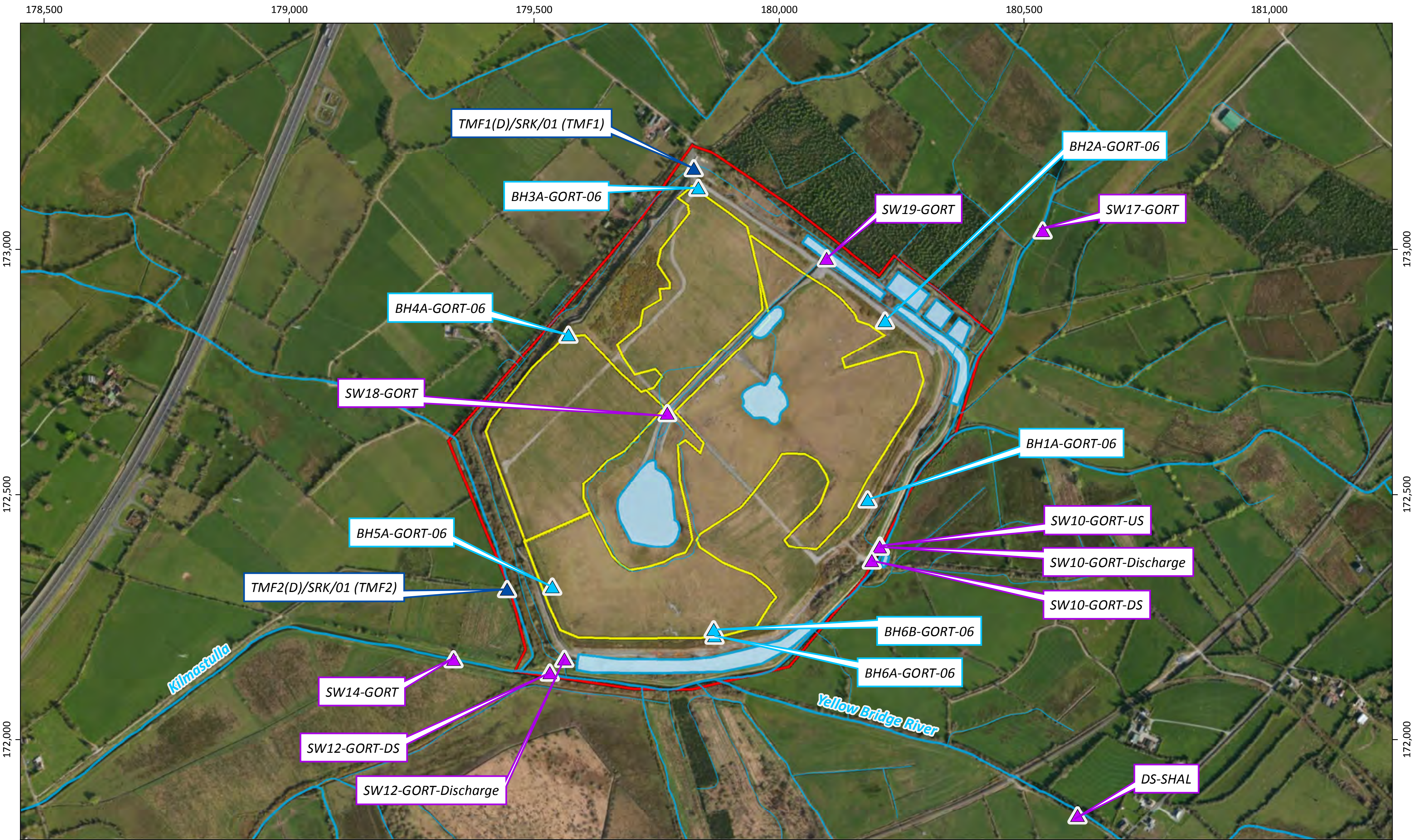
- Rivers
- Streams
- Pond / Wetland / Pit Lake

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

N W E S

Scale is 1:25,000

0 250 500 m



Map 2 - Silvermines - Gortmore TMF

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Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations

