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 (2014)

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CDM Smith

GWP consultants
earth & water resources

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Section 1

Introduction

1.1 Objectives and Scope

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

The scope of the field investigation activities was defined in the Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan, (Document Ref: 95735/40/DG01, dated 26 February 2013) and sampling activities were performed in accordance with the programme and procedures set out therein.

The Monitoring Report for the Silvermines Mining Area presents an evaluation of the results of the field investigations carried out in September 2014. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG16, dated November 2014) which contains all field observations and laboratory analytical results collected during the monitoring programme.

1.2 Background of Silvermines Mining Area

The Silvermines mining area is located in the northern foothills of the Silvermine Mountains in Co. Tipperary. The area has been mined intermittently for over one thousand years for a range of commodities including lead, zinc, copper, silver, barite and sulphur. The mining sites include Ballygown (BG), Garryard (GA), Gorteenadiha, Magcobar (MA) and Shallee South (ShS) /East (ShE), and cover an area of approximately 2,300 ha as shown on Map 1 in Appendix A. The last working mine, a barite operation at Magcobar, closed in 1993. Just over a decade previously, the final base metal mine shut down, following the cessation of underground operations by Mogul Mines Ltd. (Mogul) at Garryard. The latter operation resulted in the generation of significant volumes of fine to coarse grained sand particles referred to as tailings. Approximately 8 Mt of such tailings were deposited in a specially constructed, 60 ha tailings management facility (TMF) at Gortmore (GM). Rehabilitation works have been completed at various localities including Gortmore TMF, with the site work administered by North Tipperary County Council on behalf of the Department. To date this rehabilitation work has included:

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

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

1.3 Catchment Description

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

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

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

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

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

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

1.4 Geology and Hydrogeology

1.4.1 Geology

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

1.4.2 Hydrogeology

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

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

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

Section 2

Methodology

2.1 Field Sampling Methods

2.1.1 Groundwater Sampling

Two groundwater monitoring wells were sampled on 24 September 2014, as listed in Table 1 and shown on Map 2 in Appendix A. Water levels were measured at an additional seven monitoring wells. Four of the monitoring wells have been removed from the monitoring programme because in the first round of sampling they were either found buried, or believed to be destroyed.

Table 1 Location of Groundwater Monitoring Points

Borehole Identifier	Easting	Northing	Water Level	Field Parameters & Chemical Analysis	Depth (m bgl)	Screen Interval (m bgl)
TMF1(D)/SRK/01 (TMF1)	179826	173165	Yes	Yes	23	22-23
TMF2(D)/SRK/01 (TMF2)	179445	172307	Yes	Yes	18	none
BH1A-GORT-06	180181	172490	Yes	No	8.8	5.5 - 8.8
BH2A-GORT-06	180216	172855	Yes	No	10	7 - 10
BH3A-GORT-06	179835	173126	Yes	No	10	7 - 10
BH4A-GORT-06	179570	172826	Yes	No	10	7 - 10
BH5A-GORT-06	179537	172312	Yes	No	10	7 - 10
BH6A-GORT-06	179868	172212	Yes	No	10	7 - 10
BH6B-GORT-06	179867	172225	Yes	No	5	3 - 5

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

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

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

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

The following exceptions to the low flow sampling procedure applied:

- TMF1 borehole was damaged approximately 1m from the surface. A major obstruction exists and the pump could not be lowered into the well. The borehole was sampled by hand pumping the well using tubing with a foot valve. The sample was collected after three volumes of the well (calculated as $\pi r^2 h$; r is the inner casing radius and h is the height of the water column) had been purged and the field parameters had stabilised.

Water Level

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

2.1.2 Surface Water Sampling

Twenty-eight surface water locations were sampled between 22 and 25 September 2014, as listed in Table 2 and shown on Maps 2 to 5 in **Appendix A**. An extra surface water sampling location was added to the programme in Round 4 to assess the impact of the discharges from the Shallee and Garryard areas on the Yellow River (called DS-SHAL). Six samples could not be obtained because the stream bed was dry at SW1-GAR, SW2-GAR, SW8-GAR, SW7-SHAL and SW10-SHAL and there was no discharge at SW2-SM 'Northern Adit'.

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

Table 2 Location of Surface Water Monitoring Points

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW10-GORT-US	GM	180206	172396	Immediately upstream of the outfall on the Kilmastulla River	Yes	NR
SW10-GORT-Discharge	GM	180205	172393	Wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW10-GORT-DS	GM	180189	172365	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW12-GORT-Discharge	GM	179562	172165	Sample of wetland discharge prior to outfall	Yes	Bucket and Stopwatch
SW12-GORT-DS	GM	179532	172137	20m downstream of the outfall, on the Kilmastulla River	Yes	NR
SW14-GORT	GM	179336	172164	Site located on Kilmastulla River, downstream of TMF	Yes	NR
SW17-GORT	GM	180538	173038	Site located on Kilmastulla River, upstream of TMF	Yes	NR
SW18-GORT	GM	179772	172666	Site of discharge from the main pond on the TMF	Yes	NR
SW19-GORT	GM	180097	172982	Discharge at the bottom of the decant	Yes	Flume
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Flume
SW2-SM- North	BG	184258	171619	Discharge from 'Northern' adit.	No - No discharge	No Flow
SW2-SM-South	BG	184244	171584	Discharge from 'Southern' adit.	Yes	Bucket and Stopwatch
SW3-SM	BG	184258	171412	Site on Silvermines Stream (downstream of main Ballygown workings, but upstream of North adit)	Yes	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	No - Dry	No Flow
SW9-GAR	GA	181881	171557	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of railway	Yes	Low flow immeasur-able
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flume

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
SW12-GAR	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Bucket and Stopwatch
SW1-SHAL	ShS	180703	171776	Water-course that runs parallel to R500. Sampling site occurs close to northern-most corner of Shallee tailings impoundment.	Yes	Flow Meter
SW4-SHAL	ShS	180324	171089	Water-course occurring west of 'Drum Dump' and Shallee South workings.	Yes	Bucket and Stopwatch
SW5-SHAL	ShS	180574	171301	Water course west of fenced off area enclosing King's House and core sheds. Further west, this same feature runs along the toe of the drum dump.	Yes	Flume
SW6-SHAL	ShS	180591	171331	Stream emanating from flooded Field Shaft	Yes	Bucket and Stopwatch
SW7-SHAL	ShS	180595	171353	Stream occurring east of Field Shaft	No - Dry	No Flow
SW9-SHAL	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Flume
SW10-SHAL	ShS	180609	171499	Drainage running parallel to R499. Site occurs at northern edge of the southernmost Shallee tailings impoundment.	No - Dry	No Flow
SW12-SHAL	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Bucket and Stopwatch
DS-SHAL	ShS	180609	171845	Yellow River downstream of ShS and BG	Yes	Flow Meter

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

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 the flow was so low at one location it could not be measured, there was no flow at one adit discharge location, there was no discharge from one shaft and at three locations the stream-bed was dry (refer to Table 2).

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

2.1.3 Vegetation Sampling

Twenty vegetation samples were collected between 24 and 26 September 2014, 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 was conducted consistent with the procedure detailed in the Monitoring Plan. The predetermined vegetation sampling locations were located in the field using a GPS and a one metre square template was placed on the ground. Within the one meter square area, all obvious weed species were removed. Vegetation samples were collected from the above ground plant material using shears.

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

Table 3 Location Vegetation and Soil Sampling Sites at Gortmore TMF

Site Name	Easting	Northing	Sample Area
SM01	179853	173080	A
SM04	179799	172980	A
SM05	179869	172983	A
SM06	179922	172988	A
SM08	179851	172929	A
SM13	179903	172882	A
SM14	179748	172832	A
SM15	179815	172829	A
SM17	179694	172775	A
SM19	179802	172780	A
SM21	179603	172781	B
SM22	179502	172730	B
SM27	179629	172679	B
SM28	179706	172674	B
SM30	179511	172636	B
SM31	179587	172630	B
SM33	179448	172581	B
SM34	179532	172578	B
SM38	179551	172528	B
SM40	179502	172432	B

2.1.4 Soil Sampling

Twenty soil samples were collected between 24 and 26 September 2014, 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 consistent with the procedure detailed in the Monitoring Plan. The predetermined soil sampling locations were located in the field using a GPS. A surface soil sample was collected to a depth of 10 cm using a decontaminated stainless steel trowel. Any obvious vegetation and large rocks were removed from the soil sample and the sample was mixed to homogenize it.

2.1.5 Field QA/QC Samples

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

Groundwater and Surface water

- Groundwater:
  - One duplicate groundwater sample was collected; and
  - One decontamination blank was collected by pouring deionised (DI) water over the groundwater pump after decontamination.
- Surface Water:
  - Three duplicate surface water samples; and
  - One decontamination blank was collected by pouring DI water over the surface water sampling equipment after decontamination.
- Two certified standard reference material containing known concentrations of the 18 metals was shipped blind to ALcontrol laboratory (the SRM certificate is contained in Appendix G of the Data Report).
- One water blank was collected of the DI water during the sampling event. 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

- Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1568b (a certified standard of rice flour) was used (certificate is contained in Appendix G of the Data Report).

Sample IDs for the field QA/QC samples are listed in Table 4. The duplicate samples are an independent check on sampling and laboratory precision. The standard reference materials are an independent check on laboratory accuracy. The decontamination blanks are a check on the decontamination procedures used in the field. These checks are very important and are independent from the QA/QC samples performed by the laboratories (see discussion in Section 3).

Table 4 Field QA/ QC Sample IDs and Descriptions

Sample ID	QA/QC Sample Type	Description
Groundwater and Surface water		
SMGD01.4	GW Duplicate	Duplicate of TMF2
SMDB01.4	GW Decontamination blank	DI water (VWR Chemicals Product: 102923C, Batch 14D290025) poured over pump after decon at site TMF2
SMSD01.4	SW Duplicate	Duplicate of SW10-Gar
SMSD02.4	SW Duplicate	Duplicate of SW19-19-Gort
SMSD03.4	SW Duplicate	Duplicate of SW3-Sm
SMDB02.4	SW Decontamination blank	DI water (VWR Chemicals Product: 102923C, Batch 14D290025) poured over SW sampling beaker after final decon at site SW1-SM
SMSR01.4	Standard Reference Material	Water ERA Lot #P230-740A
SMSR02.4	Standard Reference Material	Water ERA Lot #P230-740A
WB01.4	Filtration blank	Deionised water filtered onsite (VWR Chemicals Anala R Normapur Product: 102923C, Batch 14D290025)
WB02.4	Water blank	Deionised water (VWR Chemicals Anala R Normapur Product: 102923C, Batch 14D290025)
Vegetation and Soil		
SM56-V	Vegetation Duplicate	Duplicate of SM17-V
SM57-V	Vegetation Duplicate	Duplicate of SM40-V
SMDB03.4	Decontamination blank	DI water (VWR Chemicals Product: 102923C, Batch 14D290025) poured over shears after decon
SM56-S	Soil Duplicate	Duplicate of SM17-S
SM57-S	Soil Duplicate	Duplicate of SM40-S
SMDB04.4	Decontamination blank	DI water (VWR Chemicals Product: 102923C, Batch 14D290025) poured over trowel after decon
SMSR03.4	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, decontamination blanks were generated in the field to evaluate the sampling equipment decontamination process. Each of these types of blanks is discussed below.

3.1.4 Field QA/QC Samples

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

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

- Decontamination Blanks: After the sampling equipment was cleaned, DI water was poured over or pumped through the sampling equipment and collected for laboratory analysis (see Table 4 for sample IDs). Analyses of these samples were used to evaluate the adequacy of the sampling equipment cleaning or decontamination procedure.

- Standard Reference Material (SRM):

  - Two certified water SRMs were sent blind to ALcontrol (Sample IDs SMSR01.4 and SMSR02.4) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P230-740A (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.

  - Two standard reference vegetation samples were analysed by the laboratory (CAL Ltd). SRM NIST 1568b a certified standard of rice flour was used (certificate is contained in Appendix G of the Data Report).

- One certified soil SRM was sent blind to the ALS Minerals (Sample ID SMSR03.4) 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 was collected in order to try to quantify any contamination caused by the filtration procedure.

3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Surface water and Groundwater Duplicates

Four duplicate samples (one groundwater and three surface waters) were generated in the field and sent to ALcontrol for analysis. Table 5 provides the results of the 21 metals for the four duplicate samples and the calculated RPD between each pair of samples. Note if both the original and duplicate results were less than the limit of detection (LOD), then the RPD was zero, but this cannot be done if there are different detection limits.

The majority of RPD values shown in Table 5 are below 50 %. The RPDs for the following parameters are good: arsenic (1 to 20 %), barium (1 to 11%), cadmium (2 to 32 %), cobalt (0 to 48 %), copper (3 to 38%), lead (1 to 9%), manganese (0 to 5 %), nickel (0 to 33%) and zinc (0 to 7 %).

The RPDs that were above 50% included antimony for two sample pairs ranging from 95 to 163 % RPD and molybdenum (116 %RPD). Dissolved aluminium (51.5 % RPD) and thallium (118 % RPD) also exceeded 50% in one sample pair. Each of these duplicate results were checked and confirmed with ALcontrol and the results were confirmed to be within their duplicate policy margin. According to ALcontrol, the variability in antimony can be attributed to the difficulties in “washing out” the ICP-MS systems following a high sample in the laboratory. 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)	TMF2	SMGD 01.4	RPD	SW10-GAR	SMSD 01.4	RPD	SW19 GORT	SMSD 02.4	RPD	SW3-SM	SMSD 03.4	RPD
Aluminium	<2.9	<2.9	<2.9	0	<2.9	<2.9	0	<2.9	<2.9	0	<2.9	4.91	**-51.5**
Antimony	<0.16	<0.16	1.56	**-163**	0.337	0.371	-9.6	0.823	0.932	-12.4	0.759	2.12	**-94.5**
Arsenic	<0.12	5.09	5.04	1.0	0.458	0.425	7.5	0.327	0.268	19.8	0.37	0.375	-1.3
Barium	<0.03	560	565	-0.9	27.9	26.8	4.0	27.6	27.8	-0.7	78.3	69.9	11.3
Cadmium	<0.1	<0.1	0.138	-31.9	21.7	21.7	0	3.15	3.21	-1.9	0.22	0.253	-14.0
Chromium	<0.22	3.92	3.75	4.4	1.78	1.84	-3.3	0.991	0.894	10.3	0.533	0.664	-21.9
Cobalt	<0.06	0.795	1.31	-48.9	2.27	2.22	2.2	0.699	0.705	-0.9	0.079	0.088	-10.8
Copper	<0.85	2.89	3.02	-4.4	7.34	7.12	3.0	12.2	11	10.3	1.25	0.85	38.1
Iron	<19	206	199	3.5	<19	<19	0.0	<19	<19	0	<19	<19	0
Lead	<0.02	2.22	2.44	-9.4	8.51	8.42	1.1	1.66	1.58	4.9	1.32	1.45	-9.4
Manganese	<0.04	960	946	1.5	255	250	2.0	2.99	2.98	0.3	2.13	2.02	5.3
Mercury	<0.01	<0.01	NA	-	<0.01	<0.01	0	<0.01	NA	-	<0.01	<0.01	0
Molybdenum	<0.24	0.489	1.83	**-116**	<0.24	<0.24	0	<0.24	<0.24	0	<0.24	0.905	**-116**
Nickel	<0.15	2.86	2.93	-2.4	21	22	-4.7	18	18.1	-0.6	1.2	0.859	33.1
Selenium	<0.39	<0.39	<0.39	0	<0.39	<0.39	0	<0.39	<0.39	0	0.438	0.397	9.8
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	3.74	**-118**	6.02	6	0.3	24.6	24	2.5	<0.96	<0.96	0
Tin	<0.36	<0.36	<0.36	0	<0.36	<0.36	0	<0.36	<0.36	0	0.77	0.674	13.3
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	0.502	0.609	-19.3	0.392	<0.24	48.1	<0.24	<0.24	0	<0.24	0.27	-11.8
Zinc	<0.41	7.02	7.54	-7.1	6920	7150	-3.3	2850	2930	-2.8	80.1	80	0.1

Notes:
Bold indicates an exceedance in the Duplicate RPD acceptance criteria
NA analyte not determined by the laboratory

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 duplicate pair (SM17-V and SM56-V). For the second sample pair (SM40-V and SM57-V) cadmium and zinc had the % RPD of less than 50 % which was good, however arsenic had a % RPD of 90 % and for lead 101 % which exceeded the acceptable range for field duplicates. The results of this duplicate pair were checked with CAL who re-analysed the two samples in triplicate for arsenic, cadmium, lead and zinc. The recheck results confirmed the original results and the variation between the two samples concerning arsenic and lead remained. The larger difference could be the result of homogeneous duplicates of vegetation material being difficult to generate in the field.

The highest reported value of the duplicate pair is selected for interpretive use in Section 4. No arsenic or lead concentrations exceeded the assessment criteria outlined in Section 4 and therefore this does not affect the interpretation of the results.

