Department of Communications, Energy & Natural Resources

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

Silvermines Monitoring Report - Round 1 (2014)

Final

CDM Smith

GWP consultants
earth & water resources

Document Control Sheet

Client		Department of Communications, Energy and Natural Resources		
Project		Environmental Monitoring of Former Mining Areas of Silvermines and Avoca		
Project No		95735		
Report		Monitoring Report for the Former Mining Area of Silvermines – March 2014		
Document Reference:		95735/40/DG13		
Version	**Author**	**Checked**	**Reviewed**	**Date**
Draft 1	L Gaston R L Olsen	R O'Carroll	R L Olsen	July 2014
Final	L Gaston R L Olsen	R O'Carroll	R L Olsen	September 2014

Distribution	Copy No.

Table of Contents

Section 1 Introduction 1
1.1 Objectives and Scope 1
1.2 Background of Silvermines Mining Area 1
1.3 Catchment Description 2
1.4 Geology and Hydrogeology 3
1.4.1 Geology 3
1.4.2 Hydrogeology 3

Section 2 Methodology 4
2.1 Field Sampling Methods 4
2.1.1 Groundwater Sampling 4
2.1.2 Surface Water Sampling 5
2.1.3 Vegetation Sampling 8
2.1.4 Soil Sampling 8
2.1.5 Field QA/QC Samples 9
2.2 Sample Handling 10
2.3 Sample Analysis 10
2.3.1 ALcontrol 10
2.3.2 CAL Ltd 11

Section 3 Data Quality and Usability Evaluation 12
3.1 Introduction 12
3.1.1 Accuracy 12
3.1.2 Precision 12
3.1.3 Blanks 13
3.1.4 Field QA/QC Samples 13
3.2 Results of Field QA/QC Samples 14
3.2.1 Duplicates 14
3.2.2 Decontamination Blanks 16
3.2.3 Standard Reference Materials 19
3.3 Laboratory QA/QC Samples 19
3.3.1 ALcontrol 19
3.3.2 CAL Ltd. 20
3.4 Summary of Data Checks 22
3.4.1 Field physio-chemical Versus Laboratory Data 22
3.4.2 Internal Consistency Analysis 24
3.4.3 Comparison of Total and Dissolved Metals 27

Section 4 Results and Evaluations 28
4.1 Statistical Summary of Analytical Results 28
4.1.1 Groundwater Sample Results 28
4.1.2 Surface Water Sample Results 29
4.1.3 Vegetation Sample Results 30
4.2 Assessment Criteria 31
4.2.1 Groundwater and Surface Water Assessment Criteria 31
4.2.2 Livestock Drinking Water Assessment Criteria 33
4.2.3 Vegetation Assessment Criteria 34
4.3 Comparison to Assessment Criteria 35

4.3.1 Groundwater Assessment 35
4.3.2 Surface Water Assessment 35
4.3.3 Livestock Water Quality Assessment 38
4.3.4 Vegetation Assessment 39

Section 5 Flows, Loads and Trend Analysis 40

5.1 Surface Water Flows 40
5.2 Loading Analysis 41
5.2.1 Loading Analysis Methodology 41
5.2.2 Loading Results and Discussion 41
5.3 Trend Analysis 43
5.3.1 Historical Trends 43
5.3.2 Seasonal Trends 45

Section 6 Groundwater Levels 46

Section 7 Summary and Recommendations 47

7.1 Summary of Findings 47
7.2 Recommendations for the Monitoring Programme 48

Section 8 References 49

Appendices

Appendix A Figures

Appendix B Analytical Data Tables and Assessment Criteria

List of Tables

Table 1 Location of Groundwater Monitoring Points 4
Table 2 Location of Surface Water Monitoring Points 6
Table 3 Location Vegetation Sampling Sites at Gortmore TMF 8
Table 4 Field QA/ QC Sample IDs and Descriptions 10
Table 5 Water Duplicate Pairs Reported Values (µg/l) and Calculated % RPD 15
Table 6 Vegetation Duplicate Pairs Reported Values (µg/l) and Calculated % RPD 16
Table 7 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l) 18
Table 8 Water SRM Reported Values (µg/l) and Calculated % R 19
Table 9 SRM NIST 1568b Reported Values and Calculated % R and % RPD....21
Table 10 Field physio-chemical data and Laboratory Reported Values and Calculated % RPD 23
Table 11 Charge Balance and Mass Balance Results....25
Table 12 Comparison of Specific Conductivity to Total Dissolved Solids (SC/TDS) Ratio 26
Table 13 Summary of Dissolved Metal Concentrations in Groundwater 28
Table 14 Summary of Dissolved Metal Concentrations in Discharges and Drainage....29
Table 15 Summary of Dissolved Metal Concentrations in Rivers and Streams 30
Table 16 Summary of Vegetation Concentrations (mg/kg) at Gortmore TMF 31
Table 17 Surface Water and Groundwater Assessment Criteria for Biological Elements 32
Table 18 Surface Water and Groundwater Assessment Criteria for Drinking Water....33
Table 19 Assessment Criteria for Livestock Drinking Water Quality....33
Table 20 Assessment Criteria for Vegetation (mg/kg) 34
Table 21 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria..37
Table 22 Surface Water Flow Value Measured in March 2014....41
Table 23 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in g/day 42
Table 24 Reporting the Mann-Kendall Results 44
Table 25 Mann-Kendall Trend Analysis of data from November 2006 to March 2014....44
Table 26 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 45
Table 27 Measures Groundwater Levels March 2014....46

List of Figures

Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS) 27
Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 Sept to 18 Mar 2013 40

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 March 2014. This report should be read alongside the Silvermines Data Report (Document Ref: 95735/40/DG12, dated May 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 13 March 2014, as listed in Table 1 and shown on Map 2 in Appendix A. 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 Redi-Flo). The static water level was measured prior to pumping and was also measured throughout the purging process to monitor drawdown.

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

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

The following exceptions to the low flow sampling procedure applied:

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

Water Level

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

2.1.2 Surface Water Sampling

Thirty-three surface water locations were sampled between 5 and 13 March 2014, as listed in Table 2 and shown on Maps 2 to 5 in Appendix A. One of these samples (TMF Seep 1) was an additional sample requested by DCENR of a seep at the base of the Gortmore TMF. One sample could not be obtained because 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
TMF Seep 1	GM	179887	172192	Extra sample: Seep at base of the TMF on the southern side	Yes	NR
SW1-SM	BG	184083	170732	Site on Silvermines Stream (upstream of Ballygown mine workings)	Yes	Flow Meter
SW2-SM- North	BG	184258	171619	Discharge from 'Northern' adit.	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)	Yes	NR
SW2-GAR	GA	181804	171376	Drainage south of R499 road.	Yes	NR
SW3-GAR	GA	181300	171648	Stream site containing drainage flows from both the tailings lagoon and western part of Mogul Yard.	Yes	Flow Meter
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	Overflow covered by grate
SW7-GAR	GA	181523	171493	Discharge from smaller settlement pond	Yes	Bucket and Stopwatch
SW8-GAR	GA	181695	171531	Drainage from western part of Mogul Yard sampled in open drain, south of railway	Yes	Low flow not measurable
SW9-GAR	GA	181881	171557	Drainage from eastern part of Mogul Yard sampled in open drain along northern side of	Yes	Flume

Site Name	Area	Easting	Northing	Sample Site Notes	Sample collected	Flow
				railway		
SW10-GAR	GA	181640	171730	Discharge from Garryard tailings lagoon	Yes	Flow Meter
SW12-GAR	GA	181791	171569	Combined run-off from Knight Shaft and eastern part of Mogul Yard sampled north of railway and up-gradient of tailings lagoon.	Yes	Flow Meter
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	Yes	Bucket and Stopwatch
SW9-SHAL	ShS	180571	171470	Stream occurring immediately east of the southernmost Shallee tailings impoundment. Sample site is south of R499 road.	Yes	Flume
SW10-SHAL	ShS	180609	171499	Drainage running parallel to R499. Site occurs at northern edge of the southernmost Shallee tailings impoundment.	Yes	Flume
SW12-SHAL	ShS	180670	171165	Stone lined drainage channel SSW of reservoir	Yes	Bucket and Stopwatch

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

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

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

Flow Measurements

Flow was measured at 21 locations using various methods depending upon the quantity of flow to be measured and any safety concerns as detailed in the standard operating procedures in the Monitoring Plan (see Table 2). Twenty four locations are required to have flow measured, however at the time of sampling the flow was so low at one location it could not be measured, there was no flow at one adit discharge location, and the flow from one shaft discharge could not be measured as it was inaccessible (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 12 and 13 March 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 Sampling Sites at Gortmore TMF

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

2.1.4 Soil Sampling

Annual soil sampling will be carried out in Round 4 during the summer of 2014.

2.1.5 Field QA/QC Samples

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

Groundwater and Surface water

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

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		
SMGD01.3	GW Duplicate	Duplicate of TMF2
SMDB01.3	GW Decontamination blank	DI water (Lennox Batch TE130418W) pumped though pump after decon at site TMF2
SMSD01.3	SW Duplicate	Duplicate of SW7-Gar
SMSD02.3	SW Duplicate	Duplicate of SW19-Gort
SMSD03.3	SW Duplicate	Duplicate of SW12-Gort-DS
SMDB02.3	SW Decontamination blank	DI water (Lennox Batch TE140120W) poured over SW sampling beaker after decon at site SW14-Gort
SMSR01.3	Standard Reference Material	Water ERA Lot #P222-740B
SMSR02.3	Standard Reference Material	Water ERA Lot #P222-740B
WB01.3	Water blank	Deionised water (Lennox Batch TE130418W)
Vegetation		
SM56-V	Vegetation Duplicate	Duplicate of SM17-V
SM57-V	Vegetation Duplicate	Duplicate of SM33-V
SMDB03.3	Decontamination blank	DI water (Lennox Batch TE140120W) poured over shears after final decon

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.

Section 3

Data Quality and Usability Evaluation

3.1 Introduction

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

3.1.1 Accuracy

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

%R is calculated as follows:

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

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

Acceptable QC limits are typically between 80 to 120 %R for inorganic methods (i.e. metals in this report). 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 SMSR01.3 and SMSR02.3) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P222-740B (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).

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

3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Surface water and Groundwater Duplicates

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

The majority of RPD values shown in Table 5 are below 50 %. The RPDs for the following parameters are very good: arsenic (0 to 5 %), barium (0 to 4%), cadmium (0 to 3 %), copper (0 to 11 %), cobalt (0.5 to 16 %), manganese (0.5 to 10 %), nickel (0 to 11%), iron (0 to 2%) and zinc (1 to 15 %). The RPDs range for lead (3 to 33%) were slightly higher but still considered good.

The RPDs that were above 50% included antimony for two sample pairs ranging from 79 to 118 % RPD and chromium (52 %RPD) for one sample pair. 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	SMGD01.3	RPD	SW7-GAR	SMSD01.3	RPD	SW19-GORT	SMSD02.3	RPD	SW12-GORT-DS	SMSD03.3	RPD
Aluminium	<2.9	<2.9	<2.9	0	<2.9	<2.9	0	<2.9	<2.9	0	5.23	6.43	-20.6
Antimony	<0.16	0.622	<0.16	**118**	<0.16	0.367	**-78.6**	1.03	0.905	12.9	<0.16	<0.16	0
Arsenic	<0.12	4.99	4.92	1.4	<0.12	<0.12	0	0.395	0.412	-4.2	0.438	0.416	5.2
Barium	<0.03	586	592	-1.0	60	61	-1.7	21.5	21.8	-1.4	146	152	-4.0
Cadmium	<0.1	<0.1	<0.1	0	8.6	8.92	-3.7	1.04	1.07	-2.8	0.58	0.564	2.8
Chromium	<0.22	4.48	4.41	1.6	1.16	0.683	**51.8**	1.8	2.03	-12.0	3.23	2.54	23.9
Cobalt	<0.06	1.01	1.03	-2.0	0.359	0.361	-0.6	0.163	0.191	-15.8	0.251	0.262	-4.3
Copper	<0.85	<0.85	<0.85	0.0	2.21	2.2	0.5	2.86	3.2	-11.2	1.3	1.39	-6.7
Iron	<19	191	195	-2.1	<19	<19	0.0	<19	<19	0	45.4	45.8	-0.9
Lead	<0.02	2.16	2.06	4.7	0.678	0.946	-33.0	3.25	3.16	2.8	2.22	2.31	-4.0
Manganese	<0.04	898	988	-9.5	67.5	68	-0.7	7.34	7.49	-2.0	58.7	63.7	-8.2
Mercury	<0.01	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0	<0.01	<0.01	0
Molybdenum	<0.24	0.598	0.445	29.3	<0.24	0.344	-35.6	<0.24	<0.24	0	<0.24	<0.24	0
Nickel	<0.15	2.07	2.05	1.0	20.6	21.5	-4.3	7.1	6.39	10.5	3.2	3.2	0
Selenium	<0.39	0.775	0.666	15.1	<0.39	<0.39	0	0.416	0.545	-26.8	0.567	0.594	-4.7
Silver	<1.5	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0
Thallium	<0.96	<0.96	<0.96	0	<0.96	<0.96	0	13.4	12.8	4.6	<0.96	<0.96	0
Tin	<0.36	<0.36	<0.36	0	<0.36	<0.36	0	<0.36	<0.36	0	<0.36	<0.36	0
Uranium	<1.5	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0	<1.5	<1.5	0
Vanadium	<0.24	0.962	1.18	-20.4	<0.24	<0.24	0	0.336	0.54	-46.6	1.01	0.716	34.1
Zinc	<0.41	15.6	13.4	15.2	5500	5580	-1.4	583	588	-0.9	259	263	-1.5

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

Vegetation Duplicates

Table 6 provides the results of the four metals for the two duplicate vegetation samples and the calculated RPD between each pair of samples. All the RPD values are below the +/- 50 % RPD values anticipated for field samples. The RPD values range from 0 to 15 % which is very good for field vegetation duplicates.

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

Total Metal	SM17-V (mg/kg)	SM56-V (mg/kg)	% RPD	SM33-V (mg/kg)	SM57-V (mg/kg)	% RPD
Arsenic	0.206	0.232	-11.9	0.337	0.330	2.1
Cadmium	0.081	0.094	-14.9	0.062	0.060	3.3
Lead	3.50	3.59	-2.6	2.99	2.99	0.2
Zinc	34.5	35.0	-1.4	43.0	44.3	-2.9

3.2.2 Decontamination Blanks

Surface Water and Groundwater

Three decontamination blanks were created by pumping DI water through or pouring water over the sampling equipment after decontamination and sent to ALcontrol for analysis. Table 7 provides the results of the 21 metals for the three decontamination blanks along with the results of the DI water blank also created in the field.