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

- Rivers
- Streams
- Pond / Wetland / Pit Lake

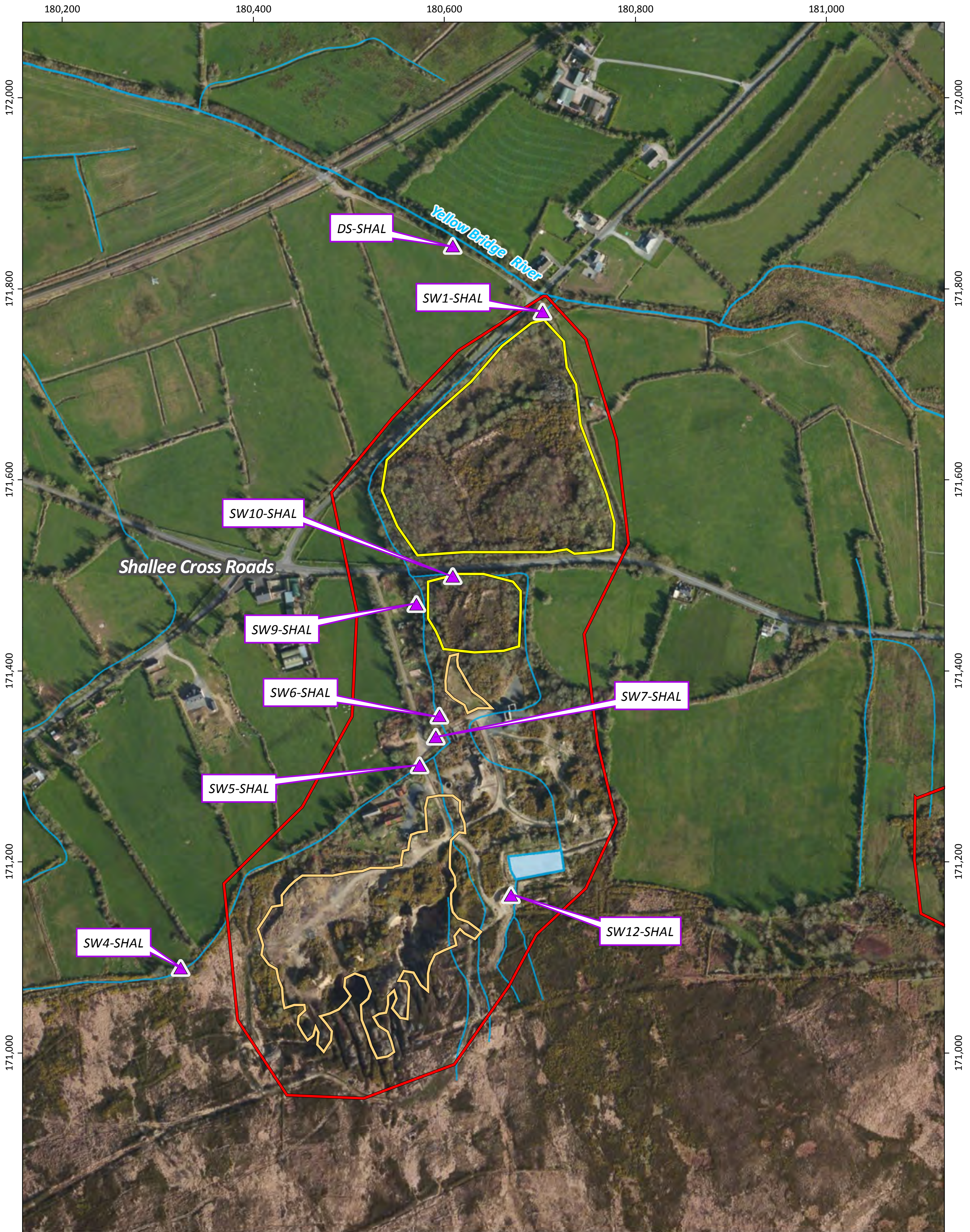
Mines

- Mining Areas

Scale is 1:10,000

0 100 200 m

N W E S



Map 3 - Silvermines - Shallee South

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Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

Mining Areas

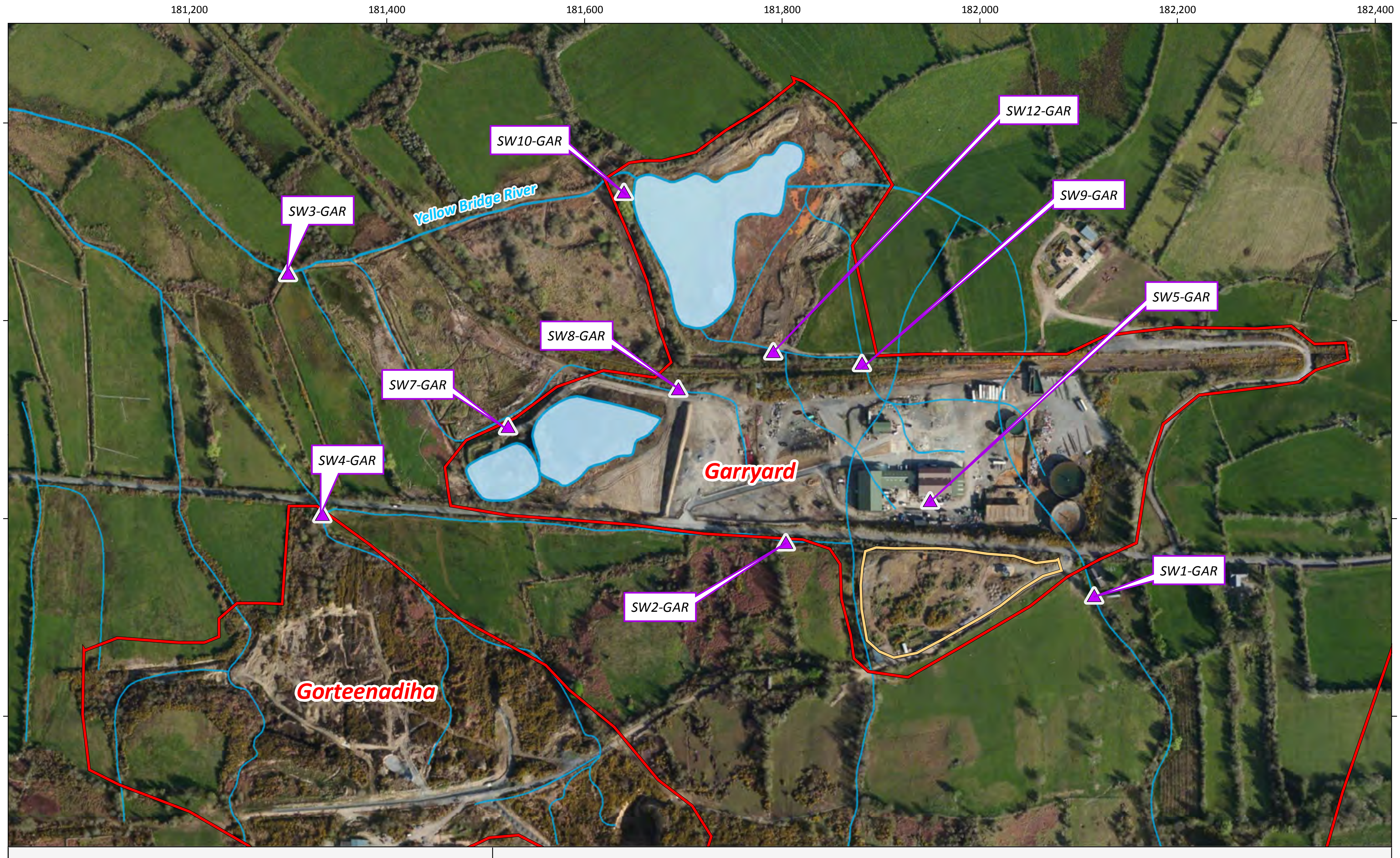
Tailings / Tailings Pond

Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:5,000

0 50 100 m



Map 4 - Silvermines - Garryard

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Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