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

Total Metal	SM17-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM40-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	0.034	0.037	-8.5	0.040	0.106	**-90.4**
Cadmium	0.039	0.038	2.6	0.042	0.056	-28.6
Lead	0.34	0.34	0	0.66	2.00	**-101**
Zinc	24.8	27.6	-10.7	28.4	26.6	6.5

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 49.1 % RPD. The majority of the % RPDs ranged from 0 to 15.4 % which is 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	SM17-S (mg/kg)	SM56-S (mg/kg)	% RPD	SM40-S (mg/kg)	SM57-S (mg/kg)	% RPD
Aluminium	6800	7000	-2.9	8500	8900	-4.6
Arsenic	10	10	0	7	7	0
Barium	70	70	0	330	200	49.1
Cadmium	0.7	0.6	15.4	<0.5	<0.5	0
Chromium	15	16	-6.5	17	19	-11.1
Copper	11	11	0	16	15	6.5
Iron	16100	16700	-3.7	18800	20000	-6.2
Mercury	<1	<1	0	1	1	0
Manganese	1000	1000	0	2600	2800	-7.4
Nickel	19	19	0	21	22	-4.7
Lead	25	25	0	38	38	0
Zinc	54	56	-3.6	53	53	0

3.2.2 Decontamination Blanks

Surface Water and Groundwater

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

The majority of reported concentrations were below the limits of detection. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. The limits of detection ranged from 0.01 to 2.9 µg/l except for iron with a detection limit of 19 µg/l.

Detections were observed for 10 dissolved metals ranging from 0.094 to 7.23 µg/l. Four of the metals (barium, chromium, manganese and zinc) were also detected in the DI water blank. The levels of detections in the decontamination blanks were very similar to those found in the DI water blank. Detections of dissolved antimony, cadmium, cobalt, copper, lead, molybdenum and tin were found in the decontamination blanks but not the DI water blank. Antimony was found in all the field decontamination blanks. Antimony was also detected in the DI water blank but not the filtration blank. The highest detections of dissolved metals in the DI water blank and the three decontamination blanks were for dissolved zinc which ranged from 2.24 to 7.23 µg/l.

In total there were 17 detections of dissolved metals in the decontamination blanks. Three of these were greater than ten times the detection limit, in SMDB01.4 lead (0.225 µg/l) and manganese (0.454 µg/l) and in SMDB02.4 zinc (7.23 µg/l). All of the detections including lead, manganese and zinc were significantly less than the assessment criteria outlined in Section 4; therefore, these low concentrations in the blanks do not affect interpretation of results.

To assess the level of cross-contamination between samples in the field, the concentrations in the decontamination blanks were compared with the concentration in the preceding water samples. The concentrations in the blanks were generally less than 10 % of the concentration in the preceding environmental samples, with 5 exceptions. In SMDB01.4 there were detections of cobalt, copper and molybdenum 14 to 64 % of the preceding environmental samples. In SMDB02.4 there was antimony at 205 % and lead at 57 % of the preceding environmental samples. These dissolved metals were only slightly above the detection limits in both the decontamination blank and the environmental sample resulting in a higher percentage and therefore the detections are not indicative of cross-contamination in the field.

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

- Three detections of parameters were present in method blank for Sample Batch 140927-51 that occurred in the decontamination blank from the same batch (Table 8): antimony 0.743 µg/l, manganese 0.123 µg/l and molybdenum 0.253 µg/l.
- Four detections of parameters were present in method blank for Sample Batch 140927-63 that occurred in the decontamination blank from the same batch (Table 8): antimony 8.75 µg/l, barium 0.033 µg/l, lead 0.039 µg/l and molybdenum 0.247 µg/l.

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

Sample Description Dissolved Metal	LOD (µg/l)				Water			Vegetation and Soil		
		Filtration Blank WB01.4 (µg/l)	Water Blank WB02.4 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB01.3 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB02.4 (µg/l)	Decon blank SMDB03.4 (µg/l)	Decon blank SMDB04.4 (µg/l)	Laboratory Method Blank (µg/l)
	Sample batch:	***140919-55***			***140927-51***		***140927-63***			
Aluminium	<2.9	**5.03**	**4.64**	<2.90	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
Antimony	<0.16	<0.16	***0.245***	**0.775**	***0.401***	**0.743**	***0.942***	***3.36***	***1.77***	**0.875**
Arsenic	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	0.136	<0.12
Barium	<0.03	**0.146**	**0.088**	<0.03	***0.094***	<0.03	***0.078***	***0.267***	***0.091***	**0.033**
Cadmium	<0.1	<0.1	<0.1	NP	**0.115**	NP	<0.1	<0.1	<0.1	NP
Chromium	<0.22	**0.711**	**0.365**	<0.22	**0.558**	<0.22	<0.22	0.318	0.556	<0.22
Cobalt	<0.06	<0.06	<0.06	<0.06	**0.265**	<0.06	<0.06	<0.06	<0.06	<0.06
Copper	<0.85	<0.85	<0.85	<0.85	**1.65**	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19
Lead	<0.02	<0.02	<0.02	<0.02	**0.225**	<0.02	***0.028***	***0.103***	***0.042***	**0.0390**
Manganese	<0.04	**0.852**	**0.258**	<0.04	***0.454***	**0.123**	**0.179**	**0.16**	**0.306**	<0.04
Mercury	<0.01	<0.01	<0.01	NP	NP	NP	<0.01	<0.01	<0.01	NP
Molybdenum	<0.24	<0.24	<0.24	<0.24	***0.318***	**0.253**	***0.283***	***0.717***	***0.59***	**0.247**
Nickel	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Selenium	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<0.39	<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
Thallium	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96	<0.96
Tin	<0.36	<0.36	<0.36	**0.747**	<0.36	<0.36	**0.532**	**1.52**	**0.824**	<0.36
Uranium	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Vanadium	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24
Zinc	<0.41	**1.69**	**1.07**	<0.41	**2.34**	<0.41	**7.23**	**6.31**	**6.56**	<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.

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

Vegetation and Soil

To assess the level of cross-contamination between vegetation samples in the field, the concentrations in decontamination blank SMDB03.4 and for soil samples SMDB04.4 were examined (Table 8). The detections of dissolved barium, manganese and zinc can be attributed to the concentrations in the DI water. Detections of dissolved antimony, lead and molybdenum were found in the decontamination blanks and also in the laboratory method blank. Detections were generally less than 10 times the detection limit with the exception of dissolved antimony and zinc, however these were detected in the laboratory method blank and the water 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 SMSR01.4 and SMSR02.4) 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, antimony, barium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thallium and vanadium are in excellent agreement with the certified value (%R ranged from 91 to 117%).

One of the reported values for dissolved iron (ID SMSR02.4) was low at 81 % and falls out of the acceptable range. However, the second reported value is within the acceptable range and therefore it is considered that results are usable. Both of the reported values for dissolved silver were low at 82 % and 83 %, which fall outside of the acceptable range. This indicates that there may be a bias in the results for dissolved silver 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. The following Table 10 summarises the SRM ERA 540 results and provides the calculated %R values for the 12 metals.

Reported values for aluminium, arsenic, barium, cadmium, chromium, copper, manganese, nickel, lead and zinc were in excellent agreement with the certified value (%R ranged from 96 to 106 %). The reported values for iron (83 % R) and mercury (115 % R) were within 20 % of the certified value and were good also and well within the acceptable range.

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

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits		SMSR01.4 (µg/l)	% R	SMSR02.4 (µg/l)	% R
		Lower (%)	Upper (%)				
Aluminium	1120	82.0	116	1130	101	1140	102
Antimony	396	79.5	117	362	91	465	117
Arsenic	210	79.5	120	198	94	194	92
Barium	1720	84.9	115	1730	101	1850	108
Cadmium	822	85.0	115	771	94	798	97
Chromium	402	85.1	115	384	96	387	96
Cobalt	564	84.9	115	570	101	569	101
Copper	563	85.1	115	525	93	533	95
Iron	1710	84.8	115	1700	99	1380	**81**
Lead	757	84.9	115	757	100	797	105
Manganese	906	85.0	115	894	99	924	102
Molybdenum	455	86.6	112	428	94	424	93
Nickel	410	86.6	114	396	97	378	92
Selenium	198	84.8	115	188	95	183	92
Silver	768	85.0	115	630	**82**	638	**83**
Thallium	654	82.9	115	661	101	670	102
Vanadium	1010	85.0	115	960	95	974	96
Zinc	1800	85.0	115	1780	99	1840	102

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		SMSR03.4 (mg/kg)	% R
		(%)	(%)		
Aluminium	8740	53.5	146	9100	96
Arsenic	151	80.8	120	155	97
Barium	262	82.8	117	260	101
Cadmium	152	81.6	118	147	103
Chromium	117	79.4	121	113	104
Copper	68.6	80.9	119	67	102
Iron	12300	40.2	160	14800	83
Mercury	5.76	71.2	129	5	115
Manganese	3600	76.7	123	3400	106
Nickel	315	82.2	118	310	102
Lead	254	81.5	119	255	100
Zinc	306	80.1	120	316	97

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

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

- Analytical Quality Control Samples (AQC) including, Certified Reference Material (CRM), Internal Reference Material (IRM) and Matrix spiked material. For batch sizes of 20 samples or less, a minimum of one AQC and for batches of greater than 20 samples, one AQC every additional twenty samples or part thereof. They are introduced into the sample batch on a random basis where possible. They are prepared at the same time as the rest of the batch and by the same person who prepares the batch;
- Process Blanks: A process blank was included with each batch of samples. The blanks are matrix matched where possible and were taken through the entire analytical system;
- Instrument Blanks: An instrument blank was run to check for any contamination within the instrument;
- Independent Check Standard: An independent check standard was included with every instrumental run of samples. This standard is prepared from a separately sourced standard to the calibration standards and is used as a check on the validity of the calibration standards. The acceptance criteria for this standard was method specific; and
- Replicate samples (samples tested more than once using the same method) were included at the same frequency as the AQCs.

All of the ALcontrol laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding times were exceeded for free cyanide in 13 samples by 2 to 6 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. 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 two SRM NIST 1568b samples after every 10 samples for a total of four analyses. The results are provided in the laboratory report in Appendix F of the Data Report (reported as CRM NIST 1568b). SRM NIST 1568b is a certified standard of rice flour provided by the USA National Institute of Standards & Technology. The certificate of analysis is provided in Appendix G of the Data Report;
- Duplicates: CAL did not analyse duplicates of the field samples. However, the two sets of SRM NIST 1568b analyses can be used to evaluate precision; and

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

SRM

Table 11 provides the results of the two analyses of SRM NIST 1568b and the % R values.

Table 11 SRM NIST 1568b Reported Values and Calculated % R

Total Metal	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	Result 4 (mg/kg)	% R
Arsenic	0.285	0.271-0.299	95-105	0.283	99	0.280	98	0.281	99	0.273	96
Cadmium	0.0224	0.0211-0.0237	94-106	0.026	116	0.024	107	0.024	107	0.025	112
Lead	0.008	0.005-0.011	63-138	0.014	175	0.017	213	0.012	150	0.015	188
Zinc	19.42	19.16-19.68	99-101	21.5	111	21.6	111	22.1	114	21.6	111

All the reported arsenic values are within the acceptable range of 95 to 105 %R. Four of the zinc results are considered slightly high with the %R values ranging from 111 to 114 %. These results are outside the acceptable range of 99 to 101 %R which is a very narrow range and therefore the high bias is not considered an issue. All of the reported cadmium values are slightly higher than the acceptable range of 94 to 106 %R.

All the lead values are outside the acceptable range with %R ranging from 150 to 213 %. The values reported by the laboratory for the lead concentrations are much higher than the certified value. It is noted that the certified value of 0.008 mg/kg for lead is very low for a SRM for solids. Two analyses on the levels of lead in reagent blanks were performed and 0.007 mg/kg were detected on each occasion which could account for the elevated lead results in the SRM NIST 1568b.

CAL also analysed an in-house reference material (GST004 a dried ground haylage sample). The reported values are compared to historical mean and standard deviation values using a control chart. If the reported values for GST004 are outside +/- 2 standard deviations of the historical mean, corrective action is taken and all samples reanalysed. If two consecutive GST004 results are between 2 and 3 standard deviations on the same side of the mean, the samples are also reanalysed. All results for the in-house reference material were acceptable.

It was concluded that SRMs are considered satisfactory for all the four parameters with results within what would be expected given the method uncertainties and different methodologies.

Duplicates

As previously discussed, the laboratory did not perform duplicate analyses of the field samples. However, the analyses of the SRM NIST 1568b (Table 12) can be considered duplicate samples. As shown in Table 12, the precision was good with the % RPD values ranging from 0.5 to 8 % for arsenic, cadmium and zinc values. The %RPDs for lead were slightly higher at 19.4 and 22.2 % but they are still well within the acceptable range for laboratory duplicates.

Table 12 SRM NIST 1568b Reported Values and Calculated % RPD

Total Metal	Result 1 (mg/kg)	Result 2 (mg/kg)	% RPD	Result 3 (mg/kg)	Result 4 (mg/kg)	% R
Arsenic	0.283	0.280	-1.1	0.281	0.273	-2.9
Cadmium	0.026	0.024	-8.0	0.024	0.025	4.1
Lead	0.014	0.017	19.4	0.012	0.015	22.2
Zinc	21.5	21.6	0.5	22.1	21.6	-2.3

Blanks

As previously discussed, CAL performed method blanks (for arsenic, cadmium, lead and zinc). All zinc results were below reporting limits (non-detects); arsenic and cadmium values were below the reporting limits; and lead was 0.007 mg/kg. Lead was above the critical value of 0.001 mg/kg and therefore could indicate carryover in the laboratory. All reported values were below the critical values for arsenic (<0.1 mg/kg), cadmium (<0.001 mg/kg) and zinc (<0.01 mg/kg) and therefore are considered acceptable.

Based on the SRM and blank results that the reported values for lead might be slightly bias high but given that the reported values in the environmental samples are significantly higher than the reported values in the SRM NIST 1568b and the method blank this will not affect the results significantly.

3.3.3 ALS Minerals

ALS Minerals provided the results for the following samples:

- SRMs: ALS Minerals analysed two in-house standard reference materials (GBM908-5 and MRGeo08). Each material was analysed twice;
- Duplicates: ALS Minerals analysed a duplicate of one of the field samples; and
- Blanks: ALS Minerals performed one method blank during the analyses.

SRM

ALS Minerals analysed two in-house standard reference materials GBM908-5 and MRGeo08 the results are contained in Appendix F of the Data Report. ALS Minerals provided a target range (upper and lower bound) for each metal and standard. All reported values for both SRMs were within the target range therefore the analytical results are accurate and acceptable to use.

Duplicates

The following Table 13 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 13 Laboratory Duplicate Reported Values for Soils (mg/kg) and % RPD

Sample Description	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
SM06-S Original	4,400	6	50	<0.5	14	13	12,900	<1	585	11	23	39
SM06-S-Duplicate	4,500	7	50	<0.5	14	13	13,100	<1	579	11	21	38
% RPD	-2.25	15.4	0	0	0	0	-1.54	0	-1.03	0	-9.09	-2.6

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 physio-chemical Versus Laboratory Data

Table 14 summarises the field and laboratory results for pH and conductivity and provides the calculated %RPD values. Note that pH measurements in the laboratory were taken from the unpreserved sample and therefore the results do not affect the results of samples from preserved bottles (e.g. metals).

The RPDs between laboratory and field conductivity was less than 21 % which is very good. The RPDs between laboratory and field pH were also good at less than 17 % which is very good. 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 14 Field physio-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)		
TMF1	7.76	7.46	3.9	0.415	0.469	-12.2
TMF2	7.61	7.26	4.7	0.441	0.502	-12.9
SW12-SHAL	5.84	5.19	11.8	0.0367	0.044	-18.1
SW1-SHAL	7.49	7.78	-3.8	0.177	0.189	-6.6
SW4-GAR	7.36	7.48	-1.6	0.148	0.158	-6.5
SW4-SHAL	6.94	7.19	-3.5	0.177	0.196	-10.2
SW5-SHAL	6.94	7.46	-7.2	0.297	0.33	-10.5
SW6-SHAL	6.83	6.52	4.6	0.118	0.145	-20.5
SW9-SHAL	7.58	7.51	0.9	0.148	0.179	-19.0
SW10-GAR	7.85	7.98	-1.6	0.85	0.952	-11.3
SW12-GAR	7.74	7.77	-0.4	1.6	1.753	-9.1
SW3-GAR	7.82	8.03	-2.6	0.864	0.958	-10.3
SW5-GAR	7.29	6.9	5.5	1.61	1.743	-7.9
SW7-GAR	7.93	7.67	3.3	0.529	0.513	3.1
SW9-GAR	7.5	7.55	-0.7	1.79	1.948	-8.5
SW17-GORT	8.14	8.03	1.4	0.439	0.475	-7.9
SW1-SM	7.88	7.94	-0.8	0.177	0.199	-11.7
SW2-SM South	7.59	7.31	3.8	0.457	0.512	-11.4
SW3-SM	7.8	8.06	-3.3	0.206	0.23	-11.0
SW4-SM-GA	8.06	8.13	-0.9	0.354	0.398	-11.7
SW6-MAG	7.72	7.87	-1.9	0.504	0.552	-9.1
SW18-GORT	7.62	7.41	2.8	2.05	2.381	-14.9
SW19-GORT	7.53	7.78	-3.3	1.98	2.249	-12.7
SW10-GORT-DISC	8.26	7.46	10.2	1.26	1.47	-15.4
SW10-GORT-DS	8.16	8.02	1.7	0.532	0.613	-14.1
SW10-GORT-US	8.3	6.94	17.8	0.521	0.607	-15.2
SW12-GORT-DISC	7.84	7.11	9.8	1.5	1.735	-14.5
SW12-GORT-DS	8.3	8.04	3.2	0.53	0.624	-16.3
SW14-GORT	8.19	8.06	1.6	0.505	0.563	-10.9
DS SHAL	7.68	7.74	-0.8	0.34	0.375	-9.8

Notes:
Bold indicates an exceedance in acceptance limits

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 15.