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

Detections were observed for 9 dissolved metals ranging from 0.08 to 10.8 µg/l. Five of the metals (barium, chromium, manganese, nickel 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 aluminum, cobalt and selenium were found in the decontamination blanks but not the DI water blank. The highest detections of dissolved metals in the DI water blank and the three decontamination blanks were for dissolved zinc which ranged from 7.17 to 10.8 µg/l.

In total there were 20 detections of dissolved metals in the decontamination blanks. Four of these were greater than ten times the detection limit, manganese in SMDB01.3 (1.24 µg/l), barium in SMDB03.3 (1.22 µg/l) and zinc in all the decontamination blanks (7.17 and 10.8 µg/l). All of the detections including manganese, barium 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 7 exceptions in total. Chromium was detected in both SMDB01.3 and SMDB02.3 at concentrations were determined to be 16.9 % and 27.7 % of the preceding environmental samples. In SMDB01.3 there were also detections of cobalt and nickel at 34.2 and 22.8 % and in SMDB02.3 there was zinc at 14.6 % and selenium at 96.4 % of the preceding environmental samples. Chromium and zinc were detected in the DI water blank and therefore the detections are not indicative of cross-contamination in the field. Dissolved cobalt, nickel, selenium were only slightly above the detection limit 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 method blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory. Four detections in Sample Batches 140314-91 and 140314-92 (0.0460 µg/l barium, 0.300 µg/l lead, 0.193 µg/l manganese 0.158 µg/l nickel) in the method blanks were reported and could contribute to the detections in the decontamination blanks shown in Table 7.

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

To assess the level of cross-contamination between vegetation samples in the field, the concentrations in decontamination blank SMDB03.3 were examined (Table 7). The detections of dissolved barium, chromium, manganese, nickel and zinc can be attributed to the concentrations in the DI water. Dissolved aluminium was detected in the decontamination blank at concentration of 4.26 µg/l. Detections were generally less than 10 times the detection limit with the exception of dissolved barium and zinc, however these were detected in the water blank. None of the parameters of concern for vegetation samples (arsenic, cadmium, lead and zinc) where detected in the decontamination blank at levels that would indicate cross-contamination of samples in the field.

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

Type		Water						Vegetation	
Sample Description Dissolved Metal	LOD (µg/l)	Water Blank WB01.3 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB01.3 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB02.3 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank SMDB03.3 (µg/l)	Laboratory Method Blank (µg/l)
	Sample batch:	***140228-68***		***140314-91***		***140314-92***		***140314-92***	
Aluminium	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	**4.26**	<2.9
Antimony	<0.16	<0.16	0.859	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16
Arsenic	<0.12	<0.12	<0.12	<0.12	0.122	<0.12	0.122	<0.12	0.122
Barium	<0.03	**0.128**	<0.03	***0.129***	*0.0460*	***0.099***	*0.0460*	***1.22***	*0.0460*
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.22	**0.437**	<0.22	**0.734**	<0.22	**0.759**	<0.22	**1.04**	<0.22
Cobalt	<0.06	<0.06	<0.06	**0.345**	<0.06	<0.06	<0.06	<0.06	<0.06
Copper	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85	<0.85
Iron	<19	<19	<19	<19	<19	<19	<19	<19	<19
Lead	<0.02	<0.02	<0.02	***0.08***	*0.03*	***0.031***	*0.03*	<0.02	*0.03*
Manganese	<0.04	**0.109**	*0.0420*	***0.641***	*0.193*	***0.257***	*0.193*	***0.389***	*0.193*
Mercury	<0.01	<0.01	NP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	<0.24	<0.24	0.241	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24
Nickel	<0.15	**0.151**	<0.15	***0.472***	*0.158*	***0.272***	*0.158*	***0.275***	*0.158*
Selenium	<0.39	<0.39	<0.39	<0.39	<0.39	**0.476**	<0.39	<0.39	<0.39
Silver	<1.5	<1.5	NP	<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
Tin	<0.36	<0.36	0.498	<0.36	<0.36	<0.36	<0.36	<0.36	<0.36
Uranium	<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
Zinc	<0.41	**8.73**	<0.41	**7.23**	<0.41	**10.8**	<0.41	**7.17**	<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.

3.2.3 Standard Reference Materials

SRM Water

As previously discussed two certified water SRMs were sent blind to the laboratory (Sample IDs SMSR01.3 and SMSR02.3) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 8 summarises the SRM results and provides the calculated %R values for the 18 requested metals.

Reported values for dissolved aluminium, arsenic, antimony, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, thallium and vanadium are in excellent agreement with the certified value (%R ranged from 90 to 105%).

One of the reported values for dissolved silver in ID SMSR02.3 and dissolved zinc SMSR01.3 were low at 89 % and 85 % respectively, which fall slightly outside of the acceptable range. However, the second reported value is within the acceptable range and therefore the reported values are considered usable.

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

Dissolved Metal	Certified Value (µg/l)	Acceptance Limits		SMSR01.3 (µg/l)	% R	SMSR02.3 (µg/l)	% R
		Lower (%)	Upper (%)				
Aluminium	420	87.4	114	414	99	425	101
Antimony	429	86.9	111	416	97	385	90
Arsenic	342	87.1	111	323	94	337	99
Barium	702	90.9	109	678	97	675	96
Cadmium	203	88.7	106	186	92	179	88
Chromium	229	90.8	109	224	98	225	98
Cobalt	409	92.9	111	416	102	397	97
Copper	490	90.4	109	474	97	461	94
Iron	836	90.1	111	796	95	760	91
Lead	741	90.1	110	775	105	731	99
Manganese	483	92.3	109	491	102	471	98
Molybdenum	273	89.7	109	252	92	245	90
Nickel	360	91.1	109	333	93	329	91.4
Selenium	638	87.5	111	607	95	608	95
Silver	572	89.7	110	523	91	509	**89**
Thallium	342	87.7	111	344	101	338	99
Vanadium	211	91.0	107	205	97	211	100
Zinc	1690	90.5	110	1440	**85**	1600	95

Notes:
Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

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

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

All of the ALcontrol laboratory reports were reviewed to ensure that reported values were ISO17025 certified (where relevant) and for any sample deviations. The sample holding times were exceeded for total dissolved solids in the laboratory. The holding times were exceeded by 1 to 2 days. These exceedances of the holding times 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 SRM NIST 1568b after every 10 samples for a total of two analyses. The results are provided in the laboratory report in Appendix F of the Data Report (reported as CRM NIST 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**.** In addition, CAL routinely analysed an in-house reference material (a dried ground haylage sample, GST004). The reference material was analysed three times for arsenic, cadmium, lead and zinc. CAL analysed an additional SRM NCS ZC73013 (dried spinach) for lead;
- Duplicates: CAL did not analyse duplicates of the field samples. However, the two analyses of SRM NIST 1568b can be used to evaluate precision; and
- Blanks: CAL performed three method blanks during the analyses of arsenic, cadmium, lead and zinc. The method blanks were clean aqueous solutions.

SRM

Table 9 provides the results of the two analyses of SRM NIST 1568b and the % R values.

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

Total Metal	Certified Value (mg/kg)	Certified value Acceptance Range (mg/kg)	Acceptance Limits (%)	Result 1 (mg/kg)	% R	Result 2 (mg/kg)	% R	% RPD
Arsenic	0.285	0.271-0.299	95-105	0.234	82	0.270	95	14.3
Cadmium	0.0224	0.0211-0.0237	94-106	0.017	76	0.021	94	21.1
Lead	0.008	0.005-0.011	63-138	0.013	163	0.025	313	63.2
Zinc	19.42	19.16-19.68	99-101	18.2	94	21.6	111	16.8

One of the zinc results is considered slightly low with the %R value of 94 % and one value is slightly high with an %R of 111 %, which is just outside the acceptable range of 99 to 101 % R. One reported cadmium value may be slightly low (% R is 76); however, the other is acceptable with %R of 94 %. One reported arsenic value may be slightly low (% R is 82); however, the other is acceptable with %R of 95 %. The lead values are both above the criteria value and above the acceptable range with an %R of 163 and 313 %. The arsenic, cadmium and zinc values are considered acceptable to use.

As shown, 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 soilds. CAL analysed an additional SRM NCS ZC73013 (dried spinach) for lead. The certified value for lead was 11.1 ±0.9 mg/kg which is better for solids. The reported values were 11.56 and 10.74 mg/kg which were well within the acceptable range.

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 9) can be considered duplicate samples. As shown in Table 9, the precision was good. The arsenic values were 0.234 and 0.270 mg/kg, cadmium values were 0.017 and 0.021 mg/kg and the zinc values were 18.2 and 21.6 mg/kg, with calculated %RPDs ranging from 14 to 21 %. The two values of lead ranged from 0.013 and 0.025 mg/kg with an RPD of 63 % which is outside the acceptable range for laboratory duplicates. These concentrations were very close to the detection limit where the accuracy is less. The RPD for the lead concentrations in SRM NCS ZC73013 (dried spinach) which had a higher detection limit was much better at 7.4 %.

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 0.01 mg/kg. All reported values were below the critical values of 0.1 mg/kg for arsenic and 0.01 mg/kg for lead, cadmium and zinc and therefore are considered acceptable. Method blanks do not indicate any carryover or contamination.

3.4 Summary of Data Checks

3.4.1 Field physio-chemical Versus Laboratory Data

Table 10 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 and generally less than 15 % which is very good, with only one exceeding 50%, TMF Seep 1 with a RPD of 72%. The pH 6.81 reported by the laboratory for TMF Seep 1 was checked and confirmed by ALcontrol. 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 10 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)		
SW10-SHAL	7.32	7.13	2.6	0.261	0.297	-12.9
SW12-SHAL	5.05	4.37	14.4	0.0589	0.065	-9.8
SW1-GAR	7.46	7.54	-1.1	1.37	1.492	-8.5
SW1-SHAL	7.47	7.27	2.7	0.206	0.225	-8.8
SW2-GAR	6.93	6.7	3.4	0.917	1.009	-9.6
SW4-GAR	7.56	7.11	6.1	0.125	0.135	-7.7
SW4-SHAL	7.65	6.66	13.8	0.138	0.17	-20.8
SW5-SHAL	6.83	6.79	0.6	0.261	0.283	-8.1
SW6-SHAL	7.46	6.44	14.7	0.136	0.147	-7.8
SW7-SHAL	6.85	6.7	2.2	0.266	0.282	-5.8
SW9-SHAL	7.35	7.04	4.3	0.177	0.191	-7.6
SW10-GAR	7.62	7.64	-0.3	0.854	0.95	-10.6
SW12-GAR	7.4	7.52	-1.6	0.878	0.956	-8.5
SW3-GAR	7.75	7.65	1.3	0.869	0.944	-8.3
SW5-GAR	7.23	7.11	1.7	0.824	0.893	-8.0
SW7-GAR	7.33	7.36	-0.4	0.75	0.741	1.2
SW8-GAR	7.33	7.26	1.0	1.69	1.804	-6.5
SW9-GAR	7.53	7.72	-2.5	1.37	1.47	-7.0
SW17-GORT	8.22	7.62	7.6	0.314	0.357	-12.8
SW1-SM	7.62	7.07	7.5	0.117	0.139	-17.2
SW2-SM South	8.14	7.02	14.8	0.492	0.544	-10.0
SW3-SM	7.84	6.91	12.6	0.15	0.167	-10.7
SW4-SM-GA	8.24	7.78	5.7	0.226	0.258	-13.2
SW6-MAG	7.64	7.73	-1.2	0.444	0.507	-13.2
SW18-GORT	7.99	8.11	-1.5	0.532	0.594	-11.0
SW19-GORT	7.89	7.78	1.4	0.669	0.742	-10.3
TMF Seep 1	6.81	3.19	**72.4**	3.22	3.935	-20.0
TMF1	7.79	7.57	2.9	0.397	0.437	-9.6
TMF2	7.52	7.27	3.4	0.437	0.486	-10.6
SW10-GORT-DISC	8.03	7.32	9.3	0.856	0.939	-9.2
SW10-GORT-DS	8.39	7.62	9.6	0.453	0.496	-9.1
SW10-GORT-US	8.23	7.54	8.8	0.441	0.483	-9.1
SW12-GORT-DISC	7.96	7.08	11.7	0.971	1.02	-4.9
SW12-GORT-DS	8.4	7.64	9.5	0.463	0.516	-10.8
SW14-GORT	8.44	7.78	8.1	0.418	0.461	-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 11.

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. There was only 1 sample greater than 10 %. 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 11 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
SW1-GAR	1146	1330	1.9	5.0	**-13.8**	Missing anions
SW2-GAR	702	807	0.2	0.7	**-13.0**	Missing anions
SW4-GAR	70	60	-0.1	-5.5	**16.2**	Too many anions
SW1-SHAL	126	148	-0.3	-7.6	**-14.8**	Missing cations
SW4-SHAL	73	81.1	-0.1	-3.3	-9.9	Missing cations
SW5-SHAL	165	174	-0.1	-2.5	-5.2	Missing cations
SW6-SHAL	76	100	-0.2	-7.4	**-23.6**	Missing cations
SW7-SHAL	165	157	-0.1	-1.6	4.9	Too many anions
SW9-SHAL	105	116	-0.3	-7.6	-9.3	Missing cations
SW10-SHAL	159	216	-0.2	-2.9	**-26.5**	Missing cations
SW12-SHAL	25	26.3	-0.1	**-12.3**	-5.0	Missing cations
SW3-GAR	656	702	0.4	1.6	-6.6	Missing anions
SW5-GAR	602	694	0.0	-0.2	**-13.3**	Missing cations
SW7-GAR	543	634	0.7	3.8	**-14.3**	Missing anions
SW8-GAR	1485	1660	1.2	2.6	**-10.5**	Missing anions
SW9-GAR	1090	1290	0.1	0.1	**-15.5**	Missing anions
SW10-GAR	651	712	-0.2	-1.0	-8.5	Missing cations
SW12-GAR	655	722	-0.2	-1.0	-9.3	Missing cations
SW17-GORT	196	217	0.0	0.3	-9.7	Missing anions
SW6-Mag	312	359	0.2	1.9	-13.2	Missing anions
SW1-SM	61	30	0.0	-0.1	**104.7**	Too many anions
SW3-SM	90	84.7	0.0	0.3	5.9	Too many cations
SW4-SM-GA	136	130	0.0	-0.8	4.7	Too many anions
SW2-SM-South	316	298	-0.2	-1.4	5.9	Too many anions
SW18-GORT	393	471	-0.4	-3.4	**-16.6**	Missing cations
SW19-GORT	521	606	-0.2	-0.9	**-14.0**	Missing cations
TMF1	249	259	-0.4	-3.8	-3.9	Missing cations
TMF2	268	273	-0.3	-2.9	-1.8	Missing cations
TMF SEEP1	3719	4020	1.6	1.3	-7.5	Missing anions
SW14-GORT	263	294	-0.2	-1.7	**-10.4**	Missing cations
SW10-GORT-Disc	671	787	-0.6	-2.8	**-14.7**	Missing cations
SW12-GORT-Disc	758	837	-0.6	-2.4	-9.5	Missing cations
SW10-GORT-DS	291	316	-0.3	-2.4	-8.1	Missing cations
SW12-GORT-DS	294	321	-0.1	-0.9	-8.4	Missing cations
SW10-GORT-US	280	317	-0.3	-2.9	**-11.7**	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 12 are within the range for natural waters and therefore the analyses are considered reliable. The one exception on the high range SW12-SHAL (with ratio of 2.6 for SC/TDS-Calc and 2.5 for SC/TDS-Meas) had the lowest measured conductivity and TDS. At these low levels, the relationships are less accurate. Another exception was SW1-SM (with ratio of 2.3 for SC/TDS-Calc and 4.6 for SC/TDS-Meas) also had low conductivity. The low TDS measurement for SW1-SM of 30 mg/l was checked and confirmed by ALcontrol.