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Legend

Sampling Locations
- Surface water

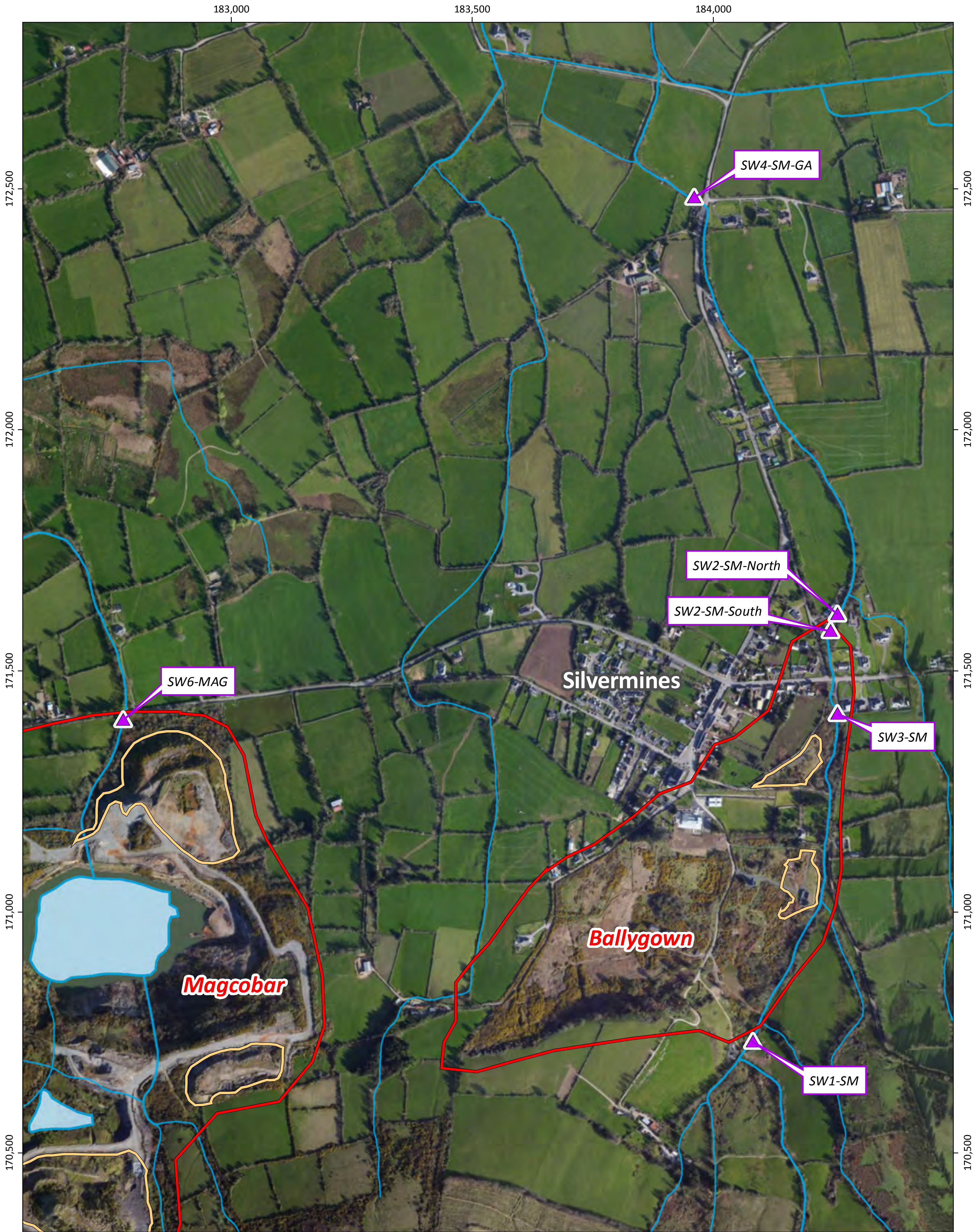
- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Stockpile Dump

Scale is 1:5,000

0 50 100 m

N E S W



Map 5 - Silvermines - Magcobar and Ballygown

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Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

CDM Smith

Legend

Sampling Locations
- Surface water

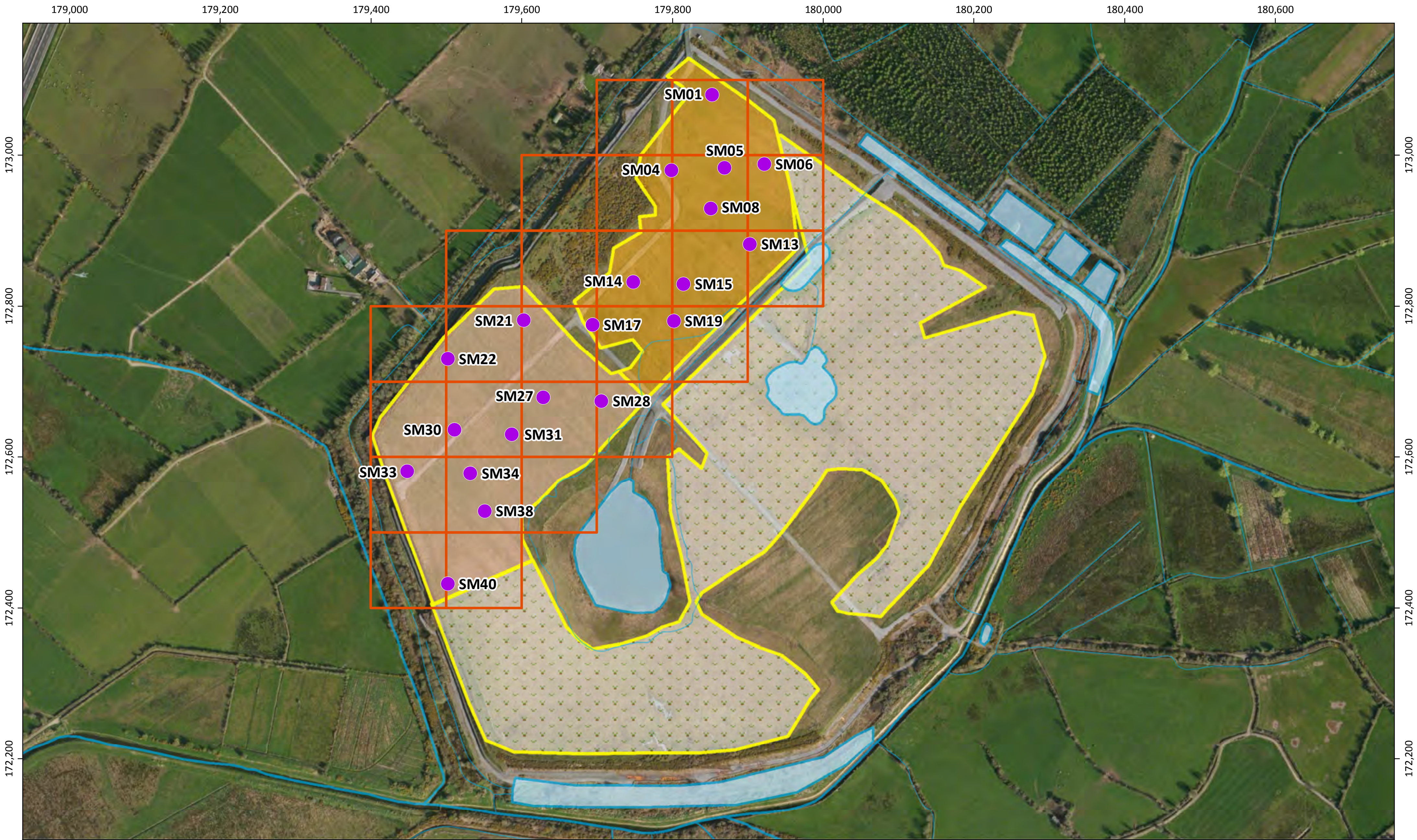
- Rivers
- Streams
- Pond / Wetland

Mines
- Mining Areas
- Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:10,000