The general acceptance criteria for internal consistency are ±10 % for both the charge balance and the mass balance. The charge balance was consistently within acceptable limits, with most values below 5 % which is excellent. The mass balance, in many cases (bolded values) did not meet these criteria. However most values were less than 20 %; which overall is very good considering the complex nature of some of the samples with high metal concentrations. The fact that the high values are all negative suggests that either one or more parameters were under-reported by the analytical laboratory and/or one or more parameters present within the samples were not analysed (e.g. silica).

Table 15 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
SW12-Shal	20	13.6	0.0	3.3	**43.6**	Too many cations
SW6-Shal	77	68.1	-0.1	-4.1	**12.8**	Too many anions
SW9-Shal	99	113	-0.1	-4.3	**-12.7**	Missing cations
SW1-Shal	104	128	-0.1	-2.1	**-18.5**	Missing cations
SW4-Shal	104	105	-0.1	-2.8	-0.6	Missing cations
SW5-Shal	196	240	-0.1	-1.1	**-18.3**	Missing cations
DS-Shal	220	274	-0.2	-2.0	**-19.9**	Missing cations
SW10-GAR	690	773	-0.7	-3.1	**-10.8**	Missing cations
SW12-GAR	1437	1660	0.0	0.1	**-13.4**	Missing anions
SW3-GAR	689	754	-0.4	-1.9	-8.7	Missing cations
SW4-GAR	87	102	-0.2	-5.1	**-14.9**	Missing cations
SW5-GAR	1520	1650	4.3	8.5	-7.7	Missing anions
SW6-MAG	362	415	-0.2	-1.8	**-12.9**	Missing cations
SW7-GAR	358	418	-0.4	-3.2	**-14.3**	Missing cations
SW9-GAR	1690	1920	1.0	2.0	**-12.0**	Missing anions
SW17-GORT	274	323	-0.3	-3.2	**-15.0**	Missing cations
SW18 GORT	2070	2430	-0.6	-1.0	**-15.0**	Missing cations
SW19 GORT	1925	2310	-0.8	-1.3	**-16.7**	Missing cations
SW10-GORT-DISC	1100	1300	0.4	1.2	**-15.5**	Missing anions
SW10-GORT-DS	353	422	-1.0	-7.6	**-16.4**	Missing cations
SW10-GORT-US	367	379	-0.1	-0.7	-3.3	Missing cations
SW12-GORT-DISC	1290	1510	0.4	0.9	**-14.8**	Missing anions
SW12-GORT-DS	365	414	-0.4	-2.7	**-11.8**	Missing cations
SW14-GORT	329	376	-0.3	-2.5	**-12.4**	Missing cations
SW1-SM	99	118	-0.2	-6.3	**-16.2**	Missing cations
SW2-SM-SOUTH	293	311	-0.4	-3.2	-5.8	Missing cations
SW3-SM	118	140	0.2	3.8	**-15.9**	Missing anions
SW4-SM-GA	221	242	-0.1	-0.7	-8.6	Missing cations
TMF1	269	295	-0.4	-3.6	-8.9	Missing cations
TMF2	271	277	-0.4	-3.9	-2.1	Missing cations

Notes:
Bold indicates an exceedance of the acceptance criteria

The specific conductivity (SC) of the solutions can be used to further evaluate the internal consistency. The specific conductivity total dissolved solids (SC/TDS) ratio of natural waters varies, but typically ranges from 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 16 are within the range for natural waters and therefore the analyses are considered reliable. The one exception was SW12-SHAL with a ratio of 2.3 for SC/TDS-Calc and 3.2 for SC/TDS-Meas and had the lowest measured conductivity and TDS. At these low levels, the relationships are less accurate.

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

Table 16 Comparison of Specific Conductivity to Total Dissolved Solids (SC/TDS) Ratio

Sample Description	Sample Type	Specific Conductance (uS/cm)	TDS (Calc) (mg/l)	TDS (Meas) (mg/l)	Ratio SC/ TDS (Calc)	Ratio SC/ TDS (Meas)
SW12-Shal	SW	44	20	14	2.3	3.2
SW6-Shal	SW	145	77	68	1.9	2.1
SW9-Shal	SW	179	99	113	1.8	1.6
SW1-Shal	SW	189	104	128	1.8	1.5
SW4-Shal	SW	196	104	105	1.9	1.9
SW5-Shal	SW	330	196	240	1.7	1.4
DS-Shal	SW	375	220	274	1.7	1.4
SW10-GAR	SW	952	690	773	1.4	1.2
SW12-GAR	SW	1753	1437	1660	1.2	1.1
SW3-GAR	SW	958	689	754	1.4	1.3
SW4-GAR	SW	158	87	102	1.8	1.5
SW5-GAR	SW	1743	1523	1650	1.1	1.1
SW6-MAG	SW	552	362	415	1.5	1.3
SW7-GAR	SW	513	358	418	1.4	1.2
SW9-GAR	SW	1948	1690	1920	1.2	1.0
SW17-GORT	SW	475	274	323	1.7	1.5
SW18 GORT	SW	2381	2065	2430	1.2	1.0
SW19 GORT	SW	2249	1925	2310	1.2	1.0
SW10-GORT-DISC	SW	1470	1099	1300	1.3	1.1
SW10-GORT-DS	SW	613	353	422	1.7	1.5
SW10-GORT-US	SW	607	367	379	1.7	1.6
SW12-GORT-DISC	SW	1735	1287	1510	1.3	1.1
SW12-GORT-DS	SW	624	365	414	1.7	1.5
SW14-GORT	SW	563	329	376	1.7	1.5
SW1-SM	SW	199	99	118	2.0	1.7
SW2-SM-SOUTH	SW	512	293	311	1.7	1.6
SW3-SM	SW	230	118	140	2.0	1.6
SW4-SM-GA	SW	398	221	242	1.8	1.6
TMF1	GW	469	269	295	1.7	1.6
TMF2	GW	502	271	277	1.9	1.8

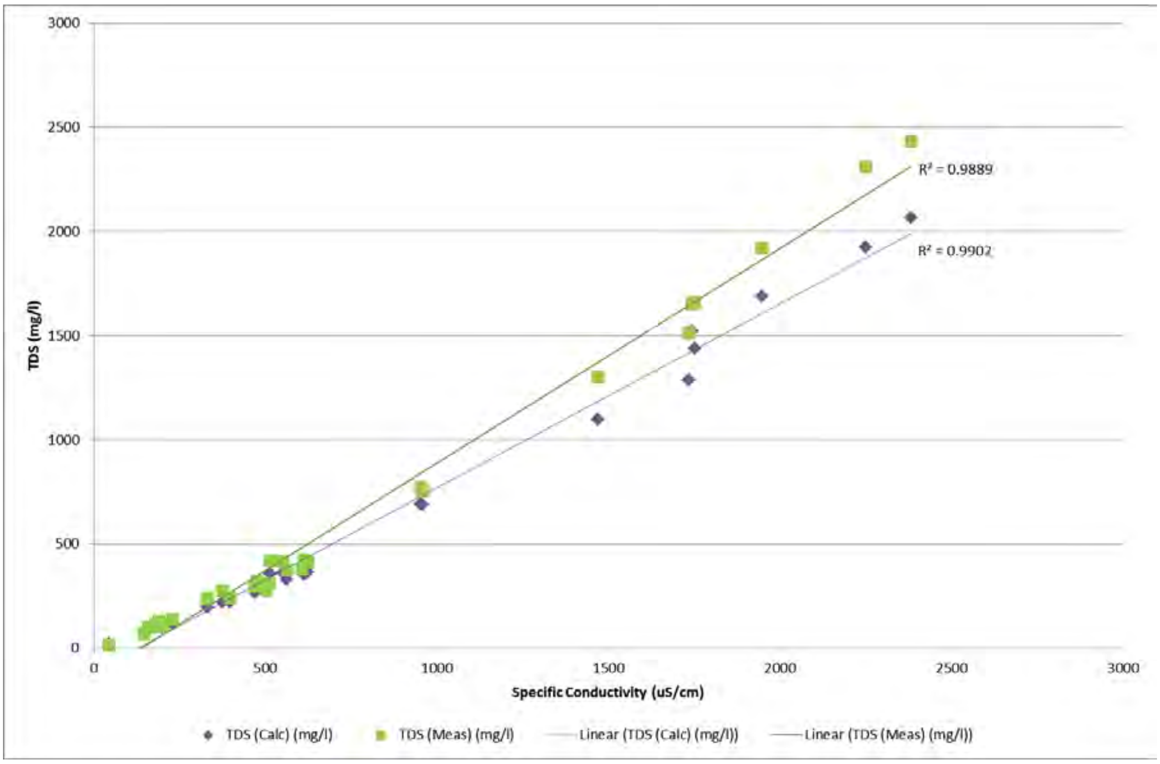


Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

3.4.3 Comparison of Total and Dissolved Metals

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

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

The total metals were generally equal to the dissolved metals, indicating that the majority of the cadmium, nickel and zinc present were dissolved. The total concentrations were significantly higher than the dissolved concentrations for lead, showing the majority of lead was total lead. The total suspended solids for these samples ranged from <1 to 36 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 17 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 17 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	1	1.45	4.42	-
Antimony	<0.16	2	2	0.963	1.56	1.26
Arsenic	<0.12	2	2	2.85	5.09	3.97
Barium	<0.03	2	2	153	565	359
Cadmium	<0.1	2	1	0.05	0.5	-
Chromium	<0.22	2	2	0.727	3.92	2.32
Cobalt	<0.06	2	2	1.18	1.31	1.25
Copper	<0.85	2	2	1.74	3.02	2.38
Iron	<19	2	1	9.5	206	-
Lead	<0.02	2	2	0.078	2.44	1.26
Manganese	<0.04	2	2	84.3	960	522
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	1	1.06	1.83	-
Nickel	<0.15	2	1	2.93	3.55	-
Selenium	<0.39	2	0	0.195	0.195	-
Silver	<1.5	2	0	0.75	0.75	-
Thallium	<0.96	2	1	0.48	3.74	-
Tin	<0.36	2	0	0.18	0.18	-
Uranium	<1.5	2	0	0.75	0.75	-
Vanadium	<0.24	2	1	0.12	0.609	-
Zinc	<0.41	2	2	2.5	7.54	5.02

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

Dissolved barium (565 µg/l), iron (206 µg/l).and manganese (960 µg/l) were found in the highest concentrations in TMF2, which were significantly higher than the concentrations in TMF1. Dissolved arsenic was detected in both wells with the highest concentration at TMF2 of 5.09 µg/l. Detections of dissolved chromium and lead were reported which were slightly more elevated in TMF2 than in TMF1.

4.1.2 Surface Water Sample Results

Surface water samples were collected for two major categories: the first includes mine adit discharges and discharges from wetlands as well as some drainage ditches and the second includes the rivers and streams. Table 18 provides a summary of the reported results of the 12 discharge/ drainage samples and Table 19 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 18 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	6	1.45	60.6	14	19.7
Antimony	<0.16	12	11	0.08	1.09	0.56	0.34
Arsenic	<0.12	12	8	0.06	2.11	0.43	0.56
Barium	<0.03	12	12	12.2	271	85.3	88.9
Cadmium	<0.1	12	8	0.05	37.9	9.81	13.3
Chromium	<0.22	12	12	0.262	2.13	1.1	0.59
Cobalt	<0.06	12	11	0.03	9.69	1.84	2.7
Copper	<0.85	12	12	0.956	15.3	6.52	4.58
Iron	<19	12	6	9.5	1570	164	445
Lead	<0.02	12	12	0.022	320	34.7	90.7
Manganese	<0.04	12	12	0.563	3480	524	950
Mercury	<0.01	12	0	0.005	0.005	-	-
Molybdenum	<0.24	12	5	0.12	1.3	0.350	0.360
Nickel	<0.15	12	12	1.2	156	29.4	43.5
Selenium	<0.39	12	5	0.195	2.13	0.49	0.72
Silver	<1.5	12	0	0.75	0.75	-	-
Thallium	<0.96	12	7	0.48	32.2	6.56	10.5
Tin	<0.36	12	1	0.18	0.387	-	-
Uranium	<1.5	12	1	0.75	1.76	-	-
Vanadium	<0.24	12	5	0.12	0.41	0.22	0.12
Zinc	<0.41	12	12	22.7	24500	5540	7850

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

SW5-GAR (Knights Shaft) had the highest concentrations of zinc (24,500 µg/l), nickel (156 µg/l), iron (1,570 µg/l) and manganese (3,480 µg/l). The highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 320 µg/l.

Rivers and Streams

Table 19 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	14	1.45	53.8	16.6	14.6
Antimony	<0.16	16	14	0.08	4.58	1.53	1.3
Arsenic	<0.12	16	11	0.06	3.6	0.63	0.87
Barium	<0.03	16	16	42.8	378	213	92.7
Cadmium	<0.1	16	11	0.05	19.7	3.74	5.9
Chromium	<0.22	16	16	0.523	2.31	1.11	0.56
Cobalt	<0.06	16	16	0.068	5.75	1.25	1.46
Copper	<0.85	16	16	0.896	17.7	7.27	5.66
Iron	<19	16	11	9.5	105	53.9	33.8
Lead	<0.02	16	16	0.049	228	44.4	68.8
Manganese	<0.04	16	16	2.13	845	182	212
Mercury	<0.01	16	0	0.005	0.005	-	-
Molybdenum	<0.24	16	9	0.12	2.65	0.66	0.69
Nickel	<0.15	16	16	0.795	58.2	11.7	14.4
Selenium	<0.39	16	4	0.195	1.17	0.18	0.35
Silver	<1.5	16	0	0.75	0.75	-	-
Thallium	<0.96	16	3	0.48	3.69	0.9	0.83
Tin	<0.36	16	5	0.18	2.56	0.53	0.63
Uranium	<1.5	16	0	0.75	0.75	-	-
Vanadium	<0.24	16	7	0.12	0.842	0.32	0.22
Zinc	<0.41	16	16	2.6	7100	1300	2180

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 (2.6 and 5.72 µg/l, respectively). SW17-Gort has background concentrations of manganese (77.2 µg/l) and barium (251 µg/l).

SW5-Shal (DS of the drum sump) has the highest concentrations of cadmium (58.2 µg/l) and zinc (7,100 µg/l).

4.1.3 Vegetation Sample Results

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

	Arsenic	Cadmium	Lead	Zinc
Number	20	20	20	20
Detections	3	20	20	20
Minimum	0.05	0.024	0.24	16.7
Maximum	0.11	0.076	2.46	33.3
Mean	0.058	0.048	0.64	24.0
SDEV	0.020	0.011	0.666	4.19

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

There were only three detections of arsenic above the detection limit of <0.1.The highest arsenic concentration of 0.11 mg/kg was in SM33-V and SM40-V. The highest lead (2.46 mg/kg) and zinc (33.3 mg/kg) were found in a sample SM21-V. The highest cadmium (0.076 mg/kg) concentration was in vegetation sample SM01-V. SM01-V, SM21-V and SM40-V are located at the edge of the capped area (see Map 6 in Appendix A).

4.1.4 Soil Sample Results

Table 21 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 21 Summary of Soil Concentrations (mg/kg) at Gortmore TMF

Metal	Count	Detections	Min	Max	Mean	SDEV	Median	Median in Irish soil *
Aluminium	20	20	4400	8900	6530	1210	6700	34800
Arsenic	20	20	6	12	8.3	1.69	8	7.3
Barium	20	20	40	330	79	64.7	60	230
Cadmium	20	13	0.25	0.7	0.472	0.18	0.5	0.33
Chromium	20	20	13	19	15.2	1.74	15	43
Copper	20	20	9	16	11.6	1.88	11.5	16.2
Iron	20	20	13100	20300	15670	1930	15300	18700
Mercury	20	9	0.5	1	0.725	0.26	0.5	0.09
Manganese	20	20	600	3600	1330	775	1050	462
Nickel	20	20	11	22	18.0	3.28	18.5	17.5
Lead	20	20	22	49	29.5	8.24	26	24.8
Zinc	20	20	39	76	52.7	10.0	53	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. 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, barium and iron compared to Irish soils.

The highest arsenic concentration (12 mg/kg) was found in a sample SM15-S, the highest lead (49 mg/kg) concentration was in soil sample SM04-S and the highest zinc concentration was in

SM21-S (79 mg/kg). These values were slightly 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 22. 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 22).

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 22. The appropriate ecological assessment criteria are highlighted in bold in Table 22.

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 23. 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 22 and Table 23).