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 12 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)
SW1-GAR	SW	1492	1146	1330	1.3	1.1
SW2-GAR	sW	1009	702	807	1.4	1.3
SW4-GAR	SW	135	70	60	1.9	2.3
SW1-SHAL	SW	225	126	148	1.8	1.5
SW4-SHAL	SW	170	73	81.1	2.3	2.1
SW5-SHAL	SW	283	165	174	1.7	1.6
SW6-SHAL	SW	147	76	100	1.9	1.5
SW7-SHAL	SW	282	165	157	1.7	1.8
SW9-SHAL	SW	191	105	116	1.8	1.6
SW10-SHAL	SW	297	159	216	1.9	1.4
SW12-SHAL	SW	65	25	26.3	2.6	2.5
SW3-GAR	SW	944	656	702	1.4	1.3
SW5-GAR	SW	893	602	694	1.5	1.3
SW7-GAR	SW	741	543	634	1.4	1.2
SW8-GAR	SW	1804	1485	1660	1.2	1.1
SW9-GAR	SW	1470	1090	1290	1.3	1.1
SW10-GAR	SW	950	651	712	1.5	1.3
SW12-GAR	SW	956	655	722	1.5	1.3
SW17-GORT	SW	357	196	217	1.8	1.6
SW6-Mag	SW	507	312	359	1.6	1.4
SW1-SM	SW	139	61	30	2.3	4.6
SW3-SM	SW	167	90	84.7	1.9	2.0
SW4-SM-GA	SW	258	136	130	1.9	2.0
SW2-SM-South	SW	544	316	298	1.7	1.8
SW18-GORT	SW	594	393	471	1.5	1.3
SW19-GORT	SW	742	521	606	1.4	1.2
TMF1	GW	437	249	259	1.8	1.7
TMF2	GW	486	268	273	1.8	1.8
TMF SEEP1	SW	3935	3719	4020	1.1	1.0
SW14-GORT	SW	461	263	294	1.8	1.6
SW10-GORT-Disc	SW	939	671	787	1.4	1.2
SW12-GORT-Disc	SW	1020	758	837	1.3	1.2
SW10-GORT-DS	SW	496	291	316	1.7	1.6
SW12-GORT-DS	SW	516	294	321	1.8	1.6
SW10-GORT-US	SW	483	280	317	1.7	1.5

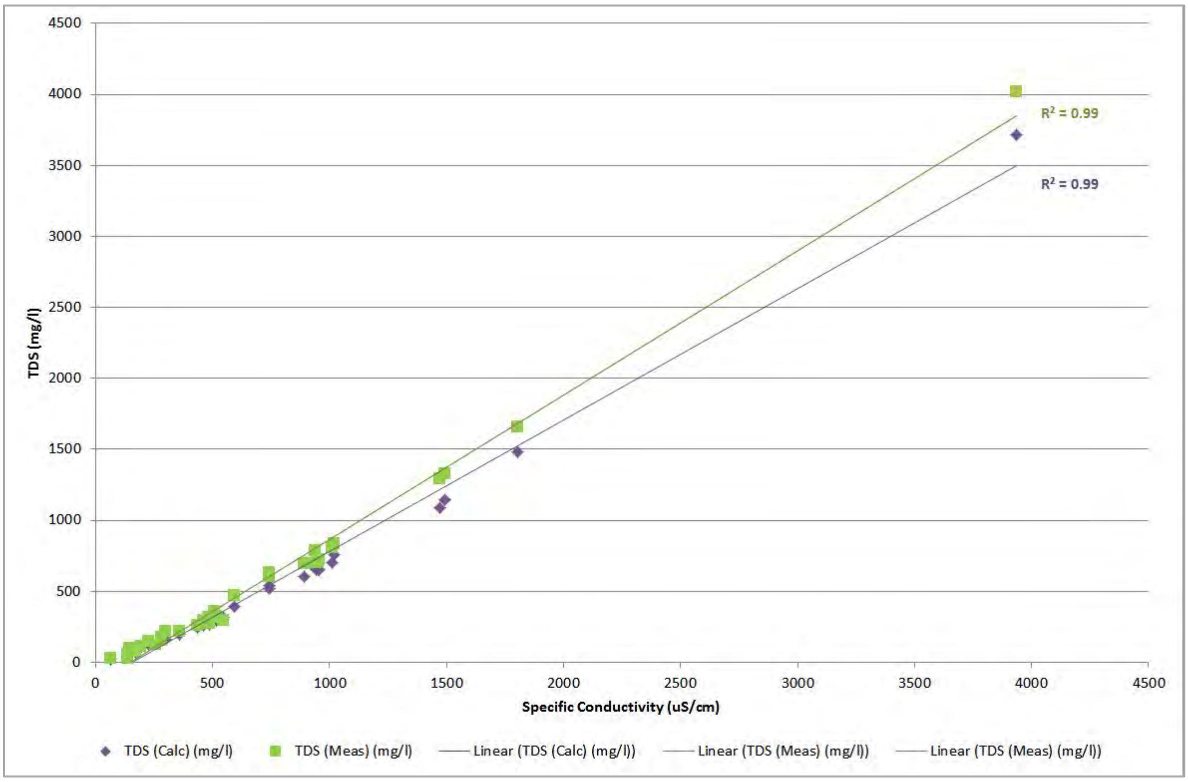


Figure 1 Relationship of Specific Conductivity and Total Dissolved Solids (TDS)

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 dissolved concentrations were higher than the total in about 25% of the nickel and zinc results. This was checked with ALcontrol alongside the AQC and blank data and no issues have been found. They confirmed that all of the nickel results where the total is lower than the dissolved are within their margin for difference between repeats. In the case of zinc the same was true with the exception of three results where the concentration was low. This difference may have been induced by the filtration procedure. Zinc contamination is known to be induced by membrane filter materials and can result in overestimated zinc detections (Hedberg *et al.*, 2011). This effect is already minimised in the field by allowing the first 10 ml of the filtered water to be wasted before the filtered sample is collected. Overall, the results are considered acceptable.

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 13 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 13 Summary of Dissolved Metal Concentrations in Groundwater

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Aluminium	<2.9	2	0	1.45	1.45	-
Antimony	<0.16	2	1	0.08	0.622	0.35
Arsenic	<0.12	2	2	2.98	4.99	3.99
Barium	<0.03	2	2	157	592	375
Cadmium	<0.1	2	0	0.05	0.05	-
Chromium	<0.22	2	2	3.22	4.48	3.85
Cobalt	<0.06	2	2	0.587	1.03	0.81
Copper	<0.85	2	0	0.425	0.425	-
Iron	<19	2	2	25.5	195	110
Lead	<0.02	2	2	0.115	2.16	1.14
Manganese	<0.04	2	2	81.7	988	535
Mercury	<0.01	2	0	0.005	0.005	-
Molybdenum	<0.24	2	2	0.271	0.598	0.43
Nickel	<0.15	2	2	2.07	2.31	2.19
Selenium	<0.39	2	1	0.195	0.775	-
Silver	<1.5	2	0	0.75	0.75	-
Thallium	<0.96	2	0	0.48	0.48	-
Tin	<0.36	2	0	0.18	0.18	-
Uranium	<1.5	2	0	0.75	0.75	-
Vanadium	<0.24	2	2	0.727	1.18	0.95
Zinc	<0.41	2	2	15.6	18.8	17.2

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

Dissolved barium (592 µg/l), iron (195 µg/l).and manganese (988 µg/l) were found in the highest concentrations in TMF2, which were significantly higher than the concentrations in TMF1. Dissolved arsenic was detected in both wells with the highest concentration at TMF2 of 4.99 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 14 provides a summary of the reported results of the 16 discharge/ drainage samples and Table 15 provides a summary of the reported results of the 17 river and stream samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV) for dissolved metals concentrations. Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

Discharges and Drainage

Table 14 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	16	6	1.45	59.8	9.8	17.4
Antimony	<0.16	16	11	0.08	3	0.86	0.86
Arsenic	<0.12	16	12	0.06	1.57	0.42	0.37
Barium	<0.03	16	16	11.6	394	102	133
Cadmium	<0.1	16	16	0.167	66.3	14.9	18.3
Chromium	<0.22	16	16	0.283	5.77	2.07	1.34
Cobalt	<0.06	16	16	0.165	14	2.48	3.57
Copper	<0.85	16	15	0.425	20.1	5.71	4.91
Iron	<19	16	6	9.5	27500	1740	6870
Lead	<0.02	16	16	0.061	477	50.5	121
Manganese	<0.04	16	16	1.86	2400	329	573
Mercury	<0.01	16	1	0.005	0.0213	-	-
Molybdenum	<0.24	16	6	0.12	1.67	0.33	0.43
Nickel	<0.15	16	16	1.68	145	35.1	38.3
Selenium	<0.39	16	9	0.195	0.859	0.4	0.21
Silver	<1.5	16	0	0.75	0.75	-	-
Thallium	<0.96	16	10	0.48	142	11.9	35
Tin	<0.36	16	2	0.18	0.699	0.24	0.17
Uranium	<1.5	16	0	0.75	0.75	-	-
Vanadium	<0.24	16	11	0.12	1.59	0.47	0.38
Zinc	<0.41	16	15	37.7	25200	7690	8450

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

SW8-GAR (drainage from the western part of the Mogul Yard) had the highest concentrations of zinc (25,200 µg/l). TMF Seep 1 also had high dissolved zinc concentrations at 20,900 µg/l and the highest dissolved nickel (145 µg/l), iron (27,500 µg/l) and manganese (2,400 µg/l). The highest dissolved aluminium was at SW12-Shal (stoned lined drainage channel at Shallee) with a value of 59.8 µg/l and the highest dissolved lead was at SW6-Shal (Field Shaft) with a value of 477 µg/l. There was only one detection of dissolved mercury at 0.0213 µg/l in SW10-Shal.

Rivers and Streams

Table 15 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	17	16	1.45	37.9	12.5	11.5
Antimony	<0.16	17	7	0.08	1.45	0.35	0.46
Arsenic	<0.12	17	12	0.06	0.506	0.26	0.17
Barium	<0.03	17	17	26.4	357	163	108
Cadmium	<0.1	17	15	0.05	23.5	4.97	8.42
Chromium	<0.22	17	17	0.691	3.66	1.68	0.99
Cobalt	<0.06	17	17	0.082	5.5	1.27	1.79
Copper	<0.85	17	14	0.425	23.7	6.38	7.2
Iron	<19	17	10	9.5	106	35.9	31.6
Lead	<0.02	17	17	0.194	310	37.1	87.5
Manganese	<0.04	17	17	2.71	752	146	232
Mercury	<0.01	17	0	0.005	0.005	-	-
Molybdenum	<0.24	17	9	0.12	10.1	1.44	2.64
Nickel	<0.15	17	17	0.923	53.8	15.1	18.7
Selenium	<0.39	17	6	0.195	0.759	0.33	0.2
Silver	<1.5	17	0	0.75	0.75	-	-
Thallium	<0.96	17	16	0.48	1.36	0.53	0.21
Tin	<0.36	17	16	0.18	0.363	0.19	0.04
Uranium	<1.5	17	0	0.75	0.75	-	-
Vanadium	<0.24	17	7	0.12	1.01	0.36	0.33
Zinc	<0.41	17	17	24.2	9030	2000	3370

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 (24.2 and 24.4 µg/l, respectively). SW17-Gort has background concentrations of manganese (71.1 µg/l) and aluminium (10.1 µg/l).

SW3-Gar (stream containing both tailings lagoon discharges and downstream of the Mogul Yard) has the highest concentrations of cadmium (23.5 µg/l) and zinc (9030 µg/l).

4.1.3 Vegetation Sample Results

Table 16 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). Only the original result of the field duplicate samples were used.

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

	Arsenic	Cadmium	Lead	Zinc
Number	20	20	20	20
Minimum	0.117	0.058	1.07	27.7
Maximum	1.07	0.263	9.02	64.7
Mean	0.414	0.103	3.15	39.6
SDEV	0.286	0.047	1.73	7.92

The highest arsenic concentration (1.07 mg/kg) and lead (9.02 mg/kg) were found in a sample SM40-V. The highest cadmium (0.263 mg/kg) and zinc (64.7 mg/kg) concentrations were in vegetation sample SM01-V. SM01-V and SM40-V are located at the edge of the site, the north-eastern edge and southern edge, respectively.

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 17. These include standards for physico-chemical conditions supporting the biological elements general conditions and standards for specific pollutants. In the case of metals the EQS refers to the dissolved concentration. Compliance with the standards in the surface water regulations is either based on an annual average (AA), a maximum allowable concentration (MAC) or a 95 percentile standard. The MAC or 95 percentile (95%ile) was selected 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 17).

For hardness-dependent metals copper, zinc and cadmium, the hardness is taken into account when selecting the appropriate EQS value. The average hardness in the rivers and streams in the Silvermines mining 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 17.

To assess the potential human health risks, the Drinking Water Regulations, 2007 (S.I. No. 106 of 2007) and amendments were utilised and are listed in Table 18. These values are the maximum permissible values for a drinking water source. In the case of metals the standards are for total metals, however they apply post treatment (including filtration) and therefore the dissolved portion is used in the assessment in Section 4.