0 100 200 m



Map 6 - Silvermines - Gortmore - Vegetation

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Source: ESRI World Imagery ©ESRI (UC-G image courtesy of Microsoft, acquired on 11/6/2011)

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

N W E S

Scale is 1:6,500

0 100 200 m

Appendix B

Analytical Data Tables and Assessment Criteria

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Table B-1 Comparison of Total versus Dissolved Metals R6

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	
DS SHAL	27/08/2015	<2	1.87	1.23	0.66	79.5	49.8	0.63	5.63	4.65	0.83	494	393	0.80
SW10 - GORT - DISCHARGE	25/08/2015	3.5	*0.25*	*0.05*	0.20	*0.25*	0.21	0.84	7.3	9.29	1.27	306	252	0.82
SW10 - GORT - DS	25/08/2015	2	*0.25*	*0.05*	0.20	4	0.608	0.15	1.62	1.99	1.23	48.3	43.7	0.90
SW10 - GORT - US	25/08/2015	5.5	*0.25*	*0.05*	0.20	3.41	0.658	0.19	1.76	2.04	1.16	43.7	40.1	0.92
SW10-GAR	26/08/2015	2.5	14.2	12	0.85	10.7	3.98	0.37	12.1	12.9	1.07	3120	2590	0.83
SW12-GAR	26/08/2015	107	13.1	7.98	0.61	866	8.35	0.01	18.1	11.7	0.65	5210	2800	0.54
SW12-GORT-DISCHARGE	25/08/2015	4.5	*0.25*	0.106	0.42	*0.25*	0.073	0.29	7.81	7.21	0.92	197	169	0.86
SW12-GORT-DS	25/08/2015	2	*0.25*	0.127	0.51	4.98	1.37	0.28	3.65	2.37	0.65	66.8	58.8	0.88
SW12-SHAL	27/08/2015	<2	*0.25*	*0.05*	0.20	35.3	22.2	0.63	1.25	1.19	0.95	40.1	17.8	0.44
SW14-GORT	25/08/2015	<2	*0.25*	0.106	0.42	3.78	1.19	0.31	2.45	2.03	0.83	52.4	51.1	0.98
SW17 - GORT	25/08/2015	2	*0.25*	*0.05*	0.20	*0.25*	0.11	0.44	1.06	1.34	1.26	*1.5*	5.9	3.93
SW1-SHAL	27/08/2015	<2	1.42	0.96	0.68	139	107	0.77	8.67	7.51	0.87	280	234	0.84
SW1-SM	28/08/2015	3.5	*0.25*	0.129	0.52	2.15	0.263	0.12	0.793	0.766	0.97	8.8	13.8	1.57
SW2-SM-NORTH	28/08/2015	<2	5.07	4.14	0.82	2.78	1.47	0.53	6.38	6.14	0.96	1860	1540	0.83
SW2-SM-SOUTH	28/08/2015	<2	4.68	4.32	0.92	1.15	0.856	0.74	6.54	6.3	0.96	1820	1560	0.86
SW3-GAR	26/08/2015	<2	8.43	6.15	0.73	6.76	2.57	0.38	9.08	9.05	1.00	1770	1510	0.85
SW3-SM	28/08/2015	2.5	*0.25*	*0.05*	0.20	3.23	0.84	0.26	0.777	0.884	1.14	26.3	23.7	0.90
SW4-GAR	25/08/2015	2	2.15	1.64	0.76	17.9	1.41	0.08	15.7	10.8	0.69	423	374	0.88
SW4-SHAL	27/08/2015	<2	*0.25*	0.278	1.11	4.89	1.47	0.30	4.29	4.37	1.02	56.6	56.9	1.01
SW4-SM-GA	28/08/2015	2	*0.25*	0.19	0.76	10.2	1.98	0.19	1.51	1.37	0.91	153	125	0.82
SW5-GAR	26/08/2015	71.5	9.69	3.56	0.37	336	7.42	0.02	17.4	7.54	0.43	3360	1310	0.39
SW6-MAG	25/08/2015	<2	1.01	0.796	0.79	4.37	0.345	0.08	5.9	5.17	0.88	411	361	0.88
SW6-SHAL	27/08/2015	<2	1.17	0.903	0.77	265	211	0.80	9.01	7.85	0.87	197	153	0.78
SW7-GAR	26/08/2015	<2	0.911	0.15	0.16	1.59	0.048	0.03	3.29	3.11	0.95	116	55.2	0.48
SW8-GAR	26/08/2015	7.5	8.81	5.73	0.65	231	1.52	0.01	57.7	49.7	0.86	17800	12200	0.69
SW9-GAR	26/08/2015	6.5	77.3	56.1	0.73	107	14.6	0.14	32.6	30.6	0.94	17300	10800	0.62
SW9-SHAL	27/08/2015	<2	1.33	1.01	0.76	172	149	0.87	9.02	7.94	0.88	250	231	0.92
TMF 1	24/08/2015	-	*0.25*	*0.05*	0.20	14.5	0.08	0.01	2.69	1.47	0.55	9.45	1.95	0.21
TMF 2	24/08/2015	-	*0.25*	*0.05*	0.20	13.7	2.95	0.22	1.25	1.59	1.27	4.62	2.67	0.58