Table 22 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 23 Surface Water and Groundwater Assessment Criteria for Drinking Water

Parameter	Unit	Parametric value
pH	pH units	>6.5 to <9.5
Chloride	mg/l	250
Conductivity	mS/cm	2.5
Free Cyanide	mg/l	0.05
Ammonium	mg/l	0.3
Fluoride	mg/l	1.5
Nitrate as NO3	mg/l	50
Nitrite as NO2	mg/l	0.5
Sulphate	mg/l	250
Sodium	mg/l	200
Aluminium	µg/l	200
Antimony	µg/l	5
Arsenic	µg/l	10
Cadmium	µg/l	5
Chromium	µg/l	50
Copper	µg/l	2,000
Iron	µg/l	200
Lead	µg/l	10
Manganese	µg/l	50
Mercury	µg/l	1
Nickel	µg/l	20
Selenium	µg/l	10

4.2.2 Livestock Drinking Water Assessment Criteria

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

Table 24 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 25 summarises the maximum content in feedingstuff for arsenic, cadmium and lead applicable to the vegetation samples collected. No values are available for zinc.

Table 25 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 25 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 25 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 26 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 26 summarises the screening level and threshold values and the information sources.

Table 26 Assessment Criteria for Soil (mg/kg)

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

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

4.3 Comparison to Assessment Criteria

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

A comparison of the 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.

A comparison of the soil results was made against the relevant assessment criteria as described in Section 4.2. Table B-5 in **Appendix B** highlights the exceedances of the assessment criteria for soil; where there is an exceedance in the threshold for soil where sewage sludge might be applied, the result is highlighted in pink and exceedances of a threshold for plants or mammals is highlighted in blue and purple, respectively.

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

4.3.1 Groundwater Assessment

In groundwater, the pH was found to be within the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria with an average of pH 7.36. The specific conductance ranged from 0.469 to 0.502 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 45.6 mg/l, which was well below the criteria for human health of 250 mg/l. Ammonia and fluoride were less than the limit of detection.

For dissolved metal concentrations, barium and manganese exceeded the assessment criteria in groundwater samples, with higher concentrations in the downgradient monitoring well. Barium exceeded the ecological health criteria of 4 µg/l in both monitoring wells; TMF1 had a result of 153 µg/l and TMF2 had a result of 565 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1 had a result of 84.3 µg/l and TMF2 had a result of 960 µg/l. In TMF2, dissolved chromium also exceeded the ecological assessment criteria of 3.4 µg/l with a value of 3.92 µg/l and dissolved iron exceeded the human health criteria of 200 µg/l with a value of 206 µg/l. Note that iron and manganese 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 was found to range from 5.19 to 8.13, with an average of 7.13. There was one exceedance of the assessment criteria for pH at SW12-Shal (5.19 pH) which was below the acceptable range for human health of 6.5 to 9.5 pH. Low acidity results were detected at thirteen locations which ranged from 5.48 to 38.30 mg/l (as HCl) with the highest acidity at SW5-GAR. The conductivity ranged from 0.044 to 2.381 mS/cm with an average of 0.789 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 and ortho-phosphate. The ammonia ecological assessment criteria (0.14 mg/l) was exceeded at SW10-Gort-US with a value of 0.202 mg/l and at SW5-Gar with a value of 0.256 mg/l. Both the ecological assessment criteria and human health (0.3 mg/l) criteria were exceeded at SW4-SM-GA which had a concentration of

0.347 mg/l. The ecological assessment criteria for ortho-phosphate (0.075 mg/l) was exceeded at SW4-SM-GA with a concentration of 0.199 mg/l and at SW12-Gar with 0.145 mg/l.

Fluoride results were elevated above the ecological assessment criteria (0.5 mg/l) ranging from 1.05 to 2.61 mg/l at 6 locations. Both the ecological and human health (1.5 mg/l) criteria were exceeded at 3 locations.

Sulphate exceeded the criteria for human health (250 mg/l) at all of the discharge and drainage locations in the Garryard and Gortmore areas, with the exception of SW7-Gar (107 mg/l). The sulphate results that exceeded the criteria ranged from 365 to 1,440 mg/l, with an average of 858 mg/l. SW3-Gar, the stream containing both tailings lagoon discharges and downstream of the Mogul Yard, also had high sulphate of 365 mg/l. The highest sulphate result was from SW18-Gort with 1,440 mg/l.

Dissolved Metals Assessment

Concentrations of dissolved barium, cadmium, lead, manganese, nickel and zinc were elevated and exceeded the assessment criteria in many locations as discussed below, see the Table B-2 in **Appendix B** for the full listing. Table 27 provides a summary of the reported values for rivers and streams at the upstream and downstream locations at the different mining areas that exceeded the relevant ecological and human health assessment criteria for dissolved metals. For the locations refer to the maps in **Appendix A**.

The ecological assessment criterion for barium of 4 µg/l was exceeded at all locations with high results even at upstream locations SW1-SM (47 µg/l) and SW17-Gort (251 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 3.6 µg/l at SW14-Gort.

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 SW2-SM discharges to the Silvermines stream and had cadmium (4.65 µg/l) and zinc (1,750 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 cadmium and zinc were also above the ecological assessment criteria's at a concentration of 1.14 µg/l and 379 µg/l, respectively.

SW6-Mag downstream of the Magcobar area also had dissolved cadmium (1.09 µg/l) and zinc (429 µg/l) above the ecological assessment criteria.

Table 27 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

Sample Description	Sample Location		Date Sampled / Units	Ammoniacal Nitrogen as N (mg/l)	Fluoride (mg/l)	Phosphate (ortho) as P (mg/l)	Sulphate (mg/l)	Cadmium (diss.filt) (µg/l)	Cobalt (diss.filt) (µg/l)	Lead (diss.filt) (µg/l)	Manganese (diss.filt) (µg/l)	Nickel (diss.filt) (µg/l)	Zinc (diss.filt) (µg/l)
			Ecological Criteria	**0.14**	**0.5**	**0.075**	**-**	**0.9**	**5.1**	**7.2**	**1100**	**20**	**100**
			Human Health Criteria	**0.3**	**1.5**	**-**	**250**	**5**	**-**	**10**	**50**	**20**	**-**
Ballygown	SW1-SM	Upstream	25/09/14	<0.2	<0.5	<0.02	<2	<0.1	0.068	0.049	3.8	0.795	2.6
	SW3-SM	DS (underground workings)	25/09/14	<0.2	<0.5	<0.02	4	0.253	0.088	1.45	2.13	1.2	80.1
	SW4-SM-Ga	Downstream (all)	25/09/14	0.347	<0.5	0.199	17.6	1.14	0.154	3.89	12.4	3.37	379
Magcobar	SW6-Mag	Downstream	23/09/14	<0.2	<0.5	<0.02	212	1.09	0.129	0.303	14.8	5.49	429
Garryard	SW1-GAR	Upstream	No Flow	-	-	-	-	-	-	-	-	-	-
	SW3-GAR	Downstream (all)	23/09/14	<0.2	1.05	<0.02	365	16.1	2.66	4.23	429	24	5990
Shallee	SW4-SHAL	Upstream	22/09/14	<0.2	<0.5	<0.02	7.2	<0.1	0.398	0.31	80.4	4.15	68.7
	SW5-SHAL	DS (drum dump)	22/09/14	<0.2	1.34	<0.02	102	19.7	5.75	22.9	845	58.2	7100
	SW9-SHAL	Downstream	22/09/14	<0.2	<0.5	<0.02	27.5	2.42	1.33	228	65.3	14.6	710
	SW1-SHAL	Downstream (all)	22/09/14	<0.2	<0.5	<0.02	28.5	2.28	1.72	179	95.9	12.7	565
Garryard/ Shallee	DS SHAL	Downstream of SW3-GAR and SW1-SHAL	22/09/14	<0.2	<0.5	<0.02	77	0.714	0.746	61.2	83.5	8.63	659
Gortmore	SW17-GORT	Upstream	23/09/14	<0.2	<0.5	0.0362	25.6	<0.1	0.334	0.239	77.2	2	5.72
	SW12-GORT-DS	Downstream (TMF)	25/09/14	<0.2	<0.5	0.0212	78.2	0.186	0.355	3.48	113	3.93	103
	SW14-GORT	Downstream (TMF and Yellow River)	25/09/14	<0.2	<0.5	0.0209	62.5	0.145	0.334	2.9	105	3.01	102

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 cadmium and zinc, exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. Levels of dissolved lead and nickel were relatively low. The concentration of dissolved cadmium exceeded the ecological assessment criterion of 0.9 µg/l with values ranging from 3.21 to 6.49 µg/l at SW18-Gort and SW19-Gort. The value of 6.49 µg/l for cadmium at SW18-Gort also exceeded the human health criteria of 5 µg/l. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at several locations, with results ranging from 77.2 to 453 µg/l. Dissolved zinc also exceeded the ecological assessment criteria of 100 µg/l at all of the drainages and discharges ranging from 124 to 2,930 µg/l. The concentration of zinc increased on the Kilmastulla River from 5.72 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 103 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 loading from these areas are discussed in Section 5.

At Shallee (Map 3 of **Appendix A**), dissolved lead exceeded both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations with the (exception of the upstream location SW4-Shal) with concentrations ranging from 22.9 to 320 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 0.31 µg/l (below both the assessment criteria's). 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 221 to 7,100 µg/l. Manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all Shallee locations, with results ranging from 65.3 to 3,480 µg/l. SW5-Shal exceeded the ecological health criteria for dissolved cobalt of 5.1 µg/l (5.75 µg/l) and both the ecological and human health criteria for dissolved nickel of 20 µg/l (58.2 µg/l). SW5-Shal also exceeded both the ecological (0.9 µg/l) and human health criteria (5 µg/l) for dissolved nickel with a value of 19.7 µg/l. Dissolved cadmium decreased further downstream to 2.42 and 2.28 µg/l at SW9-Shal and SW1-Shal, respectively, which still exceed the ecological health criteria.

DS-Shal is the extra surface water sampling location added to the programme in this round to assess the impact of the discharges from the Shallee and Garryard areas on the Yellow River. It is located on the Yellow River downstream of the Shallee and Garryard areas and upstream of the confluence with the confluence of 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 61.2 µg/l. The dissolved zinc exceeded the ecological assessment criteria (100 µg/l) with a concentration of 659 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 216 to 24,500 µg/l. SW7-Gar however had a dissolved zinc concentration of 23.5 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 8.98 to 37.9 µg/l) with the exception of two locations SW4-GAR (1.31 µg/l) that only exceeded the ecological criteria and SW7-Gar where cadmium was less than the detection limit. Dissolved lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at two locations; SW4-Gar with a concentration of 29.1 µg/l and SW5-Gar with 19.3 µg/l. Dissolved lead exceeded the ecological assessment criteria at three additional downgradient locations, SW12-Gar, SW9-Gar and SW10-Gar with concentrations ranging from 7.49 to 8.51 µg/l. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at all locations ranging from 22 to 60.2 µg/l, again with the exception of SW4-Gar (3.52 µg/l) and SW7-Gar (2.34 µg/l). Dissolved manganese was above the criteria for human health (50 µg/l) but below the ecological assessment criteria (1,100 µg/l) at all locations, with results ranging from 122 to 568 µg/l. At SW5-Gar the human health criteria for manganese was also exceeded with a concentration of 3,480 µg/l and dissolved iron exceeded the human health criteria (200 µg/l) with a concentration of 1,570 µg/l.

4.3.3 Livestock Water Quality Assessment

Recommendations for levels of toxic substances in drinking water for livestock are provided in Table 19. 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 320 µg/l and the sampling location on the stream SW9-Shal which is just downstream of the Field Shaft had concentration of 228 µg/l. Therefore it is recommended that livestock should be prevented from drinking water in the stream in the Shallee mining area.

The water quality results for all of the ponds and streams sampled at Gortmore TMF were also assessed against the recommendations for levels of toxic substances in drinking water for livestock from the National Academy of Sciences (1972).

- No exceedances of the livestock threshold values for any metals were found;
- The recommended value for Total dissolved solids (TDS) is 1000 mg/l, and the TDS values at the pond discharges exceeded the recommend value with 2,430 mg/l at SW18-Gort and 2,310 mg/l at SW19-Gort. 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 its 1,000 mg/l. The sulphate values at the pond discharges exceeded the recommend value with 1,440 mg/l at SW18-Gort and 1,340 mg/l at SW19-Gort. The guidelines for sulphates in water are not well defined, but high concentrations cause diarrhea, but at the levels found in the ponds and streams at Gortmore TMF it is likely 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 25. The measured concentrations in the vegetation were all below both the no effect and low effect levels provided in Table 25.

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 26 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 26. These values consider that in many cases the grazing animals consume the plant leaves and roots containing soil.

The reported value for arsenic in SM15-S was 12 mg/kg, which was slightly above the ORNL benchmark concentration of 10 mg/kg, there were 5 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 14 samples. In general this value is viewed as conservatively low and all reported values were significantly lower than the maximum values for concentrations of zinc of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations 1998. None of the reported values for any of the parameters exceeded the maximum values for soil specified in the Use of Sewage Sludge in Agriculture Regulations.

Section 5

Flows, Loads and Trend Analysis

5.1 Surface Water Flows

No river flow gauging stations are present within the Silvermines mining area. The nearest gauge on the Kilmastulla River is Coole (EPA station 25044) which is 10 km downstream. The flow record from 1 April 2014 to 30 September 2014 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >10 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 0.59 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 3.38 m^3/s on several occasions after rainfall events. The flow during this period shows a flashy response to rainfall. The highest recorded flow in the monitoring period was on 20 May 2014 with a mean daily flow of 10.9 m^3/s. From June to late September 2014 the flows were particularly low with a baseline of 0.34 m^3/s which is below the 95%-ile flow (low flow) of 0.36 m^3/s. Overall, the flows were relatively high in 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 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 in the Silvermines mining area from June to September. The EPA tool for ungauged catchments was used to calculate the 5%-ile flow (hign flow) which was 4.36 m^3/s as the flows were likely greater than this on several occasions in May.

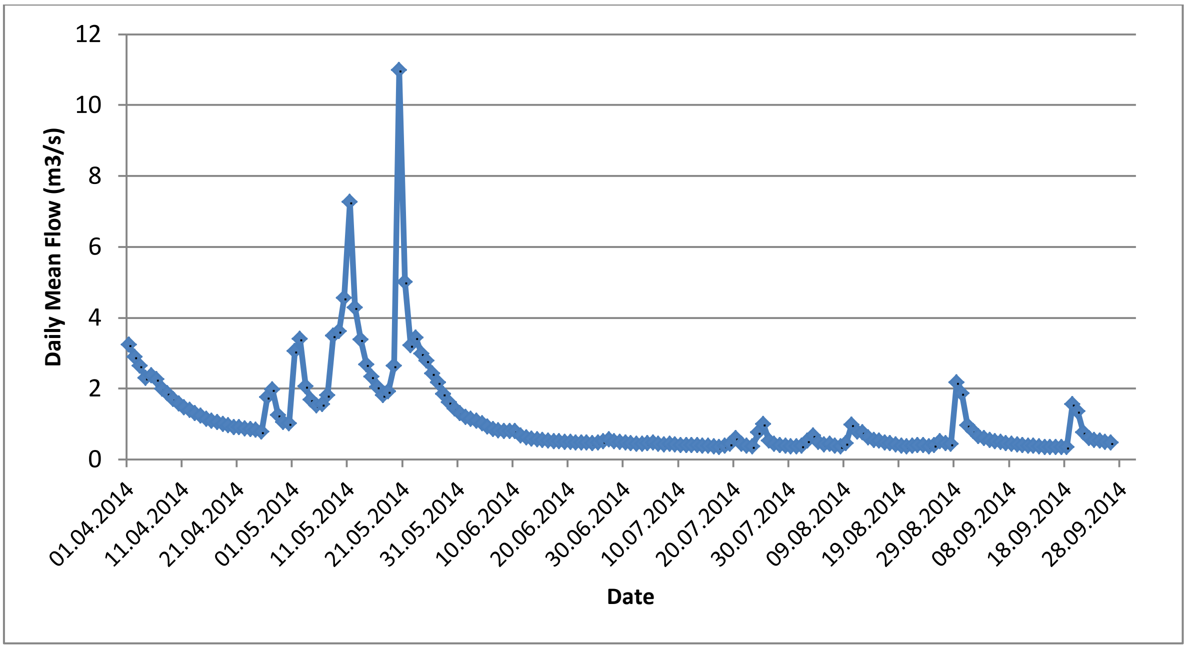


Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 April to 30 September 2014

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 28 presents a summary of the results from the flow measured in September 2014 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 28 Surface Water Flow Value Measured in September 2014