The 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 17 and Table 18).

Table 17 Surface Water and Groundwater Assessment Criteria for Biological Elements

Parameter	Unit	AA	MAC (or 95%ile)	Source	Description
Ammonia as N	mg/l	0.065	**0.14**	S.I. No. 272 of 2009	Good status
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 18 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 19 Assessment Criteria for Livestock Drinking Water Quality

Parameter	Unit	Parametric Value	Source	Comment
Aluminium	µg/l	5,000	NAS 1972	
Arsenic	µg/l	200	NAS 1972	
Cadmium	µg/l	50	NAS 1972	
Chromium	µg/l	1,000	NAS 1972	
Cobalt	µg/l	1,000	NAS 1972	
Copper	µg/l	500	NAS 1972	
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	

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

Table 20 Assessment Criteria for Vegetation (mg/kg)

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

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

The maximum content is actually the "Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12 %". For cadmium and lead, the Directive states that the extraction be "performed with nitric acid (5 % w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency." The 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 20 will be conservative and provide adequate protection.

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

4.3 Comparison to Assessment Criteria

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

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

A comparison of the vegetation results was made against the relevant assessment criteria as described in Section 4.2. Table B-4 in **Appendix B** highlights the exceedances of the assessment criteria for vegetation; where there is an exceedance in the maximum concentration in Feeding Stuff, the result is highlighted in pink and exceedances of the no effect and low effect levels for digestion in wildlife is highlighted in blue and purple, respectively.

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

4.3.1 Groundwater Assessment

In groundwater, the pH was found to be within the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria with an average of pH 7.42. The specific conductance ranged from 0.437 to 0.486 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 <12 to 12.3 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 157 µg/l and TMF2 had a result of 592 µg/l. Manganese exceeded the human health criteria of 50 µg/l in both wells that were sampled; TMF1 had a result of 81.7 µg/l and TMF2 had a result of 988 µg/l. Dissolved chromium also exceeded the ecological assessment criteria of 3.4 µg/l with a value of 4.48 µg/l in TMF2.

4.3.2 Surface Water Assessment

The pH in surface waters in the Silvermines mining area were found to range from 3.19 to 8.11, with an average of 7.10. There were three exceedances in the assessment criteria for pH at TMF Seep 1 (3.19 pH), SW12-Shal (4.37 pH), SW6-Shal (Field Shaft) (6.44 pH) and SW9-Shal (downstream of Field Shaft) (5.65 pH) which were below the acceptable range for human health of

6.5 to 9.5 pH and TMF Seep 1 and SW12-Shal were also outside the acceptable range for ecology (4.5 to 9 pH units). Low acidity results were detected at twelve locations which ranged from 5.48 to 29.2 mg/l (as HCl) with the highest acidity at TMF Seep 1. The conductivity ranged from 0.065 to 3.935 mS/cm with an average of 0.703 mS/cm. There was only one exceedance of the human health criteria (2.5 mS/cm) at TMF Seep 1 (3.935 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 SW1-Gar with a value of 0.252 mg/l. Both the ecological assessment criteria and human health (0.3 mg/l) criteria were exceeded at SW6-Shal 0.573 mg/l and TMF Seep 1 0.573 mg/l. The ecological assessment criteria for ortho-phosphate (0.075 mg/l) was not exceeded in any of the samples.

Fluoride results were elevated above the ecological assessment criteria (0.5 mg/l) ranging from 0.714 to 2.96 mg/l at 11 locations. Both the ecological and human health (1.5 mg/l) criteria were exceeded at 7 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 SW18-Gm (198 mg/l). The sulphate results that exceeded the criteria ranged from 289 to 2520 mg/l, with an average of 617 mg/l. SW3-Gar, the stream containing both tailings lagoon discharges and downstream of the Mogul Yard, also had high sulphate of 336 mg/l and so did SW1-Gar with 788 mg/l sulphate which exceeded the human health criteria. The highest sulphate result was from TMF Seep 1 with 2520 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 21 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 (36.7 µg/l) and SW17-Gort (191 µg/l), and is not discussed further. Dissolved arsenic was detected at all locations but was significantly below both the ecological (25 µg/l) and human health (10 µg/l) assessment criteria, with the highest concentration of 1.57 µg/l at TMF Seep 1.

Table 21 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

Sample Description		Sample Location	Date Sampled / Units	Cadmium	Lead	Manganese	Nickel	Zinc
			Units	µg/l	µg/l	µg/l	µg/l	µg/l
			Ecological Criteria	0.9	7.2	1100	20	100
			Human Health Criteria	5	10	50	20	-
Ballygown	SW1-SM	Upstream	11/03/2014	<0.1	13.6	2.71	0.923	24.2
	SW3-SM	DS (underground workings)	11/03/2014	0.188	1.25	3.22	1.5	123
	SW4-SM-Ga	Downstream (all)	11/03/2014	0.457	1.16	4.06	2	181
Magcobar	SW6-Mag	Downstream	11/03/2014	1.67	0.488	59.1	9.13	792
Garryard	SW1-GAR	Upstream	05/03/2014	7.38	5.14	25.5	37.6	4320
	SW3-GAR	Downstream (all)	06/03/2014	23.5	2	269	40.2	9030
Shallee	SW4-SHAL	Upstream	05/03/2014	0.867	3.66	83.7	13.8	127
	SW5-SHAL	DS (drum dump)	05/03/2014	21.4	26.3	752	53.3	8580
	SW9-SHAL	Downstream	05/03/2014	2.58	310	93.4	11.7	727
	SW1-SHAL	Downstream (all)	05/03/2014	2.37	219	130	14.1	680
Gortmore	SW17-GORT	Upstream	11/03/2014	<0.1	0.194	71.1	1.57	24.4
	SW12-GORT-DS	Downstream (TMF)	13/03/2014	0.58	2.31	63.7	3.2	263
	SW14-GORT	Downstream (TMF and Yellow River)	13/03/2014	0.542	2.21	50.7	3.16	245

Notes
xx Exceeds Ecological Assessment Criteria
xx Exceeds Human Health Assessment Criteria
xx Exceeds both Ecological and Human Health Criteria
Metals are dissolved

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 the only exceedance was of dissolved lead at 13.6 µg/l, which exceeded both the ecological health criteria of 7.2 µg/l and the human health criteria of 10 µg/l. There were no further exceedances of lead downstream on the Silvermines stream. Downstream at SW3-Sm, zinc (123 µg/l) was above the ecological assessment criteria of 100 µg/l. The southern adit SW2-SM discharges to the Silvermines stream and had cadmium (5.18 µg/l), chromium (3.6 µg/l), and zinc (1940 µg/l) above the ecological assessment criteria of 0.9 µg/l for cadmium, 3.4 µg/l for chromium and 100 µg/l for zinc. The human health criteria of 0.5 µg/l for chromium was also exceeded at this location for chromium. Downstream on the Silvermines stream at SW4-SM-GA, dissolved zinc was also above the ecological assessment criteria at a concentration of 181 µg/l. SW6-Mag downstream of the Magcobar area also had dissolved cadmium (1.67 µg/l) and zinc (792 µg/l) above the ecological assessment criteria, as well as dissolved manganese at 59.1 µg/l above the human health assessment criteria of 50 µg/l.

At Gortmore TMF (Map 2 of Appendix A), dissolved cadmium and zinc, exceeded the ecological assessment criteria and dissolved manganese exceeded the human health assessment criteria. Levels of dissolved lead and nickel were relatively low. The concentration of dissolved cadmium exceeded the ecological assessment criterion of 0.9 µg/l with values ranging from 1.02 to 9.59 µg/l at SW18-Gort, SW19-Gort and TMF Seep 1. The value of 9.59 µg/l for cadmium at TMF Seep 1 also exceeded the human health criteria of 5 µg/l. Dissolved chromium exceeded the ecological health criteria of 3.4 µg/l, with values ranging from 3.59 to 5.77 µg/l at SW10-GORT-US, SW12-GORT-

Discharge and TMF Seep 1. 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 50.7 to 269 µg/l. TMF Seep 1 also had elevated dissolved manganese above the ecological health criteria of 1,100 µg/l with a concentration of 2,400 µg/l.

Dissolved zinc also exceeded the ecological assessment criteria of 100 µg/l at all of the drainages and discharges ranging from 437 to 20,900 µg/l. The concentration of zinc increased on the Kilmastulla River from 24.4 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 263 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garrymore and Shallee. The loading from these areas are discussed in Section 5.

In addition TMF Seep 1 also exceeded the ecological assessment criteria for dissolved cobalt 5.1 µg/l (14 µg/l) and the human health criteria for dissolved iron 200 µg/l (27500 µg/l). Both the ecological and human health criteria for dissolved lead and dissolved nickel were exceeded at TMF Seep 1 with concentrations of 14.4 µg/l and 145 µg/l, respectively.

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 concentrations ranging from 19.3 to 477µg/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 3.66 µg/l (below both the assessment criteria). With the exception of SW12-Shal (stone lined drainage channel), dissolved zinc exceeded the ecological assessment criteria of 100 µg/l with values ranging from 127 to 8,600 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 83.7 to 752 µg/l. SW5-Shal and SW7-Shal exceeded the ecological health criteria for dissolved cobalt of 5.1 µg/l (5.39 to 5.5 µg/l) and both the ecological and human health criteria for dissolved nickel of 20 µg/l (53.3 to 53.8 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 176 to 25,200 µg/l. All locations exceeded both the ecological (0.9 µg/l) and human health (5 µg/l) assessment criteria for cadmium (ranging from 7.38 to 66.3 µg/l) with the exception of two locations (SW4-GAR – 1.62 µg/l) that only exceeded the ecological criteria. Dissolved lead exceeded the ecological (7.2 µg/l) and human health (10 µg/l) assessment criteria at two locations; SW4-Gar with a concentration of 20.1 µg/l and SW2-Gar with 137 µg/l. Nickel was above both the ecological and human health assessment criteria of 20 µg/l at all locations ranging from 21.5 to 81.8 µg/l, with the exception of SW4-Gar (4.98 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 68 to 480 µg/l. Exceptions were for SW1-Gar (25.5 µg/l) and SW4-Gar (24.2 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 477 µg/l and the sampling location on the stream SW9-Shal which is just downstream of the Field Shaft had concentration of 310 µg/l. Therefore it is recommended that livestock are 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 only location at Gortmore that this was exceeded was TMF Seep 1 with a value of 4,020 mg/l. It was noted that in August 2013 the TDS values at the pond discharges exceeded the recommend value with 2,900 mg/l at SW18-Gort and 2,860 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.
- The maximum recommended sulphate levels for calves is 500 mg/l and for adults its 1,000 mg/l. The only location at Gortmore that this was exceeded was TMF Seep 1 with a value of 2,520 mg/l. It was noted that in August 2013 the sulphate values at the pond discharges exceeded the recommend value with 1,700 mg/l at SW18-Gort and 1,630 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

Based on the summary in Table 16 (maximum values) and the CAL laboratory report in Appendix F of the Data Report, no measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium or lead exceeded the Maximum Content standards in Table 20.

The measured concentrations in the vegetation were all below both the no effect and low effect levels provided in Table 16, except for arsenic at four locations: SM01-V (0.818 mg/kg), SM06-V (1.026 mg/kg), SM21-V (0.708 mg/kg) and SM40-V (1.074 mg/kg) which were slightly above the no effect level of 0.62 mg/kg but below the low effect level of 6.21 mg/kg for digestion in wildlife (whitetail deer).

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 September 2013 to 18 March 2014 from Station 25044 is reproduced in Figure 2. The figure shows the measured flows ranging from >14 m^3/s following rainfall events to less than 1 m^3/s during low-flow, with a median flow of approximately 3.1 m^3/s. The recorded flow at the Coole gauging station shows that from September to early October 2014 the flows were very low with a baseline of 0.37 m^3/s which is close to the 95%-ile flow (low flow) of 0.31 m^3/s. The calculated 5%-ile flow (high flow) is 6.4 m^3/s and the flows were generally at or above this flow after rainfall events, from late December to early February. The flow during this period shows a flashy response for rainfall. The highest recorded flow in the monitoring period was on 5 February 2014 with a mean daily flow of 16.6 m^3/s. Overall, the flows were low in September and relatively high during the monitoring period with particular high flows in December, January and February.

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 for September. The EPA tool for ungauged catchments was used to calculate the 5%-ile flow which was 4.36 m^3/s as the flows were likely greater than this from late December to early February.

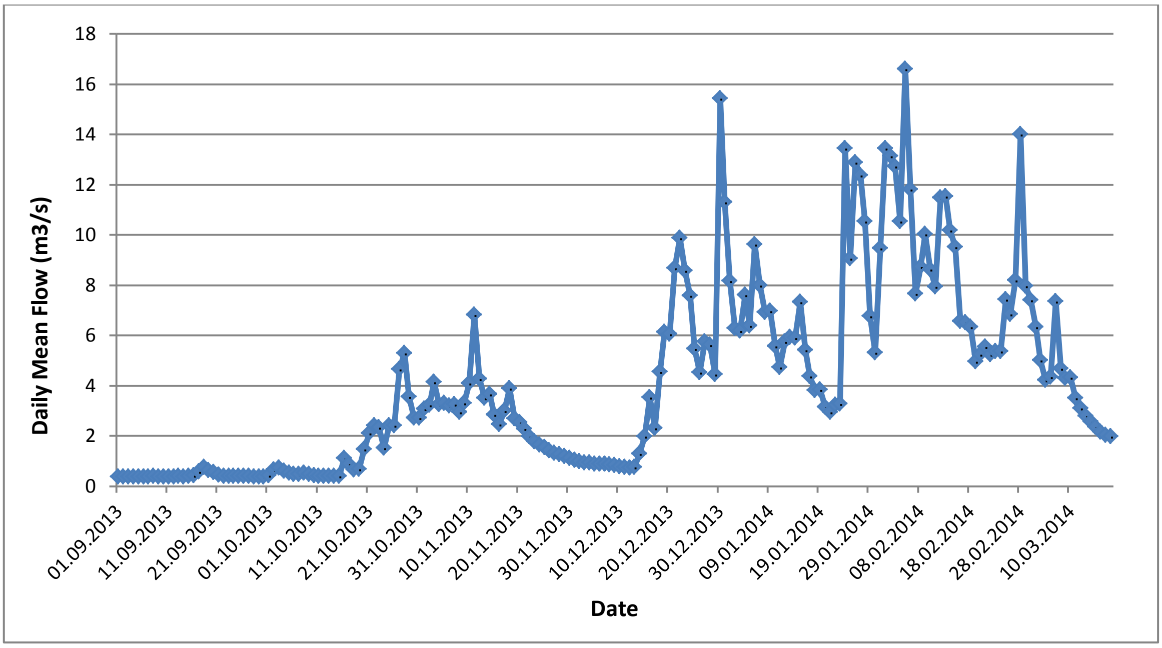


Figure 2 Mean Daily Flow (m^3/s) at Coole, Kilmastulla (Station 25044) from 1 Sept to 18 Mar 2013

Flow was measured directly in the field using different methodologies depending upon the quantity of flow to be measured and any safety concerns, as described in Section 2.1.2. Table 22 presents a summary of the results from the flow measured in March 2014 at the time of sampling. Appendix B of the Data Report contains details of methodologies used per site and associated calculations.