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 R6

Sample Description	Type	Area	Date Sampled	Acidity as HCL	Alkalinity, Total as CaCO3	Hardness as CaCO3	Ammoniacal Nitrogen as N	Chloride	COD, unfiltered	Specific Conductance @ deg.C (field)	Cyanide, Free	Dissolved solids, Total	Fluoride	Nitrate as NO3	Nitrite as NO2	Oxygen, dissolved (field)	pH (field)	Phosphate (ortho) as P	Sulphate	Sodium (diss.filt)	Suspended solids, Total
			Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	pH Units	mg/l	mg/l	mg/l	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	24/08/2015	-	215	262	*0.1*	11.7	-	0.452	*0.025*	250	*0.25*	*0.15*	*0.025*	0.452	6.95	*0.01*	15	9.64	-
TMF 2	GW	GM	24/08/2015	-	243	296	*0.1*	16.8	-	0.496	*0.025*	264	*0.25*	*0.15*	*0.025*	0.496	6.83	*0.01*	2	10.3	-
SW10-GORT - DISC.	Discharge	GM	25/08/2015	9.13	240	293	*0.1*	12.5	12.6	2.397	*0.025*	2450	0.536	*0.15*	*0.025*	63.5	7.62	*0.01*	1360	8.09	3.5
SW10-GORT - DS	River/Stream	GM	25/08/2015	7.3	240	293	*0.1*	16.9	*3.5*	0.552	*0.025*	353	*0.25*	6.46	0.067	78.7	7.83	0.0398	46.4	10.1	2
SW10-GORT - US	River/Stream	GM	25/08/2015	*2*	235	287	*0.1*	17	7	0.55	*0.025*	345	*0.25*	6.35	0.066	72	7.41	0.0369	45.2	10.3	5.5
SW12-GORT-DISC.	Discharge	GM	25/08/2015	*2*	305	372	*0.1*	21.2	13.7	2.008	*0.025*	1890	*0.25*	0.508	*0.025*	54.3	7.18	*0.01*	978	14.4	4.5
SW12-GORT-DS	River/Stream	GM	25/08/2015	*2*	225	275	*0.1*	16.7	*3.5*	0.58	*0.025*	406	*0.25*	5.53	0.052	90.9	7.91	0.0274	70.2	9.3	2
SW14-GORT	River/Stream	GM	25/08/2015	*2*	202	246	*0.1*	16.1	8.55	0.521	*0.025*	351	*0.25*	6.68	*0.025*	88.6	7.94	0.0261	55.4	9.26	*1*
SW17-GORT	River/Stream	GM	25/08/2015	7.3	205	250	*0.1*	19	13.6	0.441	*0.025*	261	*0.25*	6.63	0.168	72.2	7.5	0.0711	12	12.7	2
SW6-MAG	River/Stream	Mag	25/08/2015	*2*	70	85	*0.1*	9.2	*3.5*	0.541	*0.025*	430	*0.25*	0.702	*0.025*	92.6	7.63	*0.01*	199	5.29	*1*
SW4-GAR	River/Stream	GAR	25/08/2015	*2*	90	110	*0.1*	12.2	10.4	0.283	*0.025*	176	*0.25*	0.416	*0.025*	72.2	7.04	*0.01*	41.3	6.76	2
SW10-GAR	Discharge	GAR	26/08/2015	5.48	200	244	*0.1*	14.6	*3.5*	0.963	*0.025*	732	*0.25*	*0.15*	*0.025*	97.4	8.12	*0.01*	330	9.24	2.5
SW12-GAR	Drainage	GAR	26/08/2015	*2*	60	73	0.246	4.8	47.2	0.37	*0.025*	342	*0.25*	1.17	*0.025*	91.2	7.5	*0.01*	167	5.13	107
SW3-GAR	River/Stream	GAR	26/08/2015	5.48	205	250	*0.1*	15.2	*3.5*	0.91	*0.025*	683	*0.25*	*0.15*	*0.025*	97.1	8.06	*0.01*	283	8.94	*1*
SW5-GAR	Discharge	GAR	26/08/2015	*2*	70	85	0.226	5	35.5	0.431	*0.025*	290	*0.25*	0.603	*0.025*	100.6	6.57	0.0206	131	5.04	71.5
SW7-GAR	Drainage	GAR	26/08/2015	5.48	170	207	*0.1*	16.1	10.9	0.69	*0.025*	508	*0.25*	*0.15*	*0.025*	66.3	7.39	*0.01*	182	11.3	*1*
SW8-GAR	Drainage	GAR	26/08/2015	9.13	240	293	0.232	15.1	9.02	1.689	*0.025*	1510	2.51	1.79	*0.025*	91	7.3	*0.01*	755	14.3	7.5
SW9-GAR	Drainage	GAR	26/08/2015	*2*	50	61	0.276	17.8	*3.5*	1.109	*0.025*	963	2.34	0.944	*0.025*	59.2	7.09	0.047	533	5.8	6.5
DS SHAL	River/Stream	Shs	27/08/2015	*2*	70	85	*0.1*	11.1	21.4	0.274	*0.025*	198	*0.25*	0.636	*0.025*	98.2	7.24	*0.01*	60.3	6.33	*1*
SW12-SHAL	Drainage	Shs	27/08/2015	*2*	3	4	*0.1*	9.1	8.78	0.038	*0.025*	13	*0.25*	*0.15*	*0.025*	98.7	6.09	*0.01*	*1*	4.74	*1*
SW1-SHAL	River/Stream	Shs	27/08/2015	*2*	50	61	*0.1*	10.3	*3.5*	0.163	*0.025*	102	*0.25*	1.08	*0.025*	103.1	7.26	*0.01*	16	6.13	*1*
SW4-SHAL	River/Stream	Shs	27/08/2015	*2*	44	54	0.208	11.7	*3.5*	0.147	*0.025*	62	*0.25*	*0.15*	*0.025*	75.3	6.35	*0.01*	3.6	6.88	*1*
SW5-SHAL	River/Stream	Shs	27/08/2015	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW6-SHAL	Discharge	Shs	27/08/2015	*2*	46	56	0.242	10.5	*3.5*	0.152	*0.025*	75	*0.25*	1.15	*0.025*	68.5	5.96	*0.01*	13.4	6.54	*1*
SW9-SHAL	River/Stream	Shs	27/08/2015	*2*	55	67	*0.1*	10.4	*3.5*	0.159	*0.025*	91	*0.25*	1.18	*0.025*	96.9	6.89	*0.01*	15	6.15	*1*
SW1-SM	River/Stream	BG	28/08/2015	*2*	55	67	*0.1*	11.2	8.63	0.147	*0.025*	80	*0.25*	1.62	*0.025*	96.1	7.4	*0.01*	2.9	6.75	3.5
SW2-SM-NORTH	Discharge	BG	28/08/2015	5.48	235	287	*0.1*	13.6	*3.5*	0.509	*0.025*	294	*0.25*	5.77	*0.025*	78	7.37	*0.01*	27.5	7.97	*1*
SW2-SM-SOUTH	Discharge	BG	28/08/2015	9.13	230	281	0.261	13.6	*3.5*	0.512	*0.025*	306	*0.25*	5.96	*0.025*	69.4	6.97	*0.01*	27.8	8.58	*1*
SW3-SM	River/Stream	BG	28/08/2015	*2*	45	55	0.22	10.4	*3.5*	0.137	*0.025*	80	*0.25*	1.31	*0.025*	98.5	7.42	*0.01*	*1*	6.75	2.5
SW4-SM-GA	River/Stream	BG	28/08/2015	*2*	70	85	*0.1*	11.2	10.9	0.187	*0.025*	109	*0.25*	2.51	*0.025*	96	7.3	0.0408	5	7.15	2