Site Name	Flow l/s	Date
SW10-GORT Discharge	1.7	25/09/2014
SW12-GORT Discharge	2.6	25/09/2014
SW19-GORT	0.1	24/09/2014
SW1-SM	5.1	25/09/2014
SW3-SM	8.0	25/09/2014
SW2-SM South Discharge	1.1	25/09/2014
SW2-SM North Discharge	Dry	25/09/2014
SW4-SM-GA	10.0	25/09/2014
SW4-GAR	1.94	23/09/2014
SW5-GAR	No discharge	23/09/2014
SW7-GAR	0.07	23/09/2014
SW8-GAR	No flow	23/09/2014
SW9-GAR	Low flow immeasurable	23/09/2014
SW12-GAR	0.048	23/09/2014
SW10-GAR	3.1	23/09/2014
SW3-GAR	5.37	23/09/2014
SW4-SHAL	0.05	22/09/2014
SW5-SHAL	0.71	22/09/2014
SW7-SHAL	Dry	22/09/2014
SW6-SHAL	4.3	22/09/2014
SW9-SHAL	12.0	22/09/2014
SW12-SHAL	2.58	22/09/2014
SW10-SHAL	Dry	22/09/2014
SW1-SHAL	10.7	22/09/2014
DS-SHAL	41.7	22/09/2014

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

Table 29 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day

Site Description	Date Sampled	Flow l/s	pH	Sulphate		Cadmium		Lead		Manganese		Nickel		Zinc	
			Units	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day	µg/l	g/day
SW1-SM	25/09/2014	5.1	7.94	7940	3500	0.5	0.22	0.049	0.02	3.8	1.67	0.795	0.35	2.6	1.15
SW3-SM	25/09/2014	8	8.06	8060	5570	0.253	0.17	1.45	1	2.13	1.47	1.2	0.83	80.1	55.4
SW2-SM South	25/09/2014	1.1	7.31	7310	695	4.65	0.44	0.912	0.09	0.563	0.05	7.62	0.72	1750	166
SW4-SM-GA	25/09/2014	10	8.13	8130	7020	1.14	0.98	3.89	3.36	12.4	10.7	3.37	2.91	379	327
SW19-GORT	24/09/2014	0.1	7.78	7780	67.2	3.21	0.03	1.66	0.01	2.99	0.03	18.1	0.16	2930	25.3
SW10-GORT-DISC	25/09/2014	1.7	7.46	7460	1100	0.5	0.07	0.137	0.02	308	45.2	6.61	0.97	301	44.2
SW12-GORT-DISC	25/09/2014	2.6	7.11	7110	1600	0.5	0.11	0.022	0	453	102	5.75	1.29	124	27.9
SW4-GAR	23/09/2014	1.94	7.48	7480	1250	1.31	0.22	29.1	4.88	122	20.4	3.52	0.59	216	36.2
SW7-GAR	23/09/2014	0.07	7.67	7670	46.4	0.5	0	0.103	0	288	1.74	2.34	0.01	23.5	0.14
SW12-GAR	23/09/2014	0.048	7.77	7770	32.2	32	0.13	7.49	0.03	568	2.36	41.9	0.17	12000	49.8
SW10-GAR	23/09/2014	3.1	7.98	7980	2140	21.7	5.81	8.51	2.28	255	68.3	22	5.89	7150	1920
SW3-GAR	23/09/2014	5.37	8.03	8030	3730	16.1	7.47	4.23	1.96	429	199	24	11.1	5990	2780
SW4-SHAL	22/09/2014	0.05	7.19	7190	31.1	0.5	0	0.31	0	80.4	0.35	4.15	0.02	68.7	0.3
SW5-SHAL	22/09/2014	0.71	7.46	7460	458	19.7	1.21	22.9	1.4	845	51.8	58.2	3.57	7100	436
SW6-SHAL	22/09/2014	4.3	6.52	6520	2420	0.799	0.3	320	119	85.5	31.8	12	4.46	221	82.1
SW12-SHAL	22/09/2014	2.58	5.19	5190	1160	0.5	0.11	43.7	9.74	67.1	15.0	1.2	0.27	22.7	5.06
SW9-SHAL	22/09/2014	12	7.51	7510	7790	2.42	2.51	228	236	65.3	67.7	14.6	15.1	710	736
SW1-SHAL	22/09/2014	10.7	7.78	7780	7190	2.28	2.11	179	165	95.9	88.7	12.7	11.7	565	522
DS SHAL	22/09/2014	41.7	7.74	7740	27900	0.714	2.57	61.2	220	83.5	301	8.63	31.1	659	2370

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 0.14 to 2,780 g/day with an average of 505 g/day overall. The largest mass load of zinc was SW3-GAR of 2,780 g/day which is the stream containing the SW10-GAR discharge and the western part of the Mogul yard. SW10-GAR (the discharge from the tailings lagoon) had a smaller loading of 1,920 g/day zinc.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 1.15 g/day, which increases to 55.4 g/day downstream of the mine workings (SW3-SM). The southern adit (SW2-SM) also contributes 166 g/day of dissolved zinc to the stream. Further downstream the calculated mass load at SW4-SM-GA was 327 g/day, which indicates that there was likely another source of zinc load. The Silvermines stream contributes this load to the Kilmastulla River.

The highest load of dissolved lead was from the SW9-Shal downstream of the Shallee mining area with a calculated value of 236 g/day. SW9-Shal 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 119 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 was walked between the main road and Knights Shaft (where accessible) and no other inputs of surface water were observed. Further downstream at SW1-Shal the lead load decreases to 165 g/day.

DS-Shal is located downstream of both the Shallee and Garryard mining areas. The dissolved lead load increases from 165 g/day at SW1-Shal to 220 g/day at DS-Shal. The stream from the Garryard area only contributes 1.96 g/day of dissolved lead therefore the increase could be from diffuse flow from a tailings impoundment at Shallee. The dissolved zinc load at DS-Shal is 2,370 g/day which is an increase from the Shallee area (SW1-Shal – 522 g/day). This indicates that the main source of zinc load is from the stream emerging from the Garryard area with 2,780 g/day, which also indicates there is some loss in the zinc load.

Of the two wetland discharges at Gortmore TMF, SW10-Gort-Discharge had the highest loading of dissolved zinc at 44.2 g/day whereas SW12-Gort-Discharge had 27.9 g/day of zinc. Discharges from the Garryard and Shallee area (DS-Shal – 2,370 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 30 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 30 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 31 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 31 Mann-Kendall Trend Analysis of data from November 2006 to September 2014

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. cadmium	9	0.0382	-18	Decreasing
	Diss. lead	8	0.5	1	No Trend
	Diss. manganese	9	0.00457	-26	Decreasing
	Diss. nickel	9	0.147	-11	No Trend
	Diss. zinc	9	0.458	-2	No Trend
SW10-Gort-discharge	Diss. cadmium	6	0.226	-5	No Trend
	Diss. lead	4	n/a	n/a	Not Calculated
	Diss. manganese	6	0.13	7	No Trend
	Diss. nickel	6	0.0301	-11	Decreasing
	Diss. zinc	6	0.0664	-9	Likely decreasing
SW12-Gort-discharge	Diss. cadmium	4	0.154	4	No Trend
	Diss. lead	6	0.154	-4	No Trend
	Diss. manganese	5	n/a	n/a	Not Calculated
	Diss. nickel	5	0.11	-6	No Trend
	Diss. zinc	5	0.403	-2	No Trend
SW6-Shal	Diss. cadmium	7	0.274	-5	No Trend
	Diss. lead	7	0.5	-1	No Trend
	Diss. manganese	7	0.274	-5	No Trend
	Diss. nickel	7	0.5	-1	No Trend
	Diss. zinc	7	0.274	-5	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	5	0.403	-2	No Trend
	Diss. lead	6	0.354	3	No Trend
	Diss. manganese	6	0.0664	9	Likely Increasing
	Diss. nickel	6	0.226	5	No Trend
	Diss. zinc	6	0.354	-3	No Trend

The results of the Mann-Kendall analysis show that dissolved cadmium and manganese concentrations are decreasing at SW10-Gar. Dissolved nickel concentrations are decreasing and zinc concentrations are likely decreasing in the SW10-Gort discharge. Dissolved manganese concentrations are however are likely increasing in the Kilmastulla River at SW14-Gort. No other statistically significant trends were observed in the data that were analysed.

5.3.2 Seasonal Trends

Table 32 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) and March 2014 (R3) and the low flow sampling event in August 2013 (R2) and September 2014 (R4). As can be seen from Table 32 the concentrations of dissolved cadmium, 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 332-9320 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 and 245 µg/l in March 2014 and it was significantly lower than the assessment criterion in August 2013 with a value of 42.1 µg/l. This was not the case in September 2014 during low flow as dissolved zinc was detected at 102 µg/l, which is likely due to the high concentration of dissolved zinc in SW10-GAR (7,150 µg/l).

Table 32 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August 2013 and September 2014 due to the low flow conditions.

Table 32 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in the Main Discharges and on the most downstream location on the Kilmastulla River in 2013/ 2014

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
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
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
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
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

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
	R4 25/09/2014	2.6	0.5	0.11	0.022	0.0	453	102	124	27.9
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	-	-	-	-	-	-	-	-	-

Notes
- is not measured / calculated

Section 6

Groundwater Levels

Groundwater levels were measured at the two wells outside the Gortmore TMF and seven additional wells located within the TMF near the perimeter of the tailings surface, using a portable electronic water level recorder. Table 33 displays the measured depth to groundwater and calculated groundwater elevations.

The groundwater elevations outside the TMF decreased from 48.39 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.08 m OD at the downgradient location TMF2. These elevations are consistent with the groundwater flow in the bedrock being south-westerly towards the Kilmastulla River. The groundwater gradient was calculated to be 0.002, however the level of the river is unknown. The groundwater elevations at TMF1 and TMF2 are similar to the elevations measured on 26/8/2013 and between 0.28 and 0.33 metres lower than the elevations measured in spring (12/3/2014).

Within the tailings area, measured water levels were in the range of 2.8 to 4.9 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 48.45 to 53.12 m OD. These groundwater elevations are similar to the elevations measured on 26/8/2013 which ranged from 48.3 to 53.2 m OD and between 0.2 to 1.2 metres lower than the elevations measured in spring (12/3/2014).

Table 33 Measures Groundwater Levels September 2014

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	24/9/2014	10:00	0.61	1.2	48.39
TMF2		24/9/2014	11:20	1.92	2.38	46.08
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	24/9/2014	15:10	3.38	4.03	52.38
BH2A-GORT-06		24/9/2014	15:20	3.36	3.89	52.40
BH3A-GORT-06		24/9/2014	14:45	8.15	8.48	48.45
BH4A-GORT-06		24/9/2014	15:00	4.87	5.39	51.29
BH5A-GORT-06		24/9/2014	15:45	4.00	4.43	52.21
BH6A-GORT-06		24/9/2014	15:35	5.34	6.03	50.74
BH6B-GORT-06		24/9/2014	15:35	2.83	3.55	53.12

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

Section 7

Summary and Recommendations

7.1 Summary of Findings

Two groundwater monitoring wells were sampled and analysed in September 2014 and water levels were measured in seven additional monitoring wells. Twenty eight surface water locations were sampled and analysed in September 2014 with flows measured at 19 of the locations. Twenty vegetation samples and twenty soil samples were collected and analysed in September 2014. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QA/QC samples and laboratory reports were also reviewed. Overall the data quality is considered acceptable and the data can be used to compare to the assessment criteria and for evaluation of loads.

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

The overall conclusions are as follows:

- Dissolved metal concentrations in the two groundwater monitoring wells that were sampled had exceedances of the assessment criteria for dissolved barium and manganese, with higher concentrations in the downgradient monitoring well TMF2 (565 and 960 µg/l, respectively). Dissolved barium exceeded the ecological health criteria and dissolved manganese exceeded the human health criteria in both monitoring wells. Dissolved chromium also exceeded the ecological assessment criteria of 3.4 µg/l with a value of 3.92 µg/l and the human health criteria for iron of 200 µg/l with a value of 206 µg/l in TMF2. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- Surface water locations SW1-SM and SW17-Gort are located upstream of the mining areas of Silvermines and Gortmore respectively and have significantly lower concentrations of zinc than the rest of the rivers and streams sampled in the Silvermines area (2.6 and 5.72 µg/l, respectively), which are both below the ecological assessment criteria of 100 µg/l.

- Dissolved zinc exceeded the ecological assessment criteria of 100 µg/l at the majority of the drainages and discharges ranging from 22.7 to 24,500 µg/l. The concentration of zinc increased on the Kilmastulla River from 5.72 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 103 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garryard and Shallee.

- In the Garryard area some of the highest concentrations of dissolved metals were observed. For example, SW5-GAR (Knights Shaft) had the highest concentrations of zinc (24,500 µg/l), nickel (156 µg/l), iron (1,570 µg/l) and manganese (3,480 µg/l). Each location in Garryard exceeded the dissolved zinc ecological assessment criteria of 100 µg/l, except SW7-Gar. The majority of locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium. Dissolved nickel was above both the ecological and human health assessment criteria of 20 µg/l.

- At Shallee dissolved lead exceeded the both the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at all locations, except SW4-Shal upstream. The highest concentration was from the Field Shaft discharge (SW6-Shal) at 320 µg/l.

- The concentration of zinc increases on the Kilmastulla River to 102 µg/l at SW14-Gort (most downstream location) which is above the ecological assessment criteria of 100 µg/l. The concentration at DS-Shal on the Yellow River tributary was significantly higher at 659 µg/l.

- The dissolved metal with the highest mass loading was zinc, ranging from 0.14 to 2,780 g/day with an average of 505 g/day overall. The largest mass load of zinc was SW3-GAR of 2,780 g/day which is the stream containing the SW10-GAR discharge and the western part of the Mogul yard. The highest load of dissolved lead was from the SW9-Shal downstream of the Shallee mining area with a calculated value of 236 g/day.

- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated lead levels (>50 µg/l). The streams and ponds on top of the Gortmore TMF had high concentrations of TDS (>1,000 mg/l) and sulphate (>1,000 mg/l) which may cause diarrhea in livestock, but it is likely livestock are accustomed these levels and it is therefore safe to consume.

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

- In general, the measured soil concentrations are below the screening levels for arsenic, cadmium, copper, nickel, lead and zinc that may have adverse effects on the vegetation or mammals. One reported value for arsenic in soil sample SM15-S was at 12 mg/kg, which was slightly above the ORNL benchmark concentration of 10 mg/kg. The reported values for zinc concentrations were above the conservative ORNL benchmark concentration of 50 mg/kg for the majority of samples but were significantly lower than the maximum values for concentrations of zinc of 150 mg/kg as prescribed by the Use of Sewage Sludge in Agriculture Regulations.

7.2 Recommendations for the Monitoring Programme

Based on the data analysis and above conclusions the following recommendations are made:

- We recommend keeping the additional surface water sampling location on the Yellow River (DS-Shal) to assess the impact of the discharges from the Shallee and Garryard areas on the Yellow River before it discharges to the Kilmastulla River near the Gortmore TMF.

Section 8

References

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

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

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

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

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

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

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

Hedberg, Y., Herting, G. and Odnevall Wallinder, I. (2011). Risks of using membrane filtration for trace metal analysis and assessing the dissolved metal fraction of aqueous media e A study on zinc, copper and nickel. *Environmental Pollution,* 159, 1144-1150.