Table 22 Surface Water Flow Value Measured in March 2014

Site Name	Flow l/s	Date
SW10-GORT Discharge	6.0	13/3/2014
SW12-GORT Discharge	7.83	13/3/2014
SW19-GORT	2.34	12/3/2014
SW1-SM	44.7	11/3/2014
SW2-SM South Discharge	3.0	11/3/2014
SW2-SM North Discharge	No Discharge	11/3/2014
SW3-SM	77.4	11/3/2014
SW4-SM-GA	135	11/3/2014
SW3-GAR	56.0	6/3/2014
SW4-GAR	4.76	5/3/2014
SW5-GAR	Flow immeasurable (grating)	6/3/2014
SW7-GAR	1.29	6/3/2014
SW8-GAR	Low flow immeasurable	6/3/2014
SW9-GAR	2.60	6/3/2014
SW10-GAR	50.7	6/3/2014
SW12-GAR	39.07	6/3/2014
SW1-SHAL	3.28	5/3/2014
SW4-SHAL	0.069	5/3/2014
SW5-SHAL	0.850	5/3/2014
SW6-SHAL	2.21	5/3/2014
SW7-SHAL	0.279	5/3/2014
SW9-SHAL	11.9	5/3/2014
SW10-SHAL	0.036	5/3/2014
SW12-SHAL	1.56	5/3/2014

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:

$$\text{Load (g/day)} = [C\ (\mu g/L) * F\ (L/day)]\ /\ 1{,}000{,}000\ \mu g/g$$

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

Table 23 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	11/03/2014	44.7	7.07	1000	3860	0.05	0.19	13.6	52.5	2.71	10.5	0.923	3.56	24.2	93.5
SW3-SM	11/03/2014	77.4	6.91	2900	19400	0.188	1.26	1.25	8.36	3.22	21.5	1.5	10	123	823
SW2-SM-South	11/03/2014	3	7.02	36900	9560	5.18	1.34	1.1	0.29	1.86	0.48	8.32	2.16	1940	503
SW4-SM-Ga	11/03/2014	135.5	7.78	8400	98300	0.457	5.35	1.16	13.6	4.06	47.5	2	23.4	181	2120
SW19-GORT	12/03/2014	2.335	7.78	295000	59500	1.07	0.22	3.25	0.66	7.49	1.51	7.1	1.43	588	119
SW10-GORT-DISC	13/03/2014	6	7.32	402000	208000	0.328	0.17	0.276	0.14	91.5	47.4	9.19	4.76	1040	539
SW12-GORT-DISC	13/03/2014	7.826	7.08	374000	253000	0.462	0.31	0.061	0.04	269	182	8.44	5.71	585	396
SW4-GAR	05/03/2014	4.757	7.11	16600	6820	0.907	0.37	20.1	8.26	24.2	9.95	4.98	2.05	176	72.3
SW7-GAR	06/03/2014	1.286	7.36	312000	34700	8.92	0.99	0.946	0.11	68	7.55	21.5	2.39	5580	620
SW12-GAR	06/03/2014	39.08	7.52	333000	1120000	28.8	97.2	0.32	1.08	456	1540	57.7	195	13800	46600
SW9-GAR	06/03/2014	2.6	7.72	681000	153000	23.4	5.26	6.07	1.36	176	39.5	39	8.76	8740	1960
SW10-GAR	06/03/2014	50.71	7.64	337000	1480000	24.8	109	2.06	9.03	226	990	39.7	174	9320	40800
SW3-GAR	06/03/2014	56.01	7.65	336000	1630000	23.5	114	2	9.68	269	1300	40.2	195	9030	43700
SW4-SHAL	05/03/2014	0.069	6.66	2500	14.9	0.867	0.01	3.66	0.02	83.7	0.5	13.8	0.08	127	0.76
SW5-SHAL	05/03/2014	0.85	6.79	87500	6430	21.4	1.57	26.3	1.93	752	55.2	53.3	3.91	8580	630
SW7-SHAL	05/03/2014	0.279	6.7	87100	2100	21.7	0.52	19.3	0.46	726	17.5	53.8	1.29	8600	207
SW6-SHAL	05/03/2014	2.208	6.44	13800	2630	1.29	0.25	477	91	97.9	18.7	11	2.1	252	48.1
SW12-SHAL	05/03/2014	1.56	4.37	1000	135	0.167	0.02	76.1	10.3	146	19.7	1.68	0.23	37.7	5.08
SW10-SHAL	05/03/2014	0.036	7.13	55100	170	4.36	0.01	88	0.27	90.8	0.28	12.4	0.04	1450	4.47
SW9-SHAL	05/03/2014	11.92	7.04	29700	30600	2.58	2.66	310	319	93.4	96.2	11.7	12	727	749
SW1-SHAL	05/03/2014	19.41	7.27	34300	57500	2.37	3.97	219	367	130	218	14.1	23.6	680	1140

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 0.76 to 46,600 g/day with an average of 6,720 g/day overall. The largest mass load of zinc was SW12-GAR, the combined run-off from Knight Shaft and eastern part of Mogul Yard up-gradient of tailings lagoon, of 46,600 g/day. SW10-GAR (the discharge from the tailings lagoon) had a smaller loading of 40,800 g/day zinc. Further downstream at SW3-GAR which is located in a stream containing the SW10-GAR discharge and the western part of the Mogul yard, there was an apparent increase in zinc loading to 43,700 g/day. This stream discharges to the Yellow Bridge River which flows to the Kilmastulla River.

The dissolved zinc load upstream of Ballygown (SW1-SM) was calculated to be 93.5 g/day, which increases to 823 g/day downstream of the mine workings (SW3-SM). The southern adit (SW2-SM) also contributes 503 g/day of dissolved zinc to the stream. Further downstream the calculated mass load at SW4-SM-GA was 2,120 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 SW1-Shal downstream of the Shallee mining area with a calculated value of 367 g/day. The dissolved lead loading from Field Shaft (SW6-Shal) was 91 g/day, which discharges to a stream that had a dissolved lead loading of 319 g/day at SW9-Shal which is immediately east of the southernmost Shallee tailings impoundment. This indicates that the discharge from the Field Shaft could have been greater than what was measured using the bucket and stopwatch method i.e. it was not the only significant contributor of the dissolved lead load at the time or that the flow from the discharge was underestimated.

Of the two wetland discharges at Gortmore TMF, SW10-Gort-Discharge had the highest loading of dissolved zinc at 539 g/day whereas SW12-Gort-Discharge had 396 g/day of zinc. Discharges from the Garryard area (SW3-Gar – 43,700 g/day) and Shallee area (SW1-Shal – 1,140 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 24 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Table 24 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 25 and facilitate general observations about trends in the water quality of the main discharges and the downstream location on the Kilmastulla River.

Table 25 Mann-Kendall Trend Analysis of data from November 2006 to March 2014

Sample Location	Parameter	Reported values (n)	p value	s value	Trend
SW10-Gar	Diss. cadmium	7	0.0358	-13	Decreasing
	Diss. lead	6	0.169	-6	No Trend
	Diss. manganese	7	0.00813	-17	Decreasing
	Diss. nickel	7	0.144	-8	No Trend
	Diss. zinc	7	0.184	-7	No Trend
SW10-Gort-discharge	Diss. cadmium	4	0.0447	-6	Decreasing
	Diss. lead	2	n/a	n/a	Not Calculated
	Diss. manganese	4	0.367	2	No Trend
	Diss. nickel	4	0.0447	-6	Decreasing
	Diss. zinc	4	0.0447	-6	Decreasing
SW12-Gort-discharge	Diss. cadmium	2	n/a	n/a	Not Calculated
	Diss. lead	2	n/a	n/a	Not Calculated
	Diss. manganese	3	0.5	1	No Trend
	Diss. nickel	3	0.5	-1	No Trend
	Diss. zinc	3	0.148	-3	No Trend
SW6-Shal	Diss. cadmium	5	0.231	-4	No Trend
	Diss. lead	5	0.231	-4	No Trend
	Diss. manganese	5	0.11	-6	No Trend
	Diss. nickel	5	0.231	-4	No Trend
	Diss. zinc	5	0.11	-6	No Trend
SW14-Gort (Kilmastulla River)	Diss. cadmium	3	0.148	-3	No Trend
	Diss. lead	4	0.367	-2	No Trend
	Diss. manganese	4	0.0447	6	Increasing
	Diss. nickel	4	0.367	-2	No Trend
	Diss. zinc	4	0.154	-4	No Trend

The results of the Mann-Kendall analysis show that dissolved cadmium and manganese are concentrations are decreasing at SW10-Gar. Dissolved cadmium, nickel and zinc concentrations are decreasing in the SW10-Gort discharge. Dissolved manganese concentrations are however 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 26 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). As can be seen from Table 26 the concentrations of dissolved cadmium, manganese and zinc are generally at similar concentrations in both April and August.

However in some cases the concentrations were significantly lower in August 2013 during low flow. Examples included dissolved cadmium and zinc in the SW10-Gar, SW10-Gort-Disc and SW12-Gort-Disc discharges. Values of dissolved cadmium in these discharges ranged from 0.05-10.6 µg/l in low flow to 0.102-24.8 µg/l in high flow. Values of dissolved zinc in these discharges ranged from 99.9-2360 µg/l in low flow to 332-9320 µg/l in high flow. This difference in concentrations and loadings of dissolved zinc was reflected in the Kilmastulla River at SW14-Gort where the ecological assessment criterion of 100 µg/l was exceeded 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. Table 26 shows that the calculated loads of dissolved cadmium, lead, manganese and zinc were all significantly lower in August 2013 due to the low flow conditions.

Table 26 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
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
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
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
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
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	-

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

The groundwater elevations outside the TMF decreased from 48.72 m Ordnance Datum (OD) at the upgradient location TMF1 to 46.36 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 25/3/2013 and between 0.34 and 0.41 metres higher than the elevations measured in the summer season (26/8/2013).

Within the tailings area, measured water levels were in the range of 1.7 to 3.6m below the top of the tailings pond. The exceptions were in BH3A-GORT-06 and BH6A-GORT-06 where deeper water levels were recorded. The groundwater elevations within the TMF varied between 48.69 to 54.24 m OD. These groundwater elevations are similar to the elevations measured on 25/3/2013 which ranged from 48.5 to 53.9 m OD and between 0.3 to 1.1 metres higher than the elevations measured in the summer season (26/8/2013)

Table 27 Measures Groundwater Levels March 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	12/3/2014	10:05	0.28	0.87	48.72
TMF2		12/3/2014	11:45	1.64	2.1	46.36
BH1A-GORT-06	Located within the TMF, near the perimeter of the tailings surface	12/3/2014	14:50	2.94	3.59	52.82
BH2A-GORT-06		12/3/2014	15:05	2.75	3.28	53.01
BH3A-GORT-06		12/3/2014	16:05	7.91	8.24	48.69
BH4A-GORT-06		12/3/2014	15:55	3.66	4.18	52.5
BH5A-GORT-06		12/3/2014	13:35	3.23	3.66	52.98
BH6A-GORT-06		12/3/2014	15:20	4.41	5.1	51.67
BH6B-GORT-06		12/3/2014	15:20	1.71	2.43	54.24

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 March 2014 and water levels were measured in seven additional monitoring wells. Thirty-three surface water locations were sampled and analysed in March 2013 with flows measured at 21 of the locations. Twenty vegetation samples were collected and analysed in March 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 and vegetation were prepared and results were compared to assessment criteria. Analyses of metal loadings and groundwater levels were also provided.

The overall conclusions are as follows:

- Dissolved metal concentrations in the two groundwater monitoring wells that were sampled only had exceedances of the assessment criteria for dissolved barium and manganese, with higher concentrations in the downgradient monitoring well TMF2 (592 and 988 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 4.48 µg/l in TMF2. The groundwater flow in the bedrock was south-westerly towards the Kilmastulla River.

- 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 (24.2 and 24.4 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 all of the drainages and discharges ranging from 437 to 20,900 µg/l. The concentration of zinc increased on the Kilmastulla River from 24.4 µg/l at the upstream location, SW17-Gort, to exceed the assessment criteria with a concentration of 263 µg/l at SW12-Gort-DS. This location is downstream of the wetland discharges and the Yellow Bridge Tributary which drains Garrymore and Shallee. The loading from these areas are discussed in Section 5.

- In the Garryard area 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. 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. The highest concentration was from the Field Shaft discharge (SW6-Shal) at 477 µg/l.

- The concentration of zinc increases on the Kilmastulla River to 245 µg/l at SW14-Gort (most downstream location) which is two orders of magnitude above the ecological assessment criteria of 100 µg/l. The stream with the highest concentrations of dissolved zinc (9,030 µg/l) was the stream containing both tailings lagoon discharges and downstream of the Mogul Yard (SW3-Gar).

- The dissolved metal with the highest mass loading was zinc ranging from 0.76 to 46,600 g/day with an average of 6,720 g/day overall. The largest mass load of zinc was SW12-GAR, the combined run-off from Knight Shaft and eastern part of Mogul Yard up-gradient of tailings lagoon, of 46,600 g/day. SW10-GAR the discharge from the tailings lagoon had a decreased loading of 40,800 g/day zinc. The highest load of dissolved lead was from the SW1-Shal downstream of the Shallee mining area with a calculated value of 367 g/day.

- Livestock should be prevented from drinking water in the stream in the Shallee mining area due to the elevated lead levels. The monitoring results show that streams and ponds on top of the Gortmore TMF are safe for livestock. The previously high concentrations of TDS in August 2014 (>1,000 mg/l) and sulphate (>1,000 mg/l) may cause diarrhea in livestock, but it is likely livestock are accustomed these levels.

- No measured vegetation concentrations (in the newly remediated Area A and B) for arsenic, cadmium or lead exceeded the Maximum Content standards. The measured concentrations in the vegetation were all below both the no effect and low effect levels except for arsenic at four locations: SM01-V (0.818 mg/kg), SM06-V (1.026 mg/kg), SM21-V (0.708 mg/kg) and SM40-V (1.074 mg/kg) which were slightly above the no effect level of 0.62 mg/kg but below the low effect level of 6.21 mg/kg for digestion in wildlife (whitetail deer).