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 R6

Sample Description	Type	Area	Date Sampled	Aluminium (diss.filt)	Antimony (diss.filt)	Arsenic (diss.filt)	Barium (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Iron (diss.filt)	Lead (diss.filt)	Manganese (diss.filt)	Mercury (diss.filt)	Molybdenum (diss.filt)	Nickel (diss.filt)	Selenium (diss.filt)	Silver (diss.filt)	Thallium (diss.filt)	Tin (diss.filt)	Uranium (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**
Ecological Criteria				**1,900**	**-**	**25**	**4**	**0.9**	**3.4**	**5.1**	**30**	**-**	**7.2**	**1100**	**0.07**	**-**	**20**	**-**	**-**	**-**	**-**	**2.6**	**-**	**100**
Human Health Criteria				**200**	**5**	**10**	**-**	**5**	**50**	**-**	**2000**	**200**	**10**	**50**	**1**	**-**	**20**	**10**	**-**	**-**	**-**	**-**	**-**	**-**
TMF 1	GW	GM	24/08/2015	6.73	0.298	3.71	158	*0.05*	1.2	0.508	*0.425*	162	0.08	85.1	*0.005*	0.454	1.47	*0.195*	*0.75*	*0.48*	0.528	*0.75*	0.284	1.95
TMF 2	GW	GM	24/08/2015	4.6	*0.08*	4	622	*0.05*	1.46	0.604	*0.425*	212	3	1040	*0.005*	0.303	1.72	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.27	3.43
SW10-GORT - DISC.	Discharge	GM	25/08/2015	*1.45*	*0.08*	0.412	12.8	*0.05*	1.31	0.478	6.49	21.3	0.21	349	*0.005*	0.605	9.29	0.463	*0.75*	1.73	*0.18*	*0.75*	0.343	252
SW10-GORT - DS	River/Stream	GM	25/08/2015	*1.45*	*0.08*	0.689	146	*0.05*	1.37	0.178	1	46	0.608	38.2	*0.005*	0.385	1.99	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.303	43.7
SW10-GORT - US	River/Stream	GM	25/08/2015	*1.45*	*0.08*	0.71	150	*0.05*	1.41	0.16	1.05	47.1	0.658	39.3	*0.005*	0.25	2.04	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.345	40.1
SW12-GORT-DISC.	Discharge	GM	25/08/2015	*1.45*	0.201	0.459	96.8	0.106	1.94	0.477	4.24	103	0.073	910	*0.005*	0.283	7.21	0.644	*0.75*	*0.48*	0.446	*0.75*	0.474	169
SW12-GORT-DS	River/Stream	GM	25/08/2015	*1.45*	0.236	0.653	150	0.127	0.702	0.186	1.56	38.3	1.37	39	*0.005*	0.269	2.37	*0.195*	*0.75*	*0.48*	0.379	*0.75*	*0.12*	58.8
SW14-GORT	River/Stream	GM	25/08/2015	3.5	0.344	0.644	153	0.106	1.23	0.154	1.54	41.2	1.19	38.6	*0.005*	0.365	2.03	*0.195*	*0.75*	*0.48*	0.659	*0.75*	0.314	51.1
SW17-GORT	River/Stream	GM	25/08/2015	3.01	0.431	0.988	260	*0.05*	0.917	0.159	1.07	73.6	0.11	53.2	*0.005*	0.455	1.34	0.491	*0.75*	*0.48*	0.933	*0.75*	*0.12*	5.9
SW6-MAG	River/Stream	Mag	25/08/2015	*1.45*	0.653	0.367	40.2	0.796	0.42	0.107	3.23	*9.5*	0.345	6.88	*0.005*	1.24	5.17	0.425	*0.75*	*0.48*	1.47	*0.75*	*0.12*	361
SW4-GAR	River/Stream	GAR	25/08/2015	*1.45*	0.994	0.481	239	1.64	0.721	7.84	8.4	247	1.41	1530	*0.005*	0.335	10.8	0.407	*0.75*	*0.48*	0.819	*0.75*	*0.12*	374
SW10-GAR	Discharge	GAR	26/08/2015	*1.45*	0.64	0.742	22	12	1.42	2.27	4.76	*9.5*	3.98	141	*0.005*	0.893	12.9	*0.195*	*0.75*	4	0.65	*0.75*	0.342	2590
SW12-GAR	Drainage	GAR	26/08/2015	7.2	1.18	0.458	30.5	7.98	0.471	1.99	5.21	42.5	8.35	230	*0.005*	1.55	11.7	*0.195*	*0.75*	*0.48*	0.695	*0.75*	*0.12*	2800
SW3-GAR	River/Stream	GAR	26/08/2015	*1.45*	0.349	4.52	56.7	6.15	1.26	0.84	3.84	*9.5*	2.57	105	*0.005*	0.321	9.05	*0.195*	*0.75*	2.07	*0.18*	*0.75*	0.326	1510
SW5-GAR	Discharge	GAR	26/08/2015	11.1	1.21	4.56	47.7	3.56	0.607	1.44	5.67	27.6	7.42	63.9	*0.005*	1.43	7.54	*0.195*	*0.75*	*0.48*	1.63	*0.75*	0.266	1310
SW7-GAR	Drainage	GAR	26/08/2015	*1.45*	0.26	*0.06*	100	0.15	0.848	0.987	0.954	30.4	0.475	168	*0.005*	0.274	3.2	*0.195*	*0.75*	*0.48*	0.378	*0.75*	*0.12*	56.1
SW8-GAR	Drainage	GAR	26/08/2015	*1.45*	0.481	0.235	26	5.73	0.687	3.11	4.45	81.6	1.52	1540	*0.005*	0.574	49.7	*0.195*	*0.75*	6.3	*0.18*	*0.75*	*0.12*	12200
SW9-GAR	Drainage	GAR	26/08/2015	*1.45*	0.572	0.462	22.3	56.1	0.824	3.31	6.47	101	14.6	371	*0.005*	0.585	30.6	0.391	*0.75*	2.6	*0.18*	*0.75*	*0.12*	10800
DS SHAL	River/Stream	Shs	27/08/2015	47.8	0.388	0.506	199	1.23	0.806	0.361	12.1	179	49.8	35	*0.005*	*0.12*	4.65	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	393
SW12-SHAL	Drainage	Shs	27/08/2015	53.3	0.23	0.214	260	*0.05*	0.379	0.227	1.62	110	22.9	70	*0.005*	*0.12*	1.19	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	17.8
SW1-SHAL	River/Stream	Shs	27/08/2015	8.16	1.25	0.601	221	0.96	0.514	0.841	5.93	41.9	107	36.5	*0.005*	0.543	7.51	0.454	*0.75*	*0.48*	1.41	*0.75*	*0.12*	234
SW4-SHAL	River/Stream	Shs	27/08/2015	3.53	0.309	0.31	301	0.278	0.633	0.888	2.01	75.7	1.47	251	*0.005*	*0.12*	4.37	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	56.9
SW5-SHAL	River/Stream	Shs	27/08/2015	35.6	0.609	4.12	202	7.11	0.513	0.756	9.29	34.6	17.5	77.4	*0.005*	*0.12*	20.3	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	2520
SW6-SHAL	Discharge	Shs	27/08/2015	8.66	0.689	0.308	231	0.903	0.578	1.18	10.8	41.3	211	46.4	*0.005*	*0.12*	7.85	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	153
SW9-SHAL	River/Stream	Shs	27/08/2015	7.81	0.671	0.563	230	1.01	0.661	0.961	7.83	35.5	149	37.5	*0.005*	0.625	7.94	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	231
SW1-SM	River/Stream	BG	28/08/2015	8.46	0.913	0.353	41.8	0.129	0.739	0.177	*0.425*	69.4	0.263	9.35	*0.005*	1.89	0.794	*0.195*	*0.75*	*0.48*	3.89	*0.75*	0.341	8.06
SW2-SM-NORTH	Discharge	BG	28/08/2015	*1.45*	0.901	0.167	155	4.14	0.928	0.12	*0.425*	*9.5*	1.47	0.252	*0.005*	0.682	6.14	*0.195*	*0.75*	*0.48*	1.38	*0.75*	*0.12*	1540
SW2-SM-SOUTH	Discharge	BG	28/08/2015	*1.45*	*0.08*	4.62	152	4.32	1.59	0.097	*0.425*	*9.5*	0.856	0.547	*0.005*	0.596	6.3	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.441	1560
SW3-SM	River/Stream	BG	28/08/2015	10.2	0.327	0.313	34.6	*0.05*	0.692	0.06	*0.425*	*82.8*	0.84	6.75	0.0114	0.949	0.884	*0.195*	*0.75*	*0.48*	0.497	*0.75*	*0.12*	23.7
SW4-SM-GA	River/Stream	BG	28/08/2015	9.08	0.718	0.213	59.9	0.19	0.872	0.073	*0.425*	70.2	1.98	4.17	*0.005*	0.819	1.37	*0.195*	*0.75*	*0.48*	1.15	*0.75*	*0.12*	125