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

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

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

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

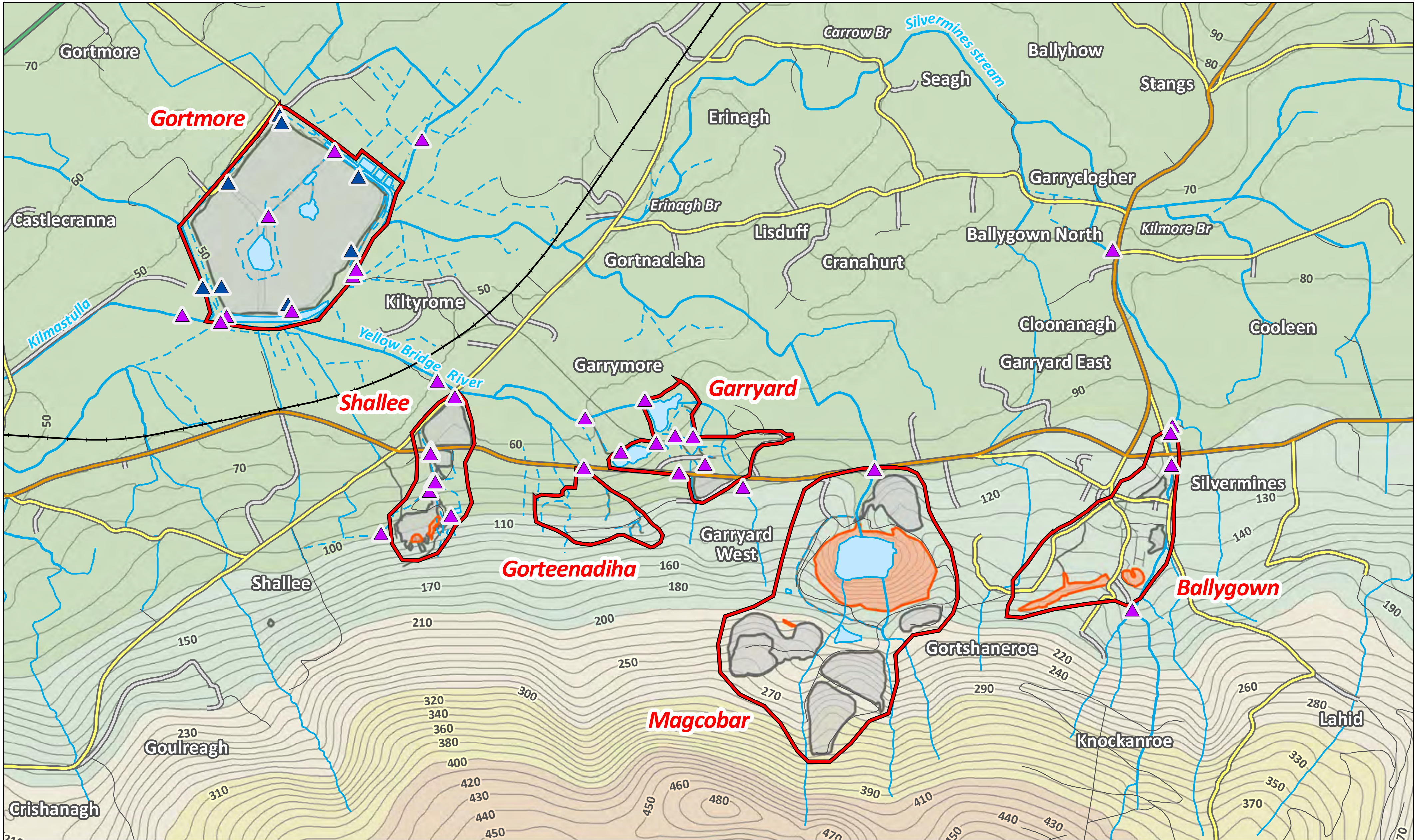
Suter, G.W. II and Tsao. C.L. (1996). Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

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

Appendix A

Figures

CDM Smith



Map 1 - Silvermines - Overview

Drawn by: OC Date: 07/01/2015

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CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater

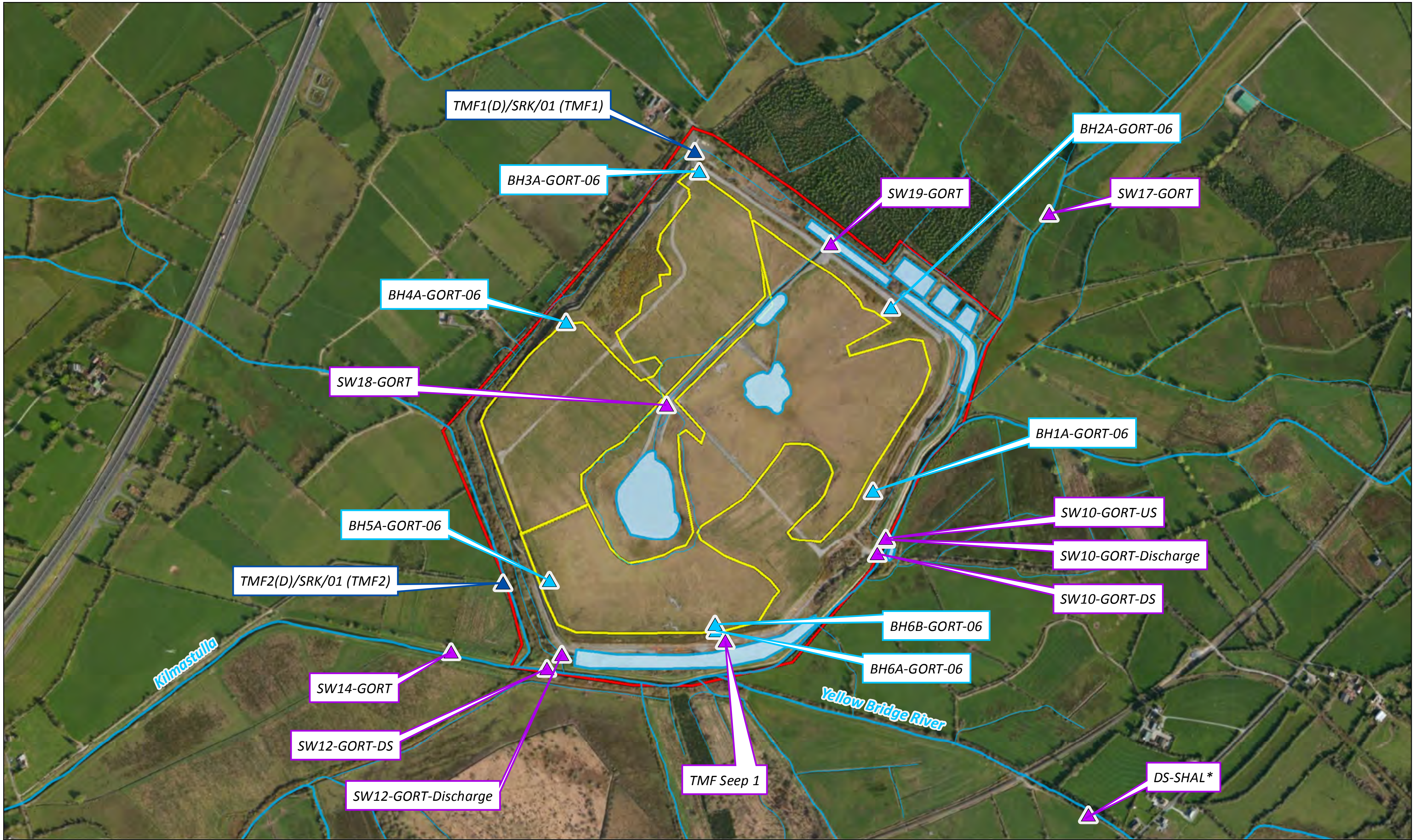
- Rivers
- Streams
- Pond / Wetland / Pit Lake

Mines

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

Scale is 1:25,000

0 250 500 1,000 m



Map 2 - Silvermines - Gortmore TMF

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InInternal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\09_MonRptR4\MXD\02_SilverMonGM.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater
- Groundwater (Levels only)

**New sampling location in Round 4*

- Rivers
- Streams
- Pond / Wetland

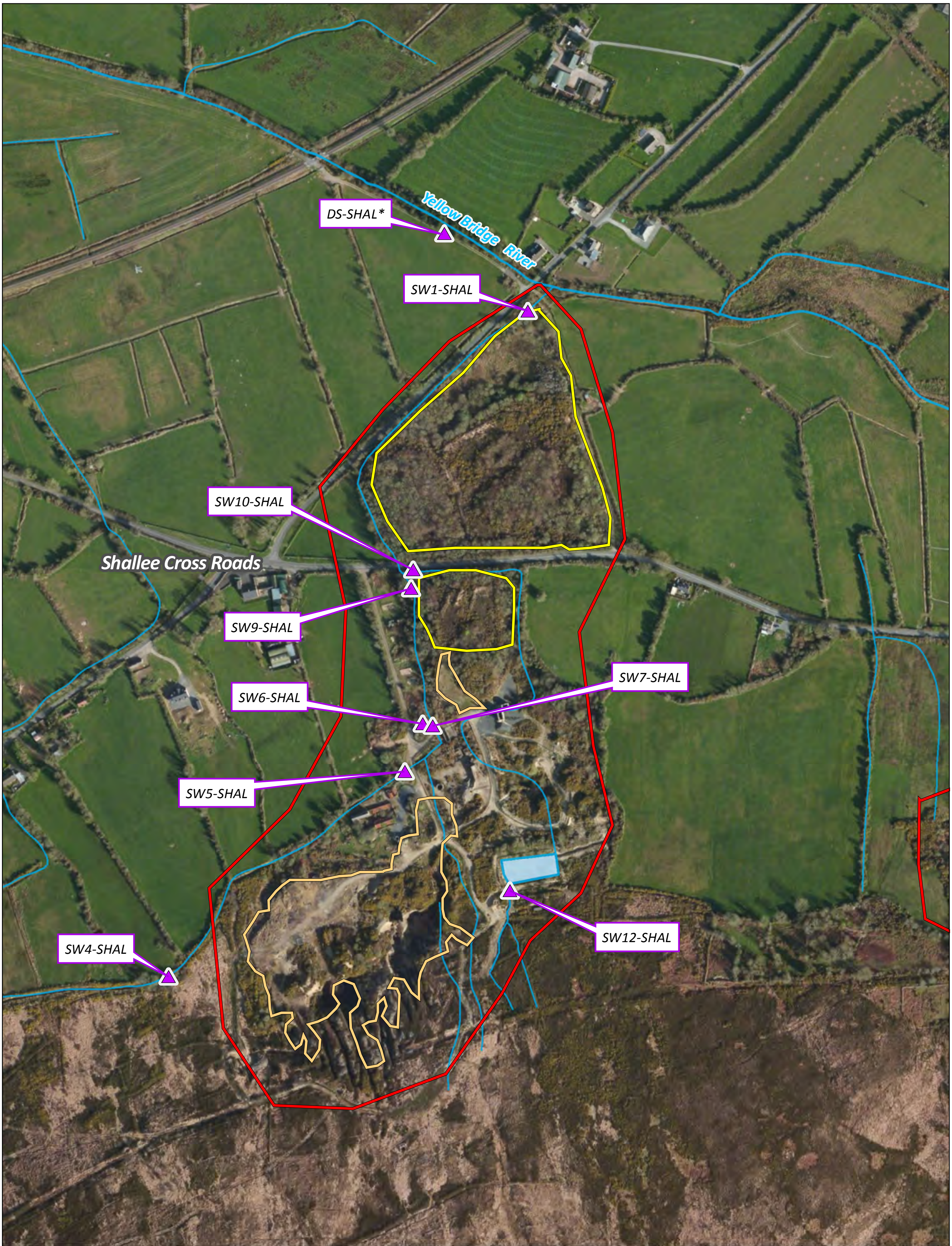
Mines

- Mining Area

Scale is 1:10,000

0 125 250 500 m

N W E S



Map 3 - Silvermines - Shallee South

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Internal Project Reference: Q:\95500-95999\95735\40 Documents Generated\GIS\02_GIS_Tasks\09_MonRptR4\MXD\03_SilverMonSh.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

- ▲ Surface water
- **New sampling location in Round 4*

- Rivers
- Streams
- Pond / Wetland

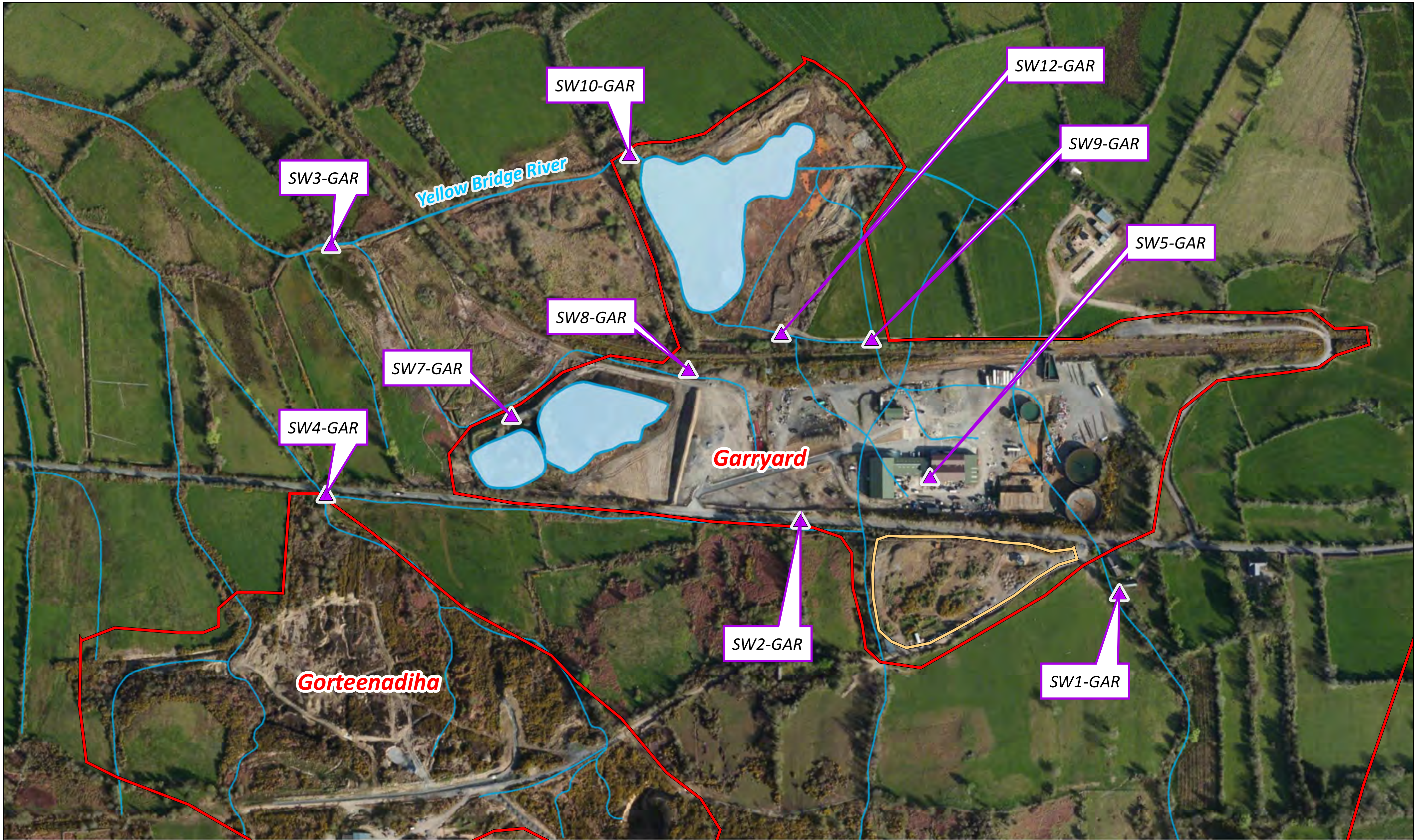
Mines

- Mining Area
- 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 Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