7.2 Recommendations for the Monitoring Programme

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

- The Yellow River is located downstream of all of the mine workings and tailings in these areas and ultimately discharges into the Kilmastulla River near the Gortmore TMF (see **Appendix A** Map 1). The impact of the discharges from the Shallee and Garryard areas on the Yellow River should be assessed. We recommend adding an extra surface water sampling location on the Yellow River itself. The accessibility of this location will be checked during the next sampling round.

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.

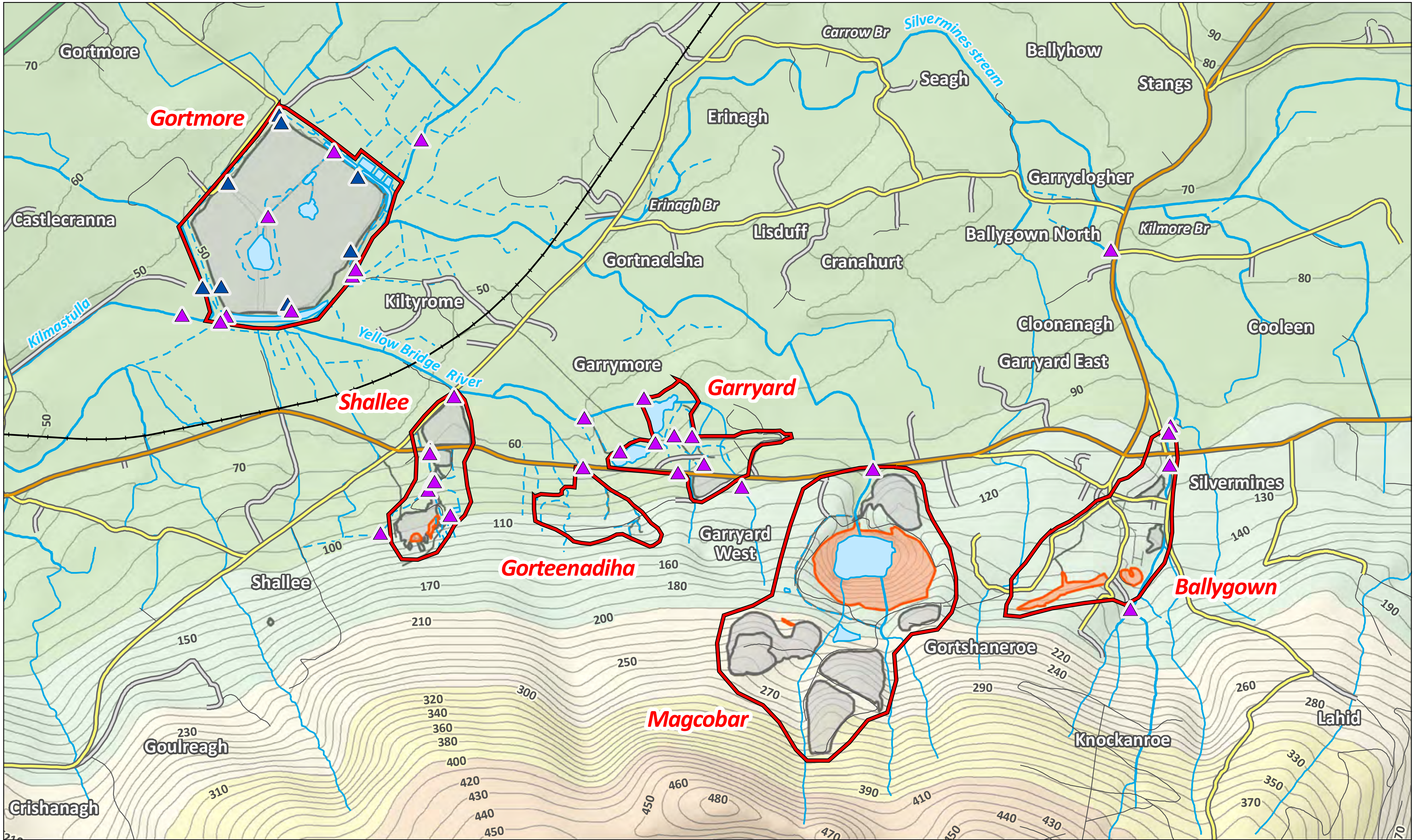
Soltanpour, P.N. and Raley, W.L. (2007). Livestock Drinking Water Quality. Livestock Series no. 4.908. Colorado State University.

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



Map 1 - Silvermines - Overview

Drawn by: OC *Date:* 03/04/2014

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\01_SilverMon1.mxd

CDM Smith

Legend

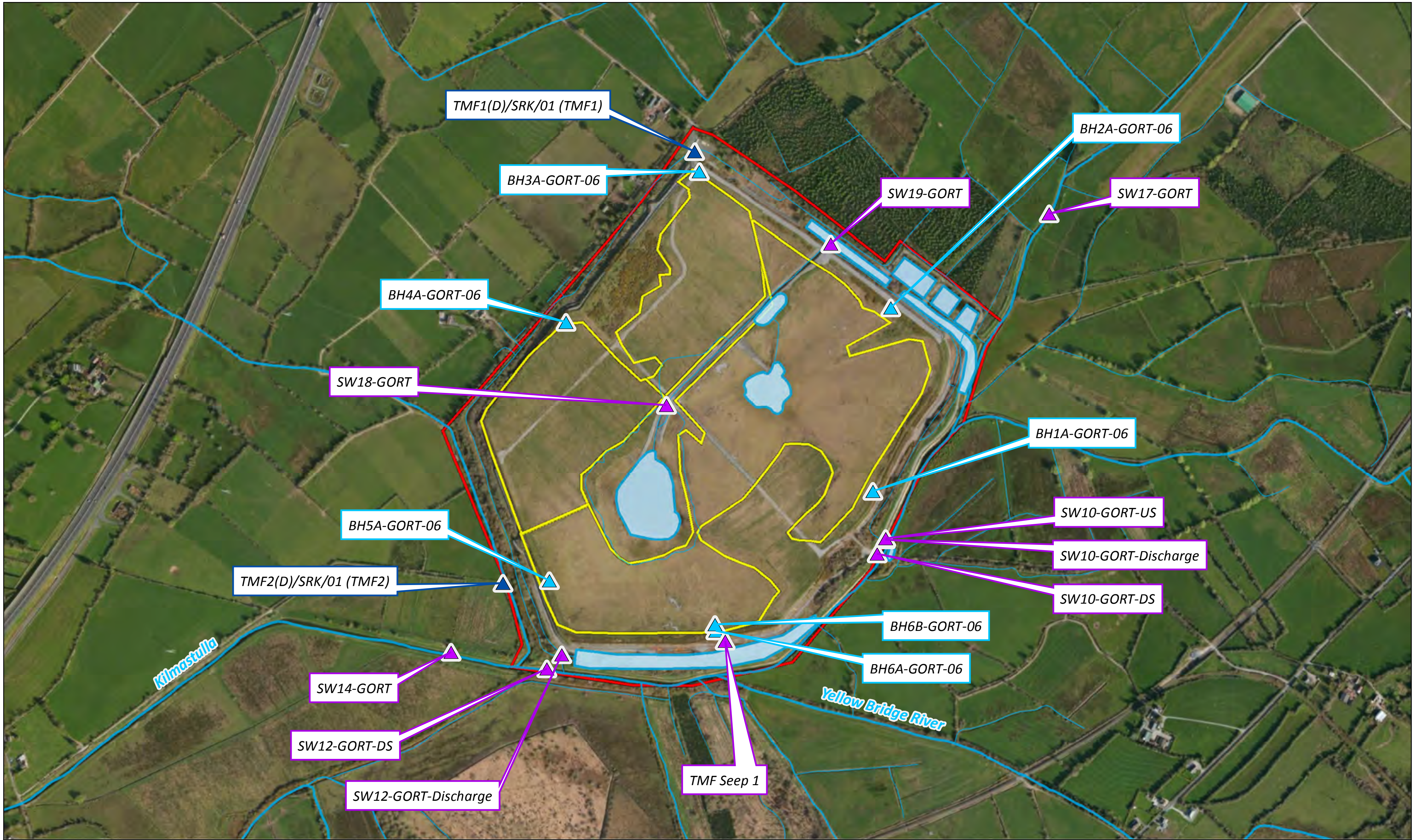
Sampling Locations
- Surface water
- Groundwater

- 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

Drawn by: OC   Date: 03/04/2014

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\02_SilverMonGM.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

- Surface water
- Groundwater
- Groundwater (Levels only)

- Rivers
- Streams
- Pond / Wetland

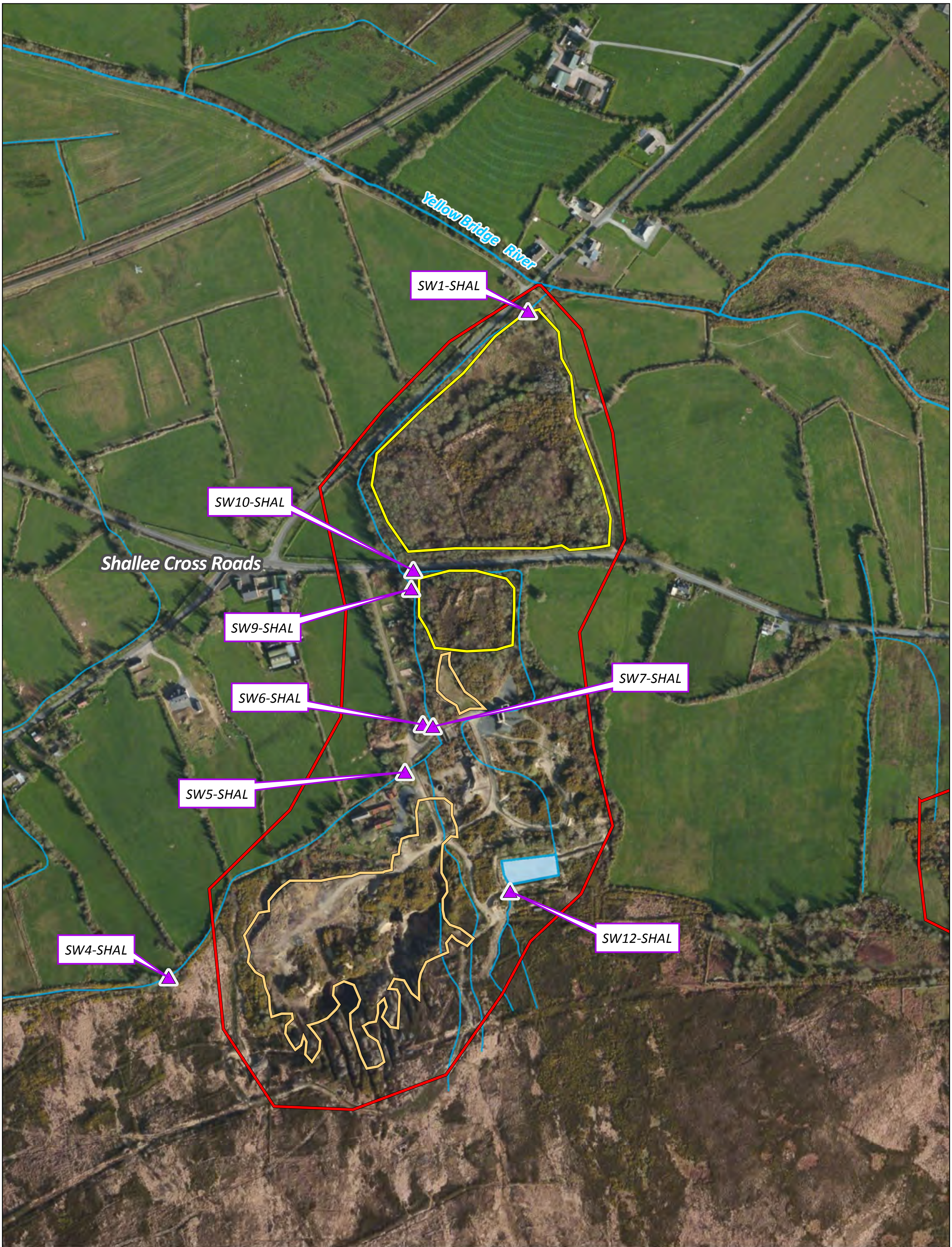
Mines

- Mining Area

Scale is 1:10,000

0 125 250 500 m

N E S W



Map 3 - Silvermines - Shallee South

Drawn by: OC/LG Date: 26/05/2014

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\03_SilverMonSh.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