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 R6

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**
SW10 - GORT - DISC.	Discharge	GM	25/08/2015	2450	0.536	1360	*1.45*	0.412	*0.05*	1.31	0.478	6.49	0.21	*0.005*	0.463	0.343	252
SW10 - GORT - DS	River/Stream	GM	25/08/2015	353	*0.25*	46.4	*1.45*	0.689	*0.05*	1.37	0.178	1	0.608	*0.005*	*0.195*	0.303	43.7
SW10 - GORT - US	River/Stream	GM	25/08/2015	345	*0.25*	45.2	*1.45*	0.71	*0.05*	1.41	0.16	1.05	0.658	*0.005*	*0.195*	0.345	40.1
SW12-GORT-DISC.	Discharge	GM	25/08/2015	1890	*0.25*	978	*1.45*	0.459	0.106	1.94	0.477	4.24	0.073	*0.005*	0.644	0.474	169
SW12-GORT-DS	River/Stream	GM	25/08/2015	406	*0.25*	70.2	*1.45*	0.653	0.127	0.702	0.186	1.56	1.37	*0.005*	*0.195*	*0.12*	58.8
SW14-GORT	River/Stream	GM	25/08/2015	351	*0.25*	55.4	3.5	0.644	0.106	1.23	0.154	1.54	1.19	*0.005*	*0.195*	0.314	51.1
SW17 - GORT	River/Stream	GM	25/08/2015	261	*0.25*	12	3.01	0.988	*0.05*	0.917	0.159	1.07	0.11	*0.005*	0.491	*0.12*	5.9
SW6-MAG	River/Stream	Mag	25/08/2015	430	*0.25*	199	*1.45*	0.367	0.796	0.42	0.107	3.23	0.345	*0.005*	0.425	*0.12*	361
SW4-GAR	River/Stream	GAR	25/08/2015	176	*0.25*	41.3	*1.45*	0.481	1.64	0.721	7.84	8.4	1.41	*0.005*	0.407	*0.12*	374
SW10-GAR	Discharge	GAR	26/08/2015	732	*0.25*	330	*1.45*	0.742	12	1.42	2.27	4.76	3.98	*0.005*	*0.195*	0.342	2590
SW12-GAR	Drainage	GAR	26/08/2015	342	*0.25*	167	7.2	0.458	7.98	0.471	1.99	5.21	8.35	*0.005*	*0.195*	*0.12*	2800
SW3-GAR	River/Stream	GAR	26/08/2015	683	*0.25*	283	*1.45*	4.52	6.15	1.26	0.84	3.84	2.57	*0.005*	*0.195*	0.326	1510
SW5-GAR	Discharge	GAR	26/08/2015	290	*0.25*	131	11.1	4.56	3.56	0.607	1.44	5.67	7.42	*0.005*	*0.195*	0.266	1310
SW7-GAR	Drainage	GAR	26/08/2015	508	*0.25*	182	*1.45*	*0.06*	0.15	0.848	0.987	0.86	0.048	*0.005*	*0.195*	*0.12*	55.2
SW8-GAR	Drainage	GAR	26/08/2015	1510	2.51	755	*1.45*	0.235	5.73	0.687	3.11	4.45	1.52	*0.005*	*0.195*	*0.12*	12200
SW9-GAR	Drainage	GAR	26/08/2015	963	2.34	533	*1.45*	0.462	56.1	0.824	3.31	6.47	14.6	*0.005*	0.391	*0.12*	10800
DS SHAL	River/Stream	Shs	27/08/2015	198	*0.25*	60.3	47.8	0.506	1.23	0.806	0.361	12.1	49.8	*0.005*	*0.195*	*0.12*	393
SW12-SHAL	Drainage	Shs	27/08/2015	13	*0.25*	*1*	53.1	0.214	*0.05*	0.379	0.227	1.62	22.2	*0.005*	*0.195*	*0.12*	17.8
SW1-SHAL	River/Stream	Shs	27/08/2015	102	*0.25*	16	8.16	0.601	0.96	0.514	0.841	5.93	107	*0.005*	0.454	*0.12*	234
SW4-SHAL	River/Stream	Shs	27/08/2015	62	*0.25*	3.6	3.53	0.31	0.278	0.633	0.888	2.01	1.47	*0.005*	*0.195*	*0.12*	56.9
SW5-SHAL	River/Stream	Shs	27/08/2015	-	-	-	35.6	4.12	7.11	0.513	0.756	9.29	17.5	*0.005*	*0.195*	*0.12*	2520
SW6-SHAL	Discharge	Shs	27/08/2015	75	*0.25*	13.4	8.66	0.308	0.903	0.578	1.18	10.8	211	*0.005*	*0.195*	*0.12*	153
SW9-SHAL	River/Stream	Shs	27/08/2015	91	*0.25*	15	7.81	0.563	1.01	0.661	0.961	7.83	149	*0.005*	*0.195*	*0.12*	231
SW1-SM	River/Stream	BG	28/08/2015	80	*0.25*	2.9	8.04	0.353	0.129	0.739	0.177	*0.425*	0.263	*0.005*	*0.195*	0.341	13.8
SW2-SM-NORTH	Discharge	BG	28/08/2015	294	*0.25*	27.5	*1.45*	0.167	4.14	0.928	0.12	*0.425*	1.47	*0.005*	*0.195*	*0.12*	1540
SW2-SM-SOUTH	Discharge	BG	28/08/2015	306	*0.25*	27.8	*1.45*	4.62	4.32	1.59	0.097	*0.425*	0.856	*0.005*	*0.195*	0.441	1560
SW3-SM	River/Stream	BG	28/08/2015	80	*0.25*	*1*	10.2	0.313	*0.05*	0.692	0.06	*0.425*	0.84	0.0114	*0.195*	*0.12*	23.7
SW4-SM-GA	River/Stream	BG	28/08/2015	109	*0.25*	5	9.08	0.213	0.19	0.872	0.073	*0.425*	1.98	*0.005*	*0.195*	*0.12*	125