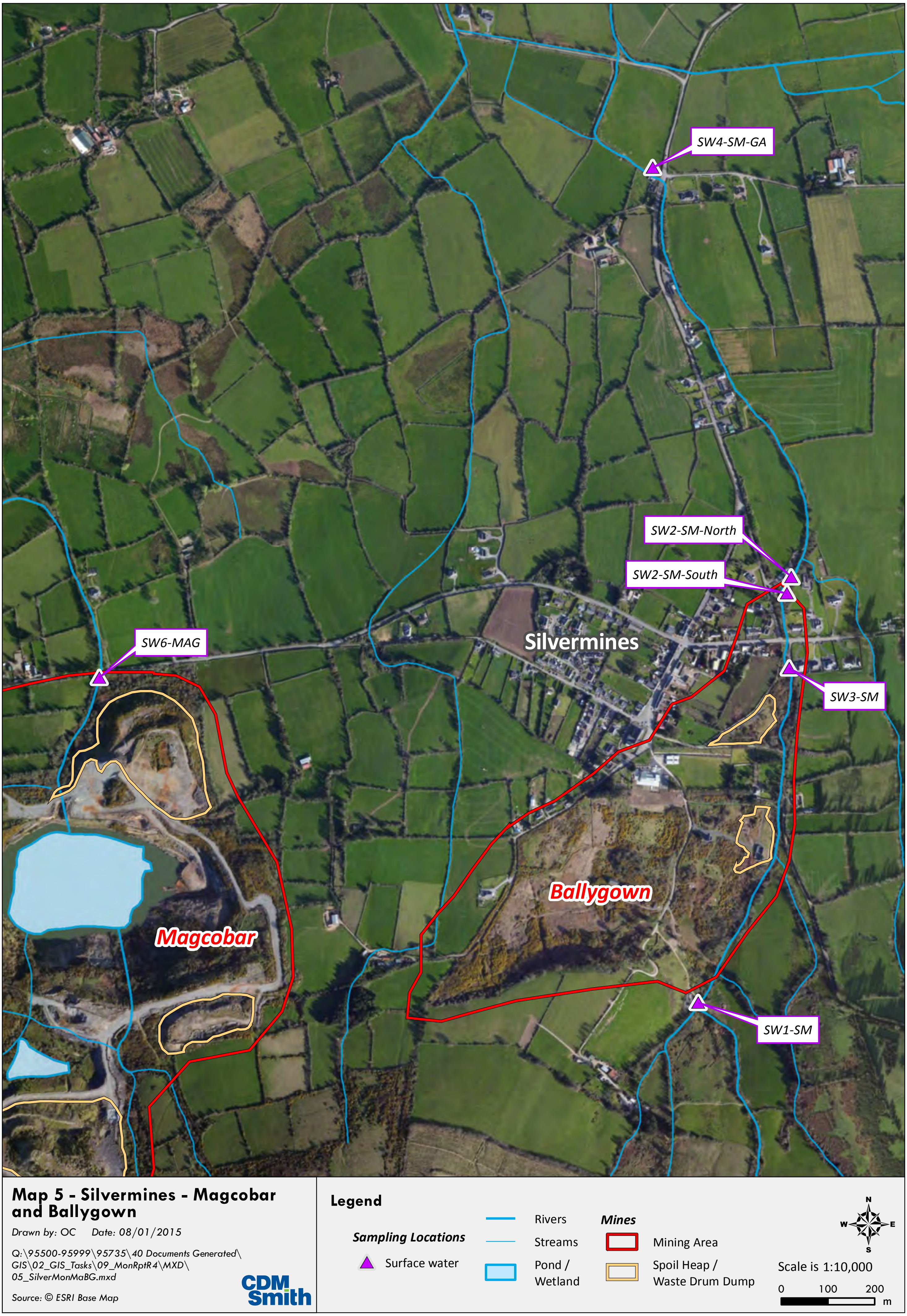
Mining Areas

Stockpile Dump

Scale is 1:5,000

0 50 100 200 m

N E S W



Map 5 - Silvermines - Magcobar and Ballygown

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Source: © ESRI Base Map

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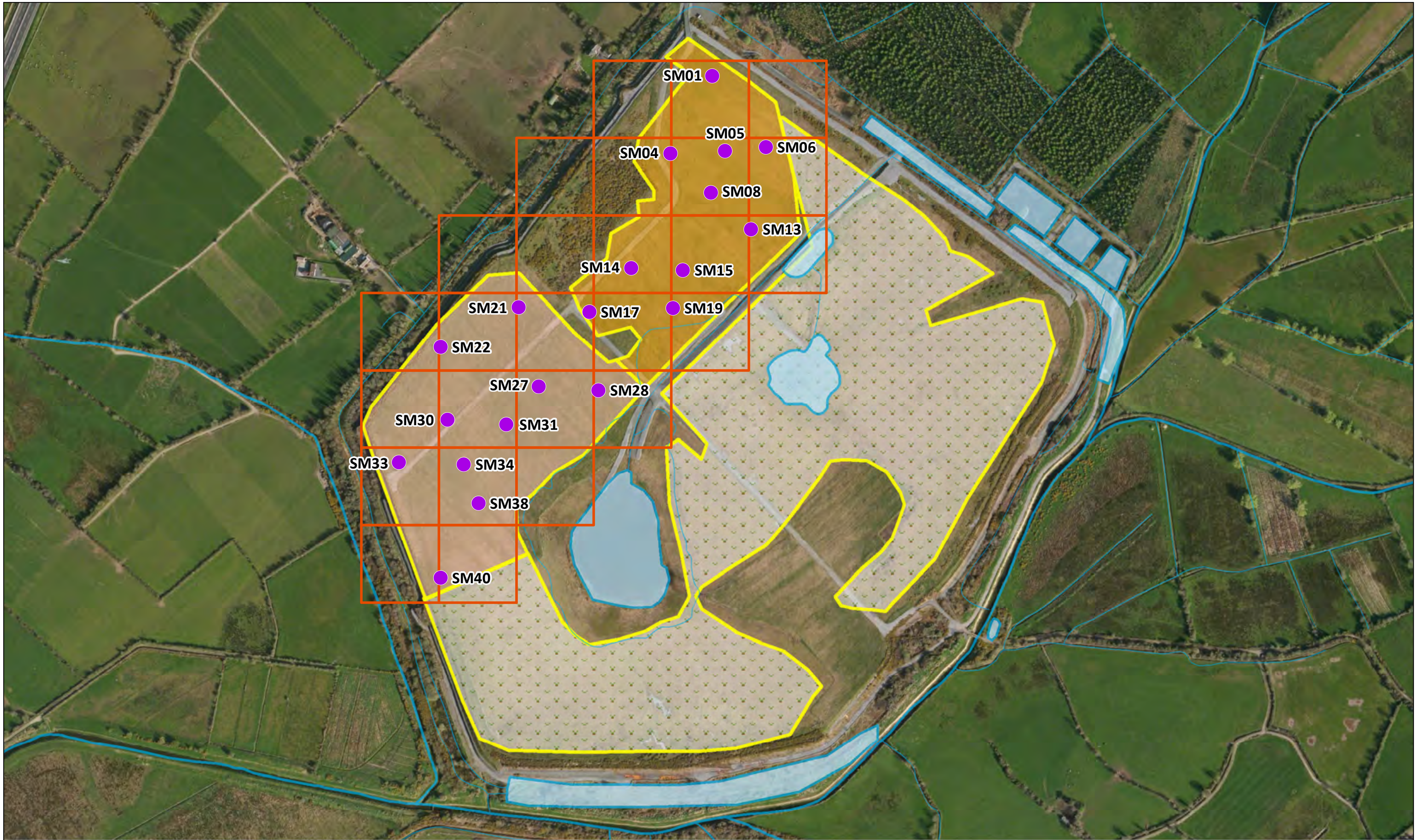

Map 6 - Silvermines - Gortmore - Vegetation & Soil

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Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Areas A and B *(vegetation samples)*

Grid *(1 ha)*

Sampling Areas

Sampling Area A

Sampling Area B

Sampling Area GS1 to GS3

Rivers

Streams

Pond / Wetland / Pit Lake

Scale is 1:6,500

0 50 100 200 m

N S W E

Appendix B

Analytical Data Tables and Assessment Criteria

Table B-1 Comparison of Total versus Dissolved Metals R4

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	22/09/2014	*1*	1.03	0.714	0.7	151	61.2	0.4	7.95	8.63	1.1	831	659	0.8
SW 12 - Shal	22/09/2014	*1*	*0.25*	*0.5*	-	59.1	43.7	0.7	2.92	1.2	0.4	29.2	22.7	0.8
SW 6 - Shal	22/09/2014	*1*	*0.25*	0.799	3.2	379	320	0.8	13.9	12	0.9	237	221	0.9
SW 9 - Shal	22/09/2014	*1*	2.1	2.42	1.2	285	228	0.8	16.4	14.6	0.9	868	710	0.8
SW1-Shal	22/09/2014	*1*	1.88	2.28	1.2	303	179	0.6	13.3	12.7	1.0	734	565	0.8
SW4-Shal	22/09/2014	*1*	*0.25*	*0.5*	-	3.38	0.31	0.1	4.73	4.15	0.9	85.4	68.7	0.8
SW5-Shal	22/09/2014	2.5	26	19.7	0.8	79.7	22.9	0.3	70.5	58.2	0.8	9430	7100	0.8
SW10-GAR	23/09/2014	5	23.9	21.7	0.9	17.7	8.51	0.5	21.4	21	1.0	8530	6920	0.8
SW12-GAR	23/09/2014	*1*	34.9	32	0.9	8.8	7.49	0.9	43	41.9	1.0	13300	12000	0.9
SW17-GORT	23/09/2014	*1*	*0.25*	*0.5*	-	*0.25*	0.239	1.0	1.11	2	1.8	4	5.72	1.4
SW3-GAR	23/09/2014	2	19	16.1	0.8	13.9	4.23	0.3	28.5	24	0.8	8340	5990	0.7
SW4-GAR	23/09/2014	*1*	1.13	1.31	1.2	29.4	29.1	1.0	3.46	3.52	1.0	250	216	0.9
SW5-GAR	23/09/2014	36	8.36	8.98	1.1	58.5	19.3	0.3	153	156	1.0	24400	24500	1.0
SW6-MAG	23/09/2014	*1*	0.966	1.09	1.1	1.84	0.303	0.2	5.21	5.49	1.1	472	429	0.9
SW7-GAR	23/09/2014	*1*	*0.25*	*0.5*	-	*0.25*	0.103	0.4	2.76	2.34	0.8	25.5	23.5	0.9
SW9-GAR	23/09/2014	3	40.2	37.9	0.9	39.9	8.38	0.2	59.4	60.2	1.0	23900	15300	0.6
SW18 GORT	24/09/2014	2.5	7.45	6.49	0.9	19.1	6.77	0.4	21.8	18.9	0.9	2380	2130	0.9
SW19 GORT	24/09/2014	2	3.73	3.15	0.8	3.25	1.66	0.5	17.3	18	1.0	2820	2850	1.0
TMF1	24/09/2014	-	*0.25*	*0.5*	-	0.768	0.078	0.1	3.99	3.55	0.9	*1.5*	2.5	1.7
TMF2	24/09/2014	-	*0.25*	*0.5*	-	4.56	2.22	0.5	4.11	2.86	0.7	6.91	7.02	1.0
SW10-GORT-DISC	25/09/2014	*1*	*0.25*	*0.5*	-	*0.25*	0.137	0.5	7.39	6.61	0.9	386	301	0.8
SW10-GORT-DS	25/09/2014	3	0.645	*0.5*	0.8	3.09	0.714	0.2	*0.25*	1.91	7.6	47.8	38.2	0.8
SW10-GORT-US	25/09/2014	3.5	*0.25*	*0.5*	-	4.49	0.612	0.1	2.14	3.27	1.5	42.5	36	0.8
SW12-GORT-DISC	25/09/2014	*1*	*0.25*	*0.5*	-	*0.25*	0.022	0.1	6.65	5.75	0.9	160	124	0.8
SW12-GORT-DS	25/09/2014	3.5	*0.25*	0.186	0.7	12	3.48	0.3	2.85	3.93	1.4	130	103	0.8
SW14-GORT	25/09/2014	3.5	*0.25*	0.145	0.6	8.41	2.9	0.3	2.5	3.01	1.2	101	102	1.0
SW1-SM	25/09/2014	*1*	*0.25*	*0.5*	-	0.559	0.049	0.1	*0.25*	0.795	3.2	*1.5*	2.6	1.7
SW2-SM-SOUTH	25/09/2014	*1*	5.21	4.65	0.9	1.23	0.912	0.7	7.27	7.62	1.0	2080	1750	0.8
SW3-SM	25/09/2014	*1*	*0.25*	0.22	0.9	2.17	1.32	0.6	0.568	1.2	2.1	88.9	80.1	0.9
SW4-SM-GA	25/09/2014	*1*	1.16	1.14	1.0	6	3.89	0.6	2.24	3.37	1.5	419	379	0.9

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 R4

Sample Description	Area	Type	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	-
TMF1	GW	GM	24/09/2014	-	205	250	*0.1*	8.5	-	0.469	*0.025*	295	*0.25*	*0.15*	*0.025*	8.1	7.46	*0.01*	45.6	7.65	-
TMF2	GW	GM	24/09/2014	-	250	305	*0.1*	19	-	0.502	*0.025*	277	*0.25*	*0.15*	*0.025*	3.9	7.26	*0.01*	*1*	10.1	-
SW1-SM	River/Stream	BG	25/09/2014	*2*	85	104	*0.1*	11.5	13.8	0.199	*0.025*	118	*0.25*	1.39	*0.025*	92.5	7.94	*0.01*	*1*	7.63	*1*
SW3-SM	River/Stream	BG	25/09/2014	*2*	90	110	*0.1*	12	9.98	0.23	*0.025*	140	*0.25*	1.52	*0.025*	95.6	8.06	*0.01*	4	9.69	*1*
SW2-SM South	Discharge	BG	25/09/2014	7.3	240	293	*0.1*	13.1	*3.5*	0.512	*0.025*	311	*0.25*	5.68	*0.025*	67.2	7.31	*0.01*	26.8	8.5	*1*
SW4-SM-GA	River/Stream	BG	25/09/2014	*2*	165	201	0.347	15.7	14.5	0.398	*0.025*	242	*0.25*	7.59	0.216	89.5	8.13	0.199	17.6	14.5	*1*
SW6-MAG	River/Stream	MG	23/09/2014	*2*	65	79	*0.1*	10.1	*3.5*	0.552	*0.025*	415	*0.25*	0.82	*0.025*	95.2	7.87	*0.01*	212	5.92	*1*
SW18-GORT	Drainage	GM	24/09/2014	5.48	110	134	*0.1*	13	14.2	2.381	*0.025*	2430	*0.25*	0.417	*0.025*	89.3	7.41	*0.01*	1440	7.61	2.5
SW19-GORT	Drainage	GM	24/09/2014	5.48	120	146	*0.1*	11.3	15.3	2.249	*0.025*	2310	*0.25*	*0.15*	*0.025*	91.2	7.78	*0.01*	1340	6.52	2
SW17-GORT	River/Stream	GM	23/09/2014	5.48	205	250	*0.1*	19.4	15.2	0.475	*0.025*	323	*0.25*	8.14	0.075	98.5	8.03	0.0362	25.6	11.4	*1*
SW10-GORT-DISC	Discharge	GM	25/09/2014	9.13	180	220	*0.1*	11	15.2	1.47	*0.025*	1300	*0.25*	*0.15*	*0.025*	62.7	7.46	*0.01*	663	8.47	*1*
SW10-GORT-DS	River/Stream	GM	25/09/2014	*2*	260	317	*0.1*	17.7	12.2	0.613	*0.025*	422	*0.25*	7.89	*0.025*	79.9	8.02	0.0245	57.4	8.7	3
SW10-GORT-US	River/Stream	GM	25/09/2014	7.3	265	323	0.202	17.7	9	0.607	*0.025*	379	*0.25*	7.93	*0.025*	71.5	6.94	0.0271	50.5	17.4	3.5
SW12-GORT-DISC	Discharge	GM	25/09/2014	11	270	329	*0.1*	21	14.6	1.735	*0.025*	1510	*0.25*	2.45	0.064	47.3	7.11	*0.01*	732	13.9	*1*
SW12-GORT-DS	River/Stream	GM	25/09/2014	9.13	235	287	*0.1*	17.1	9.75	0.624	*0.025*	414	*0.25*	6.36	*0.025*	87.1	8.04	0.0212	78.2	10.3	3.5
SW14-GORT	River/Stream	GM	25/09/2014	*2*	220	268	*0.1*	16.3	9.34	0.563	*0.025*	376	*0.25*	6.66	*0.025*	88.2	8.06	0.0209	62.5	8.84	3.5
SW4-GAR	River/Stream	GAR	23/09/2014	*2*	36.5	45	*0.1*	13	11.8	0.158	*0.025*	102	*0.25*	0.653	*0.025*	96.3	7.48	*0.01*	23.5	7.11	*1*
SW5-GAR	Discharge	GAR	23/09/2014	38.3	225	275	0.256	10.2	18.7	1.743	*0.025*	1650	2.61	1.51	*0.025*	30.3	6.9	*0.01*	869	7.14	36
SW7-GAR	Drainage	GAR	23/09/2014	7.3	205	250	*0.1*	15.4	16.5	0.513	*0.025*	418	*0.25*	*0.15*	*0.025*	88.3	7.67	*0.01*	107	7.88	*1*
SW12-GAR	Drainage	GAR	23/09/2014	14.6	185	226	*0.1*	13.6	8	1.753	*0.025*	1660	2.15	1.15	*0.025*	95.7	7.77	0.145	890	9.37	*1*
SW9-GAR	Drainage	GAR	23/09/2014	21.9	180	220	*0.1*	13.2	13.9	1.948	*0.025*	1920	2.28	3.76	*0.025*	71.6	7.55	*0.01*	1060	9.36	3
SW10-GAR	Discharge	GAR	23/09/2014	7.3	180	220	*0.1*	14.1	*3.5*	0.952	*0.025*	773	1.38	*0.15*	*0.025*	90.5	7.98	0.0503	366	7.53	5
SW3-GAR	River/Stream	GAR	23/09/2014	5.48	175	214	*0.1*	14.4	8.55	0.958	*0.025*	754	1.05	*0.15*	*0.025*	95.7	8.03	*0.01*	365	8.6	2
SW4-SHAL	River/Stream	ShS	22/09/2014	5.48	75	92	*0.1*	14	*3.5*	0.196	*0.025*	105	*0.25*	0.31	*0.025*	78.6	7.19	*0.01*	7.2	8.72	*1*
SW5-SHAL	River/Stream	ShS	22/09/2014	7.3	35.5	43	*0.1*	11.1	*3.5*	0.33	*0.025*	240	1.34	1.02	*0.025*	82.4	7.46	*0.01*	102	6.62	2.5
SW6-SHAL	Discharge	ShS	22/09/2014	*2*	37	45	*0.1*	10.3	*3.5*	0.145	*0.025*	68.1	*0.25*	1.43	*0.025*	62.5	6.52	*0.01*	17.9	6.13	*1*
SW12-SHAL	Drainage	ShS	22/09/2014	*2*	2.5	3	*0.1*	8.6	*3.5*	0.044	*0.025*	13.6	*0.25*	0.865	*0.025*	87.8	5.19	*0.01*	*1*	5.19	*1*
SW9-SHAL	River/Stream	ShS	22/09/2014	5.48	46	56	*0.1*	10.4	*3.5*	0.179	*0.025*	113	*0.25*	1.46	*0.025*	94.6	7.51	*0.01*	27.5	6.27	*1*
SW1-SHAL	River/Stream	ShS	22/09/2014	*2*	50	61	*0.1*	10.2	*3.5*	0.189	*0.025*	128	*0.25*	1.07	*0.025*	97.5	7.78	*0.01*	28.5	6.42	*1*
DS SHAL	River/Stream	ShS	22/09/2014	*2*	100	122	*0.1*	11.5	*3.5*	0.375	*0.025*	274	*0.25*	0.77	*0.025*	92.2	7.74	*0.01*	77	8.35	*1*

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- 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 R4