Mining Area

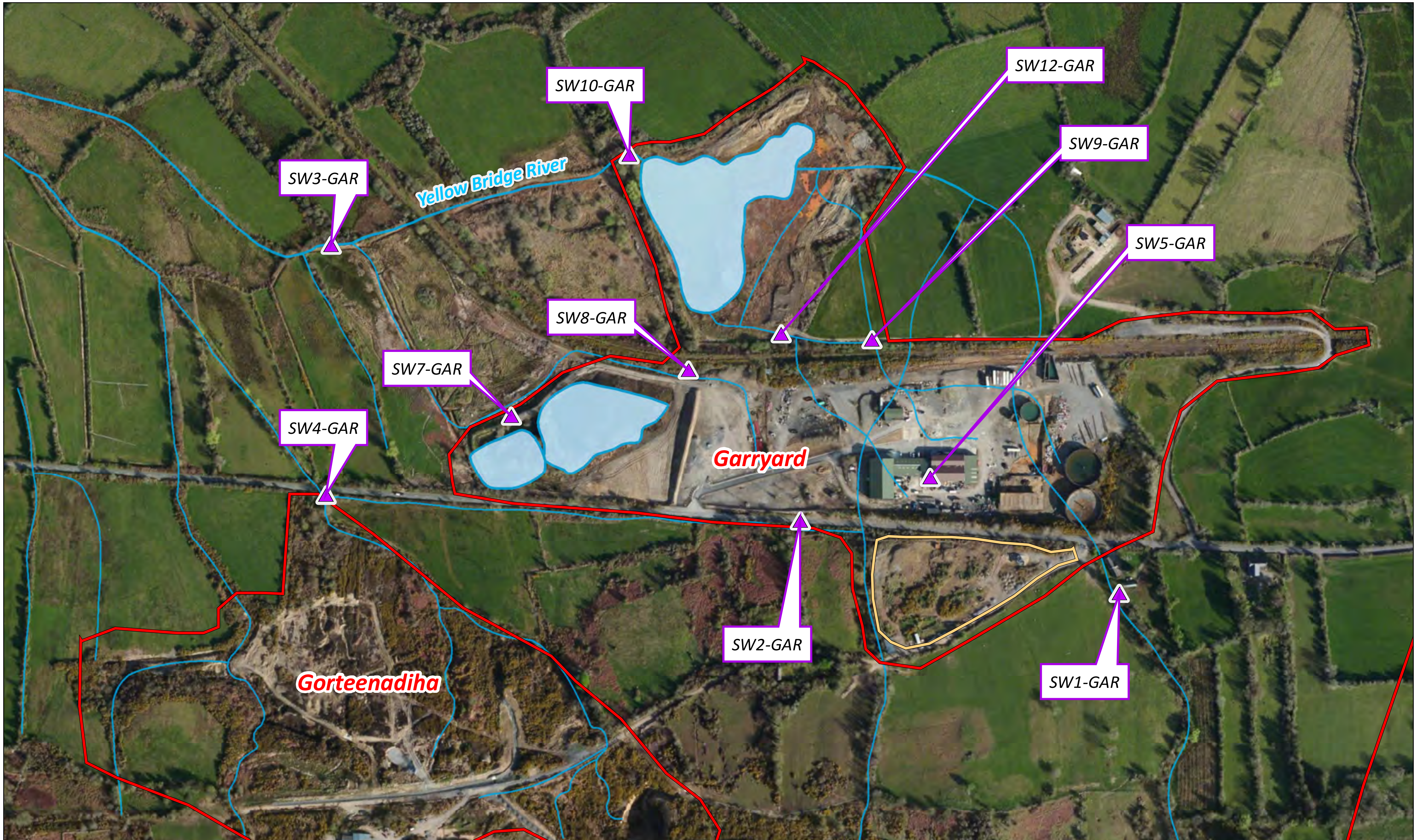
Tailings / Tailings Pond

Spoil Heap / Waste Drum Dump

N W E S

Scale is 1:5,000

0 50 100 m



Map 4 - Silvermines - Garryard

Drawn by: OC/LG Date: 26/05/2014

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\04_SilverMonGAR.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

Mines

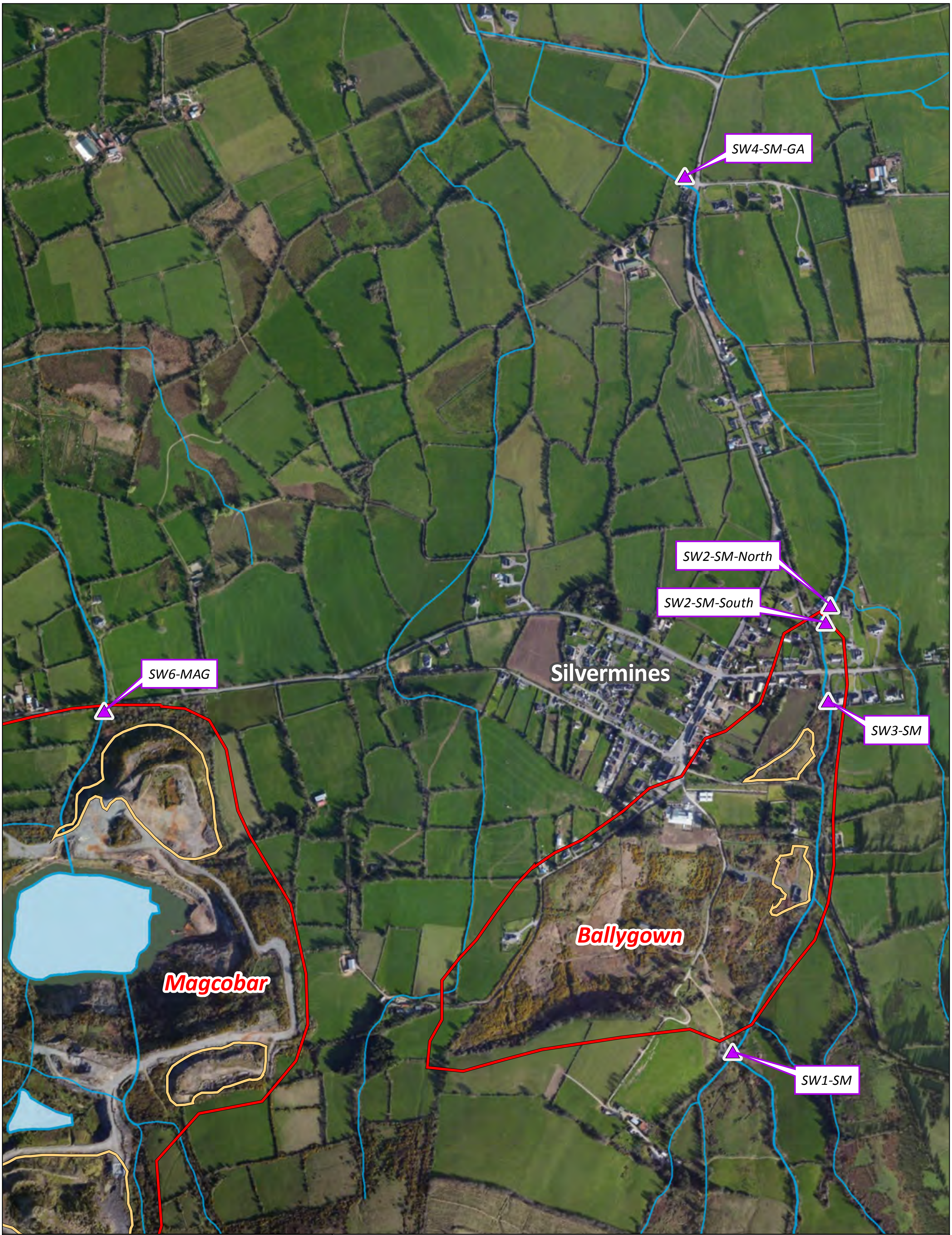
Mining Areas

Stockpile Dump

N W E S

Scale is 1:5,000

0 50 100 200 m



Map 5 - Silvermines - Magcobar and Ballygown

Drawn by: OC *Date: 03/04/2014*

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\03_SilverMonSh.mxd

Source: © ESRI Base Map

CDM Smith

Legend

Sampling Locations

Surface water

Rivers

Streams

Pond / Wetland

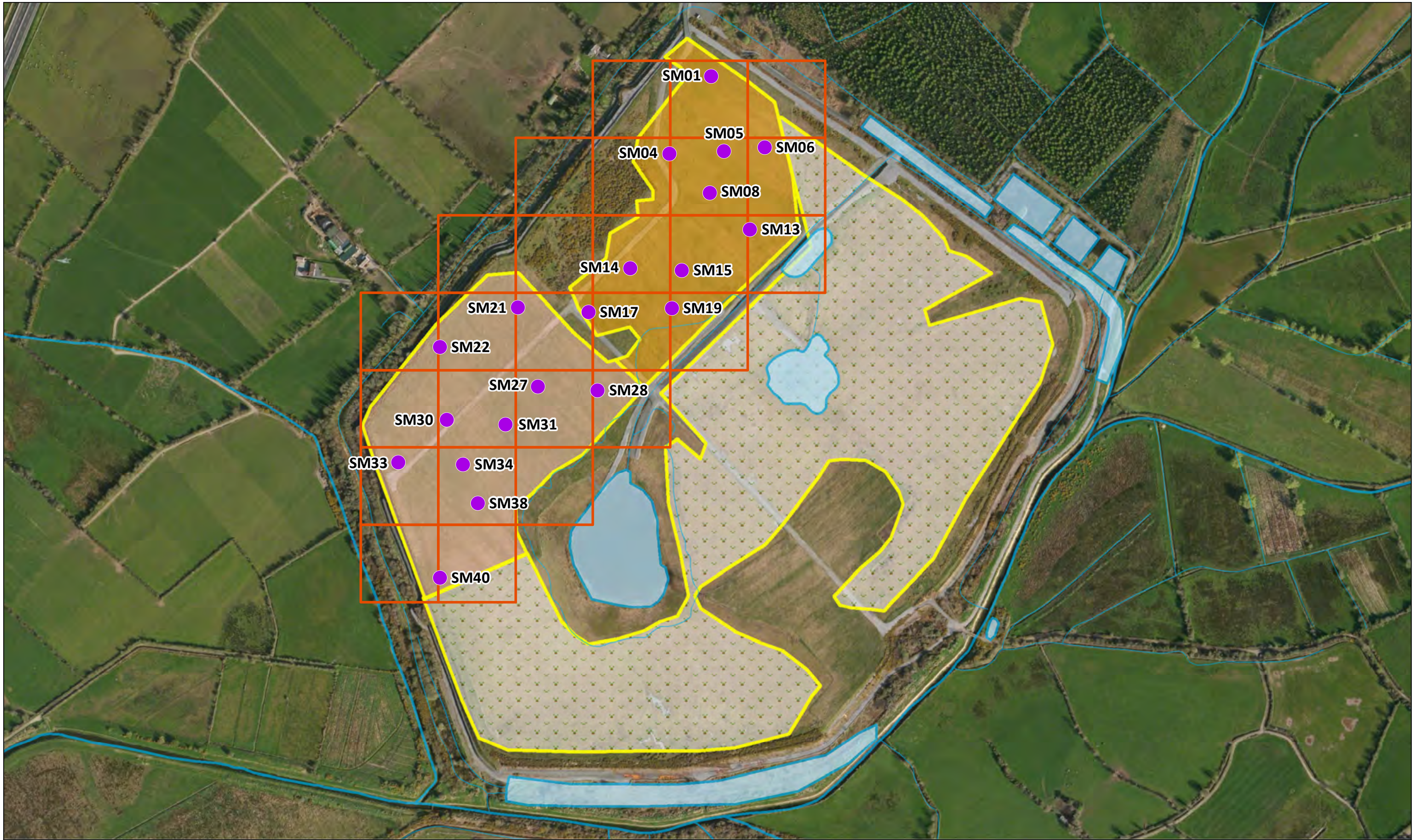
Mines

Mining Area

Spoil Heap / Waste Drum Dump

Scale is 1:10,000

0 100 200 m



Map 6 - Silvermines - Gortmore - Vegetation

Drawn by: OC *Date:* 03/04/2014

Internal Project Reference: S:\CURRENT_PROJECTS\95735_Avoca_Silver\02_GIS_Tasks\07_MonRptR3\MXD\06_SilverMonVeg.mxd

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

N W E S

Scale is 1:6,500

0 50 100 200 m

Appendix B

Analytical Data Tables and Assessment Criteria

CDM Smith

Table B-1 Total versus Dissolved Metals Comparison R3

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	
SW1-GAR	05/03/2014	1	9.57	7.38	0.8	33.4	5.14	0.2	45.6	37.6	0.8	5030	4320	0.9
SW2-GAR	05/03/2014	14.5	79.6	66.3	0.8	1000	137	0.1	61	52.6	0.9	23400	17600	0.8
SW4-GAR	05/03/2014	1	1.16	0.907	0.8	34.2	20.1	0.6	1.7	4.98	2.9	230	176	0.8
SW1-SHAL	05/03/2014	2	3.12	2.37	0.8	354	219	0.6	14.3	14.1	1.0	882	680	0.8
SW4-SHAL	05/03/2014	2.5	1.23	0.867	0.7	31	3.66	0.1	6.58	13.8	2.1	172	127	0.7
SW5-SHAL	05/03/2014	4	25.2	21.4	0.8	210	26.3	0.1	60.2	53.3	0.9	10500	8580	0.8
SW6-SHAL	05/03/2014	1	1.7	1.29	0.8	666	477	0.7	10.3	11	1.1	330	252	0.8
SW7-SHAL	05/03/2014	7.5	25.9	21.7	0.8	240	19.3	0.1	60	53.8	0.9	10300	8600	0.8
SW9-SHAL	05/03/2014	3	3.73	2.58	0.7	508	310	0.6	14.3	11.7	0.8	1030	727	0.7
SW10-SHAL	05/03/2014	2	5.62	4.36	0.8	158	88	0.6	12.6	12.4	1.0	1720	1450	0.8
SW12-SHAL	05/03/2014	2	0.25	0.167	0.7	112	76.1	0.7	1.45	1.68	1.2	38.8	37.7	1.0
SW3-GAR	06/03/2014	2	31	23.5	0.8	14.9	2	0.1	46.5	40.2	0.9	11200	9030	0.8
SW5-GAR	06/03/2014	4.5	37.7	30.3	0.8	115	0.138	0.0	76.4	61.5	0.8	17600	15600	0.9
SW7-GAR	06/03/2014	1	13.1	8.6	0.7	3.93	0.678	0.2	24.3	20.6	0.8	6360	5500	0.9
SW8-GAR	06/03/2014	10.5	43.2	33	0.8	84.4	1.01	0.0	109	81.8	0.8	30200	25200	0.8
SW9-GAR	06/03/2014	1	31.1	23.4	0.8	37.3	6.07	0.2	47.3	39	0.8	12000	8740	0.7
SW10-GAR	06/03/2014	1	31.4	24.8	0.8	6.81	2.06	0.3	47	39.7	0.8	9420	9320	1.0
SW12-GAR	06/03/2014	1	35.5	28.8	0.8	9.06	0.32	0.0	70.9	57.7	0.8	16000	13800	0.9
SW17-Gort	11/03/2014	1	*0.25*	*0.05*	0.2	*0.25*	0.194	0.8	*0.25*	1.57	6.3	4.58	24.4	5.3
SW6-Mag	11/03/2014	1	2.1	1.67	0.8	6.06	0.488	0.1	7.97	9.13	1.1	1060	792	0.7
SW1-SM	11/03/2014	4	*0.25*	*0.05*	0.2	*0.25*	13.6	54.4	*0.25*	0.923	3.7	4.11	24.2	5.9
SW3-SM	11/03/2014	3	0.25	0.188	0.8	2.97	1.25	0.4	*0.25*	1.5	6.0	101	123	1.2
SW4-SM-Ga	11/03/2014	1	0.501	0.457	0.9	2.02	1.16	0.6	*0.25*	2	8.0	199	181	0.9
SW2-SM-South	11/03/2014	1	6.68	5.18	0.8	1.96	1.1	0.6	6.78	8.32	1.2	2730	1940	0.7
SW18-GORT	12/03/2014	1	1.53	1.02	0.7	38.9	14.4	0.4	2.99	5.46	1.8	546	437	0.8
SW19-GORT	12/03/2014	1	*1.16*	1.04	0.9	10.6	3.25	0.3	2.98	7.1	2.4	708	583	0.8
TMF1	12/03/2014	-	*0.25*	*0.05*	0.2	15.1	0.115	0.0	0.699	2.31	3.3	7.6	18.8	2.5
TMF2	12/03/2014	-	0.25	*0.05*	0.2	11.8	2.16	0.2	*0.25*	2.07	8.3	8.69	15.6	1.8
TMF SEEP1	12/03/2014	138	14	9.59	0.7	34.3	0.263	0.0	198	145	0.7	27800	20900	0.8
SW14-GORT	13/03/2014	2	0.681	0.542	0.8	7.77	2.21	0.3	4.52	3.16	0.7	325	245	0.8
SW10-GORT-DISCHARGE	13/03/2014	1	0.605	0.328	0.5	0.771	0.276	0.4	11.9	9.19	0.8	1180	1040	0.9
SW12-GORT-DISCHARGE	13/03/2014	1	0.691	0.462	0.7	*0.25*	0.061	0.2	9.17	8.44	0.9	795	585	0.7
SW10-GORT-DS	13/03/2014	3	0.25	0.107	0.4	1.39	0.513	0.4	2.31	2.64	1.1	103	92.5	0.9
SW12-GORT-DS	13/03/2014	2.5	0.555	0.58	1.0	4.19	2.22	0.5	3.74	3.2	0.9	296	259	0.9
SW10-GORT-US	13/03/2014	3	0.25	0.107	0.4	2.5	2.65	1.1	2.27	2.55	1.1	69.9	58.4	0.8