xx Exceeds Livestock Assessment Criteria

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

Table B-4 Comparison of Vegetation Results to Assessment Criteria R6

	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	1.444	0.152	2.376	37.0
SM04-V	0.374	0.084	1.884	31.7
SM05-V	0.372	0.050	0.978	22.9
SM06-V	0.430	0.054	1.907	29.2
SM08-V	0.505	0.055	1.786	27.6
SM13-V	0.518	0.073	4.539	38.2
SM14-V	0.239	0.053	1.669	22.5
SM15-V	0.176	0.037	1.386	20.7
SM17-V	0.147	0.043	1.626	24.0
SM19-V	0.242	0.086	4.383	23.0
SM21-V	0.090	0.038	0.554	25.2
SM22-V	0.564	0.079	6.183	28.5
SM27-V	0.182	0.064	2.771	26.2
SM28-V	0.318	0.074	7.219	25.0
SM30-V	0.098	0.038	1.797	21.5
SM31-V	0.045	0.046	0.469	16.3
SM33-V	0.336	0.073	4.656	32.1
SM34-V	0.103	0.034	1.268	23.8
SM38-V	0.065	0.026	0.749	24.7
SM40-V	0.059	0.040	0.561	21.3

xx Exceeds the Maximum Concentration in Feeding Stuff

xx Exceeds No effect level for digestion in wildlife

xx Exceeds Low effect level for digestion in wildlife

Table B-5 Comparison of Vegetation Results to Assessment Criteria R6

Metal	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Threshold for soil where sewage sludge might be applied	-	-	-	**1**	-	**50**	-	-	-	**30**	**50**	**150**
Threshold for plant toxicity via direct contact/ uptake	-	**18**	-	**32**	-	**70**	-	-	-	**38**	**120**	**160**
Threshold for adverse effects in terrestrial plants	-	**10**	-	**4**	-	**100**	-	-	-	**30**	**50**	**50**
Threshold for toxicity to mammals via dietary transfer	-	**46**	-	**0.36**	-	**49**	-	-	-	**130**	**56**	**79**
TRV for protection of cattle via diet	-	**419**	-	**15**	-	**413**	-	-	-	-	**244**	**1082**
TRV for protection of sheep via diet	-	**352**	-	**12**	-	**86**	-	-	-	-	**203**	**545**
SM01-S	6200	7	60	0.5	15	12	17200	1	688	16	23	47
SM04-S	6600	5	80	*0.025*	15	11	18600	*0.5*	714	14	29	48
SM05-S	5200	7	60	*0.025*	14	9	14900	*0.5*	614	12	27	40
SM06-S	5300	7	60	*0.025*	14	10	17700	*0.5*	683	10	23	43
SM08-S	5500	7	60	*0.025*	15	10	17100	*0.5*	597	12	25	40
SM13-S	8700	10	70	0.6	20	15	22600	*0.5*	957	19	39	63
SM14-S	7300	10	50	0.7	18	13	17300	*0.5*	904	17	22	56
SM15-S	9500	12	50	*0.025*	21	13	22900	1	964	22	35	65
SM17-S	7400	10	80	0.7	18	13	17300	1	1180	18	27	61
SM19-S	7700	9	60	0.7	19	12	18700	*0.5*	1040	18	25	61
SM21-S	8600	11	150	0.9	19	13	19800	*0.5*	1110	20	58	147
SM22-S	7300	10	70	0.5	17	13	18600	*0.5*	771	18	27	59
SM27-S	8900	10	130	*0.025*	20	14	21100	1	1010	23	32	56
SM28-S	7800	12	130	0.7	20	14	20300	*0.5*	1100	20	32	68
SM30-S	6900	7	50	0.6	18	16	17400	*0.5*	671	18	23	60
SM31-S	7400	10	80	0.8	20	13	18200	1	933	20	32	65
SM33-S	6600	9	40	0.5	16	14	16900	*0.5*	649	21	23	58
SM34-S	6700	6	50	0.5	15	9	16300	*0.5*	373	14	24	42
SM38-S	6600	7	40	*0.025*	15	10	15500	*0.5*	462	15	20	45
SM40-S	7200	9	50	0.5	17	12	19000	*0.5*	646	20	24	58

xx Exceeds the Maximum Concentration for Soil where sewage sludge is to be applied
xx Exceeds a threshold for plants
xx Exceeds a threshold for mammals
xx Less than the Limit of Detection (LOD) - Value taken to be 0.5 of the LOD
- no assessment criteria