Sample Description	Area	Type	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	-	-	-	-	-	-
TMF1	GW	GM	24/09/2014	4.42	0.963	2.85	153	*0.05*	0.727	1.18	1.74	*9.5*	0.078	84.3	*0.005*	1.06	3.55	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	2.5
TMF2	GW	GM	24/09/2014	*1.45*	1.56	5.09	565	0.138	3.92	1.31	3.02	206	2.44	960	*0.005*	1.83	2.93	*0.195*	*0.75*	3.74	*0.18*	*0.75*	0.609	7.54
SW1-SM	River/Stream	BG	25/09/2014	27.6	0.459	0.279	47	*0.05*	0.562	0.068	0.896	*9.5*	0.049	3.8	*0.005*	*0.12*	0.795	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	2.6
SW3-SM	River/Stream	BG	25/09/2014	4.91	2.12	0.37	78.3	0.253	0.664	0.088	1.25	*9.5*	1.45	2.13	*0.005*	0.905	1.2	0.438	*0.75*	*0.48*	0.77	*0.75*	0.27	80.1
SW2-SM South	Discharge	BG	25/09/2014	9.35	0.561	0.308	151	4.65	0.902	0.172	0.956	*9.5*	0.912	0.563	*0.005*	*0.12*	7.62	0.407	*0.75*	*0.48*	0.387	*0.75*	*0.12*	1750
SW4-SM-GA	River/Stream	BG	25/09/2014	6.26	0.48	0.647	164	1.14	0.675	0.154	2.1	*9.5*	3.89	12.4	*0.005*	*0.12*	3.37	0.423	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	379
SW6-MAG	River/Stream	MG	23/09/2014	9.05	0.375	0.233	51.5	1.09	0.7	0.129	3.63	*9.5*	0.303	14.8	*0.005*	0.8	5.49	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	429
SW18-GORT	Drainage	GM	24/09/2014	60.6	1.09	0.608	21.6	6.49	0.7	0.584	9.35	*9.5*	6.77	260	*0.005*	*0.12*	18.9	0.66	*0.75*	32.2	*0.18*	*0.75*	*0.12*	2130
SW19-GORT	Drainage	GM	24/09/2014	*1.45*	0.932	0.327	27.8	3.21	0.991	0.705	12.2	*9.5*	1.66	2.99	*0.005*	*0.12*	18.1	*0.195*	*0.75*	24.6	*0.18*	*0.75*	*0.12*	2930
SW17-GORT	River/Stream	GM	23/09/2014	*1.45*	*0.08*	0.799	251	*0.05*	2.31	0.334	2.86	83.4	0.239	77.2	*0.005*	*0.12*	2	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.842	5.72
SW10-GORT-DISC	Discharge	GM	25/09/2014	*1.45*	0.189	0.272	12.2	*0.05*	0.981	0.305	3.21	*9.5*	0.137	308	*0.005*	0.3	6.61	1.63	*0.75*	1.69	*0.18*	*0.75*	0.299	301
SW10-GORT-DS	River/Stream	GM	25/09/2014	4.58	3.87	1.1	171	*0.05*	1.17	0.228	1.22	31.6	0.714	84.1	*0.005*	2.65	1.91	0.786	*0.75*	1.23	0.87	*0.75*	0.454	38.2
SW10-GORT-US	River/Stream	GM	25/09/2014	5.25	1.1	*0.06*	187	*0.05*	1.82	0.256	2.81	54.4	0.612	89.4	*0.005*	0.31	3.27	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.472	36
SW12-GORT-DISC	Discharge	GM	25/09/2014	3.16	0.16	0.401	131	*0.05*	1.39	0.486	4.06	115	0.022	453	*0.005*	*0.12*	5.75	2.13	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	124
SW12-GORT-DS	River/Stream	GM	25/09/2014	17.9	2.11	*0.06*	194	0.186	1.68	0.355	4.07	59.4	3.48	113	*0.005*	0.375	3.93	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	0.486	103
SW14-GORT	River/Stream	GM	25/09/2014	32.5	1.97	3.6	189	0.145	1.64	0.334	2.81	49.3	2.9	105	*0.005*	1.02	3.01	1.17	*0.75*	*0.48*	1.07	*0.75*	0.487	102
SW4-GAR	River/Stream	GAR	23/09/2014	7.81	1.19	0.196	269	1.31	0.66	0.911	16.7	64.9	29.1	122	*0.005*	1.3	3.52	*0.195*	*0.75*	*0.48*	0.468	*0.75*	*0.12*	216
SW5-GAR	Discharge	GAR	23/09/2014	4.19	0.83	2.11	23.2	8.98	0.838	9.69	5.44	1570	19.3	3480	*0.005*	1.3	156	0.917	*0.75*	2.56	*0.18*	1.76	0.36	24500
SW7-GAR	Drainage	GAR	23/09/2014	16.9	0.457	0.252	110	*0.05*	0.799	0.124	1.03	*9.5*	0.103	288	*0.005*	0.534	2.34	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	23.5
SW12-GAR	Drainage	GAR	23/09/2014	*1.45*	0.535	*0.06*	19.2	32	1.87	2.65	9.05	25.9	7.49	568	*0.005*	0.516	41.9	*0.195*	*0.75*	3.83	*0.18*	*0.75*	0.41	12000
SW9-GAR	Drainage	GAR	23/09/2014	*1.45*	0.987	0.213	15.4	37.9	2.13	3.24	8.57	119	8.38	514	*0.005*	0.676	60.2	*0.195*	*0.75*	5.39	*0.18*	*0.75*	0.297	15300
SW10-GAR	Discharge	GAR	23/09/2014	*1.45*	0.371	0.458	27.9	21.7	1.84	2.27	7.34	*9.5*	8.51	255	*0.005*	*0.12*	22	*0.195*	*0.75*	6.02	*0.18*	*0.75*	0.392	7150
SW3-GAR	River/Stream	GAR	23/09/2014	8.22	0.658	0.604	42.8	16.1	0.83	2.66	4.72	27.3	4.23	429	*0.005*	0.434	24	*0.195*	*0.75*	3.69	*0.18*	*0.75*	0.353	5990
SW4-SHAL	River/Stream	ShS	22/09/2014	*1.45*	*0.08*	*0.06*	378	*0.05*	0.598	0.398	1.42	38.1	0.31	80.4	*0.005*	*0.12*	4.15	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	68.7
SW5-SHAL	River/Stream	ShS	22/09/2014	53.8	1.2	*0.06*	289	19.7	0.537	5.75	17.7	*9.5*	22.9	845	*0.005*	1.19	58.2	*0.195*	*0.75*	1.5	*0.18*	*0.75*	*0.12*	7100
SW6-SHAL	Discharge	ShS	22/09/2014	28.8	0.533	*0.06*	213	0.799	0.462	1.78	15.3	96.9	320	85.5	*0.005*	*0.12*	12	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	221
SW12-SHAL	Drainage	ShS	22/09/2014	43	*0.08*	*0.06*	271	*0.05*	0.262	*0.03*	1.69	43.3	43.7	67.1	*0.005*	*0.12*	1.2	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	22.7
SW9-SHAL	River/Stream	ShS	22/09/2014	25.5	0.596	*0.06*	197	2.42	0.614	1.33	12.9	75.6	228	65.3	*0.005*	*0.12*	14.6	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	710
SW1-SHAL	River/Stream	ShS	22/09/2014	29.2	4.58	0.666	195	2.28	0.523	1.72	9.8	105	179	95.9	*0.005*	*0.12*	12.7	*0.195*	*0.75*	*0.48*	2.56	*0.75*	*0.12*	565
DS SHAL	River/Stream	ShS	22/09/2014	11.5	0.947	0.343	194	0.714	0.935	0.746	10.2	57.2	61.2	83.5	*0.005*	*0.12*	8.63	*0.195*	*0.75*	*0.48*	*0.18*	*0.75*	*0.12*	659

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

- 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 R4

Sample Description	Area	Type	Date Sampled	Dissolved solids, Total	Fluoride	Sulphate	Aluminium (diss.filt)	Arsenic (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Lead (diss.filt)	Mercury (diss.filt)	Selenium (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Livestock Criteria				**1000**	**2**	**500**	**5000**	**200**	**50**	**1000**	**1000**	**500**	**100**	**10**	**50**	**100**	**24000**
SW1-SM	River/Stream	BG	25/09/2014	118	*0.25*	*1*	27.6	0.279	*0.5*	0.562	0.068	0.896	0.049	*0.05*	*0.018*	*0.12*	2.6
SW3-SM	River/Stream	BG	25/09/2014	140	*0.25*	4	4.91	0.37	0.253	0.664	0.088	1.25	1.45	*0.05*	0.438	0.27	80.1
SW2-SM South	Discharge	BG	25/09/2014	311	*0.25*	26.8	9.35	0.308	4.65	0.902	0.172	0.956	0.912	*0.05*	0.407	*0.12*	1750
SW4-SM-GA	River/Stream	BG	25/09/2014	242	*0.25*	17.6	6.26	0.647	1.14	0.675	0.154	2.1	3.89	*0.05*	0.423	*0.12*	379
SW6-MAG	River/Stream	MG	23/09/2014	415	*0.25*	212	9.05	0.233	1.09	0.7	0.129	3.63	0.303	*0.05*	*0.018*	*0.12*	429
SW18-GORT	Drainage	GM	24/09/2014	2430	*0.25*	1440	60.6	0.608	6.49	0.7	0.584	9.35	6.77	*0.05*	0.66	*0.12*	2130
SW19-GORT	Drainage	GM	24/09/2014	2310	*0.25*	1340	*1.45*	0.327	3.21	0.991	0.705	12.2	1.66	*0.05*	*0.018*	*0.12*	2930
SW17-GORT	River/Stream	GM	23/09/2014	323	*0.25*	25.6	*1.45*	0.799	*0.5*	2.31	0.334	2.86	0.239	*0.05*	*0.018*	0.842	5.72
SW10-GORT-DISC	Discharge	GM	25/09/2014	1300	*0.25*	663	*1.45*	0.272	*0.5*	0.981	0.305	3.21	0.137	*0.05*	1.63	0.299	301
SW10-GORT-DS	River/Stream	GM	25/09/2014	422	*0.25*	57.4	4.58	1.1	*0.5*	1.17	0.228	1.22	0.714	*0.05*	0.786	0.454	38.2
SW10-GORT-US	River/Stream	GM	25/09/2014	379	*0.25*	50.5	5.25	*0.06*	*0.5*	1.82	0.256	2.81	0.612	*0.05*	*0.018*	0.472	36
SW12-GORT-DISC	Discharge	GM	25/09/2014	1510	*0.25*	732	3.16	0.401	*0.5*	1.39	0.486	4.06	0.022	*0.05*	2.13	*0.12*	124
SW12-GORT-DS	River/Stream	GM	25/09/2014	414	*0.25*	78.2	17.9	*0.06*	0.186	1.68	0.355	4.07	3.48	*0.05*	*0.018*	0.486	103
SW14-GORT	River/Stream	GM	25/09/2014	376	*0.25*	62.5	32.5	3.6	0.145	1.64	0.334	2.81	2.9	*0.05*	1.17	0.487	102
SW4-GAR	River/Stream	GAR	23/09/2014	102	*0.25*	23.5	7.81	0.196	1.31	0.66	0.911	16.7	29.1	*0.05*	*0.018*	*0.12*	216
SW5-GAR	Discharge	GAR	23/09/2014	1650	2.61	869	4.19	2.11	8.98	0.838	9.69	5.44	19.3	*0.05*	0.917	0.36	24500
SW7-GAR	Drainage	GAR	23/09/2014	418	*0.25*	107	16.9	0.252	*0.5*	0.799	0.124	1.03	0.103	*0.05*	*0.018*	*0.12*	23.5
SW12-GAR	Drainage	GAR	23/09/2014	1660	2.15	890	*1.45*	*0.06*	32	1.87	2.65	9.05	7.49	*0.05*	*0.018*	0.41	12000
SW9-GAR	Drainage	GAR	23/09/2014	1920	2.28	1060	*1.45*	0.213	37.9	2.13	3.24	8.57	8.38	*0.05*	*0.018*	0.297	15300
SW10-GAR	Discharge	GAR	23/09/2014	773	1.38	366	*1.45*	0.458	21.7	1.84	2.27	7.34	8.51	*0.05*	*0.018*	0.392	7150
SW3-GAR	River/Stream	GAR	23/09/2014	754	1.05	365	8.22	0.604	16.1	0.83	2.66	4.72	4.23	*0.05*	*0.018*	0.353	5990
SW4-SHAL	River/Stream	ShS	22/09/2014	105	*0.25*	7.2	*1.45*	*0.06*	*0.5*	0.598	0.398	1.42	0.31	*0.05*	*0.018*	*0.12*	68.7
SW5-SHAL	River/Stream	ShS	22/09/2014	240	1.34	102	53.8	*0.06*	19.7	0.537	5.75	17.7	22.9	*0.05*	*0.018*	*0.12*	7100
SW6-SHAL	Discharge	ShS	22/09/2014	68.1	*0.25*	17.9	28.8	*0.06*	0.799	0.462	1.78	15.3	320	*0.05*	*0.018*	*0.12*	221
SW12-SHAL	Drainage	ShS	22/09/2014	13.6	*0.25*	*1*	43	*0.06*	*0.5*	0.262	*0.03*	1.69	43.7	*0.05*	*0.018*	*0.12*	22.7
SW9-SHAL	River/Stream	ShS	22/09/2014	113	*0.25*	27.5	25.5	*0.06*	2.42	0.614	1.33	12.9	228	*0.05*	*0.018*	*0.12*	710
SW1-SHAL	River/Stream	ShS	22/09/2014	128	*0.25*	28.5	29.2	0.666	2.28	0.523	1.72	9.8	179	*0.05*	*0.018*	*0.12*	565
DS SHAL	River/Stream	ShS	22/09/2014	274	*0.25*	77	11.5	0.343	0.714	0.935	0.746	10.2	61.2	*0.05*	*0.018*	*0.12*	659

xx Exceeds Livestock Assessment Criteria

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

Table B-4 Comparison of Vegetation Results to Assessment Criteria R4

	Total Arsenic	Total Cadmium	Total Lead	Total Zinc
	mg/kg	mg/kg	mg/kg	mg/kg
Max Concentration in Feeding stuff	**2**	**1**	**30**	**-**
No effect for digestion in wildlife	**0.621**	**8.787**	**72.88**	**1457.6**
Low effect for digestion in wildlife	**6.211**	**87.871**	**728.78**	**2915.1**
SM01-V	*0.05*	0.076	0.6	26.9
SM06-V	*0.05*	0.047	0.3	23.1
SM05-V	*0.05*	0.061	0.4	21.8
SM04-V	*0.05*	0.041	0.3	21.8
SM08-V	*0.05*	0.047	0.2	21.4
SM13-V	*0.05*	0.056	0.3	20.8
SM14-V	*0.05*	0.055	0.4	19.6
SM15-V	*0.05*	0.024	0.3	21.6
SM19-V	*0.05*	0.040	0.3	20.7
SM17-V	*0.05*	0.039	0.3	27.6
SM28-V	*0.05*	0.053	0.5	26.3
SM21-V	*0.05*	0.059	2.5	33.3
SM22-V	0.100	0.051	0.5	29.3
SM27-V	*0.05*	0.037	0.4	26.8
SM31-V	*0.05*	0.039	0.3	18.2
SM30-V	*0.05*	0.041	0.2	25.2
SM34-V	*0.05*	0.043	0.7	23.6
SM38-V	*0.05*	0.042	0.2	16.7
SM33-V	0.106	0.056	1.98	27.5
SM40-V	0.106	0.056	2.00	28.4

xx Exceeds the Maximum Concentration in Feeding Stuff

xx Exceeds No effect level for digestion in wildlife

xx Exceeds Low effect level for digestion in wildlife

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

Table B-5 Comparison of Vegetation Results to Assessment Criteria R4

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	5600	7	70	0.5	14	9	15000	*0.5*	900	16	48	45
SM04-S	5300	7	60	0.5	13	10	14100	1	800	15	49	50
SM05-S	4400	7	40	*0.25*	13	9	13100	1	600	12	23	39
SM06-S	4500	6	50	0.5	13	12	13100	1	700	11	23	39
SM08-S	4500	6	50	0.5	14	9	14000	1	600	14	22	40
SM13-S	6600	10	70	*0.25*	15	12	17000	*0.5*	1000	17	31	50
SM14-S	7000	9	60	0.7	16	12	15800	*0.5*	1000	19	27	60
SM15-S	8500	12	50	*0.25*	19	14	20300	1	1600	22	38	69
SM17-S	7000	10	70	0.7	16	11	16700	*0.5*	1000	19	25	56
SM19-S	6300	10	40	0.6	15	11	14800	*0.5*	800	18	24	53
SM21-S	6700	8	70	0.7	15	11	15100	*0.5*	1100	21	31	76
SM22-S	7700	8	150	*0.25*	16	14	17400	*0.5*	2200	20	36	51
SM27-S	7100	10	60	0.7	16	11	15300	*0.5*	1100	20	25	56
SM28-S	7200	9	90	0.7	16	12	15300	*0.5*	1400	18	28	59
SM30-S	6700	8	70	0.5	15	13	16000	1	1400	20	27	55
SM31-S	6600	10	60	0.6	16	12	15400	*0.5*	1600	21	23	60
SM33-S	6700	9	40	0.5	16	13	16000	1	700	22	25	59
SM34-S	7100	6	110	*0.25*	14	11	15100	1	3600	17	24	39
SM38-S	6200	7	40	*0.25*	13	9	13800	*0.5*	1700	15	22	44
SM40-S	8900	7	330	*0.25*	19	16	20000	1	2800	22	38	53

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