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 R3

Sample Description	Area	Type	Date Sampled Units	Acidity as HCL mg/l	Alkalinity, Total as CaCO3 mg/l	Hardness as CaCO3 mg/l	Ammoniacal Nitrogen as N mg/l	Chloride mg/l	COD, unfiltered mg/l	Specific Conductance @ deg.C (field) mS/cm	Cyanide, Free mg/l	Dissolved solids, Total mg/l	Fluoride mg/l	Nitrate as NO3 mg/l	Nitrite as NO2 mg/l	Oxygen, dissolved (field) mg/l	pH (field) pH Units	Phosphate (ortho) as P mg/l	Sulphate mg/l	Sodium (diss.filt) mg/l	Suspended solids, Total mg/l
Ecological Criteria				-	-	-	0.14	-	-	-	0.01	-	0.5	-	-	80 to 120*	4.5 to 9	0.075	-	-	-
Human Health Criteria				-	-	-	0.3	250	-	2.5	0.05	-	1.5	50	0.5	-	6.5 to 9.5	-	250	200	-
TMF1	GW	GM	12/03/2014	-	225	274.5	0.1	13.7	-	0.437	0.025	259	0.25	0.15	0.025	8.6	7.57	0.01	12.3	9.9	-
TMF2	GW	GM	12/03/2014	-	245	298.9	0.1	19	-	0.486	0.025	273	0.25	0.15	0.051	2.6	7.27	0.01	1	10.2	-
SW1-SM	River/Stream	BG	11/03/2014	2	35.5	43.31	0.1	14.6	3.5	0.139	0.025	30	0.25	2	0.025	98.5	7.07	0.01	1	6.48	4
SW3-SM	River/Stream	BG	11/03/2014	2	60	73.2	0.1	15	3.5	0.167	0.025	84.7	0.25	2.45	0.025	99.3	6.91	0.01	2.9	7.35	3
SW2-SM-South	Discharge	BG	11/03/2014	5.48	240	292.8	0.1	14.6	3.5	0.544	0.025	298	0.25	7.19	0.025	58.9	7.02	0.01	36.9	7.63	1
SW4-SM-Ga	River/Stream	BG	11/03/2014	2	95	115.9	0.1	16.2	3.5	0.258	0.025	130	0.25	4.81	0.025	100.4	7.78	0.01	8.4	7.29	1
SW6-MAG	River/Stream	MG	11/03/2014	2	40	48.8	0.1	11.3	3.5	0.507	0.025	359	0.25	1.45	0.025	99.4	7.73	0.01	185	5.68	1
TMF Seep 1	Discharge	GM	12/03/2014	29.2	260	317.2	0.573	18.3	13.6	3.935	0.025	4020	2.96	0.15	0.061	-	3.19	0.01	2520	8.44	138
SW18-GORT	Drainage	GM	12/03/2014	5.48	110	134.2	0.1	11.2	10.7	0.594	0.025	471	0.25	0.15	0.025	97.3	8.11	0.01	198	7.12	1
SW19-GORT	Drainage	GM	12/03/2014	2	100	122	0.1	11.5	7.26	0.742	0.025	606	0.25	0.15	0.025	100.9	7.78	0.01	295	6.98	1
SW17-Gort	River/Stream	GM	11/03/2014	2	130	158.6	0.1	19.2	3.5	0.357	0.025	217	0.25	17.2	0.088	86.1	7.62	0.032	9.7	9.51	1
SW10-GORT-US	River/Stream	GM	13/03/2014	2	205	250.1	0.1	18.7	3.5	0.483	0.025	317	0.25	12.6	0.025	89.4	7.54	0.01	27.3	9	3
SW10-GORT-DISC	Discharge	GM	13/03/2014	5.48	115	140.3	0.1	12.9	3.5	0.939	0.025	787	0.25	0.15	0.025	75	7.32	0.01	402	7.76	1
SW10-GORT-DS	River/Stream	GM	13/03/2014	5.48	195	237.9	0.1	18.7	3.5	0.496	0.025	316	0.25	12.4	0.025	89.4	7.62	0.0209	41.7	8.81	3
SW12-GORT-DISC	Discharge	GM	13/03/2014	16.4	215	262.3	0.1	21.9	3.5	1.02	0.025	837	0.25	14.5	0.054	64.9	7.08	0.01	374	10.3	1
SW12-GORT-DS	River/Stream	GM	13/03/2014	2	190	231.8	0.1	18.7	9.63	0.516	0.025	321	0.25	11.5	0.073	92.5	7.64	0.01	46.7	8.9	2.5
SW14-GORT	River/Stream	GM	13/03/2014	2	175	213.5	0.1	18.4	16.5	0.461	0.025	294	0.25	11.8	0.025	93.6	7.78	0.01	36.2	8.67	2
SW1-GAR	River/Stream	GA	05/03/2014	2	41	50.02	0.252	14.2	3.5	1.492	0.025	1330	0.714	1.5	0.052	93.7	7.54	0.01	788	6.3	1
SW2-GAR	Drainage	GA	05/03/2014	5.48	60	73.2	0.1	21.5	3.5	1.009	0.025	807	2.14	3.77	0.025	68.2	6.7	0.01	438	8.72	14.5
SW4-GAR	River/Stream	GA	05/03/2014	2	24.5	29.89	0.1	15.3	9.49	0.135	0.025	60	0.25	0.981	0.055	91.2	7.11	0.01	16.6	7.01	1
SW5-GAR	Discharge	GA	06/03/2014	5.48	190	231.8	0.1	12.2	3.5	0.893	0.025	694	2.37	0.419	0.025	6.3	7.11	0.01	289	7.71	4.5
SW7-GAR	Discharge	GA	06/03/2014	2	75	91.5	0.1	20.3	14.7	0.741	0.025	634	0.958	1.11	0.025	95.5	7.36	0.01	312	9.46	1
SW8-GAR	Drainage	GA	06/03/2014	14.6	160	195.2	0.1	22.6	3.5	1.804	0.025	1660	1.94	5.11	0.025	75.3	7.26	0.01	909	11.9	10.5
SW12-GAR	Drainage	GA	06/03/2014	2	185	225.7	0.1	13.4	3.5	0.956	0.025	722	1.91	0.835	0.025	98.6	7.52	0.01	333	10.1	1
SW9-GAR	Drainage	GA	06/03/2014	7.3	135	164.7	0.1	18.2	3.5	1.47	0.025	1290	1.77	3.4	0.025	94.4	7.72	0.01	681	9.33	1
SW10-GAR	Discharge	GA	06/03/2014	2	175	213.5	0.1	14	8.16	0.95	0.025	712	0.25	1.08	0.025	97.4	7.64	0.01	337	7.87	1
SW3-GAR	River/Stream	GA	06/03/2014	2	170	207.4	0.1	14.4	7.15	0.944	0.025	702	1.75	0.867	0.025	95.5	7.65	0.01	336	7.06	2
SW4-SHAL	River/Stream	ShS	05/03/2014	2	42.5	51.85	0.1	17.9	3.5	0.17	0.025	81.1	0.25	0.69	0.059	62.5	6.66	0.01	2.5	8.58	2.5
SW5-SHAL	River/Stream	ShS	05/03/2014	5.48	15.5	18.91	0.1	16.4	8	0.283	0.025	174	1.47	1.34	0.025	94	6.79	0.01	87.5	7.61	4
SW7-SHAL	River/Stream	ShS	05/03/2014	5.48	15	18.3	0.1	16.3	8.06	0.282	0.025	157	1.42	1.37	0.051	91.1	6.7	0.01	87.1	7.74	7.5
SW6-SHAL	Discharge	ShS	05/03/2014	2	36.5	44.53	0.573	14.6	3.5	0.147	0.025	100	0.25	1.86	0.025	77	6.44	0.01	13.8	6.62	1
SW12-SHAL	Drainage	ShS	05/03/2014	2	2	2.44	0.1	14.3	3.5	0.065	0.025	26.3	0.25	0.563	0.05	94.5	4.37	0.01	1	5.68	2
SW10-SHAL	Drainage	ShS	05/03/2014	2	60	73.2	0.1	16.9	3.5	0.297	0.025	216	0.25	1.1	0.025	79.3	7.13	0.01	55.1	7.8	2
SW9-SHAL	River/Stream	ShS	05/03/2014	2	44.5	54.29	0.1	14.8	14.1	0.191	0.025	116	0.25	1.79	0.025	91.3	7.04	0.01	29.7	6.8	3
SW1-SHAL	River/Stream	ShS	05/03/2014	2	60	73.2	0.1	15.3	7.79	0.225	0.025	148	0.25	1.64	0.025	94	7.27	0.01	34.3	7.25	2

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

Table B-2 Comparison of Groundwater and Surface Water Results to Assessment Criteria R3

Sample Description	Area	Type	Date Sampled Units	Aluminium (diss.filt) µg/l	Antimony (diss.filt) µg/l	Arsenic (diss.filt) µg/l	Barium (diss.filt) µg/l	Cadmium (diss.filt) µg/l	Chromium (diss.filt) µg/l	Cobalt (diss.filt) µg/l	Copper (diss.filt) µg/l	Iron (diss.filt) µg/l	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Mercury (diss.filt) µg/l	Molybdenum (diss.filt) µg/l	Nickel (diss.filt) µg/l	Selenium (diss.filt) µg/l	Silver (diss.filt) µg/l	Thallium (diss.filt) µg/l	Tin (diss.filt) µg/l	Uranium (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) µg/l
Ecological Criteria				**1,900**	**-**	**25**	**4**	**0.9**	**3.4**	**5.1**	**30**	**-**	**7.2**	**1100**	**0.07**	**-**	**20**	**-**	**-**	**-**	**-**	**2.6**	**-**	**100**
Human Health Criteria				**200**	**5**	**10**	**-**	**5**	**50**	**-**	**2000**	**200**	**10**	**50**	**1**	**-**	**20**	**10**	**-**	**-**	**-**	**-**	**-**	**-**
TMF1	GW	GM	12/03/2014	1.45	0.08	2.98	157	0.05	3.22	0.587	0.425	25.5	0.115	81.7	0.005	0.271	2.31	0.195	0.75	0.48	0.18	0.75	0.727	18.8
TMF2	GW	GM	12/03/2014	1.45	0.622	4.99	592	0.05	4.48	1.03	0.425	195	2.16	988	0.005	0.598	2.07	0.775	0.75	0.48	0.18	0.75	1.18	15.6
SW1-SM	River/Stream	BG	11/03/2014	3.86	0.08	0.173	36.7	0.05	1.2	0.082	0.425	9.5	13.6	2.71	0.005	0.12	0.923	0.195	0.75	0.48	0.18	0.75	0.12	24.2
SW3-SM	River/Stream	BG	11/03/2014	4.82	0.08	0.155	60.4	0.188	1.36	0.087	0.425	9.5	1.25	3.22	0.005	0.12	1.5	0.195	0.75	0.48	0.18	0.75	0.12	123
SW2-SM-South	Discharge	BG	11/03/2014	3.58	0.08	0.299	162	5.18	3.6	0.165	0.425	9.5	1.1	1.86	0.005	0.12	8.32	0.477	0.75	0.48	0.18	0.75	0.848	1940
SW4-SM-Ga	River/Stream	BG	11/03/2014	3.8	0.08	0.252	104	0.457	1.83	0.101	0.425	9.5	1.16	4.06	0.005	0.12	2	0.393	0.75	0.48	0.18	0.75	0.426	181
SW6-MAG	River/Stream	MG	11/03/2014	7.59	0.08	0.233	40.7	1.67	1.02	0.597	5.61	70.2	0.488	59.1	0.005	0.704	9.13	0.195	0.75	0.48	0.18	0.75	0.12	792
TMF Seep 1	Discharge	GM	12/03/2014	1.45	0.08	1.57	11.6	9.59	5.77	14	4.72	27500	0.263	2400	0.005	0.12	145	0.859	0.75	142	0.18	0.75	1.59	20900
SW18-GORT	Drainage	GM	12/03/2014	1.45	1.55	0.544	18.4	1.02	1.91	0.203	3.7	9.5	14.4	35.5	0.005	0.12	5.46	0.519	0.75	13.3	0.18	0.75	0.374	437
SW19-GORT	Drainage	GM	12/03/2014	1.45	1.03	0.412	21.8	1.07	2.03	0.191	3.2	9.5	3.25	7.49	0.005	0.12	7.1	0.545	0.75	13.4	0.18	0.75	0.54	588
SW17-Gort	River/Stream	GM	11/03/2014	10.1	0.08	0.504	191	0.05	2.12	0.198	1.34	72.1	0.194	71.1	0.005	0.12	1.57	0.631	0.75	0.48	0.18	0.75	0.503	24.4
SW10-GORT-US	River/Stream	GM	13/03/2014	12.4	0.08	0.506	138	0.107	3.66	0.228	1.02	106	2.65	60.7	0.005	0.12	2.55	0.759	0.75	0.48	0.18	0.75	0.909	58.4
SW10-GORT-DISC	Discharge	GM	13/03/2014	1.45	0.39	0.286	16.2	0.328	2.3	0.188	1.99	9.5	0.276	91.5	0.005	0.12	9.19	0.438	0.75	6.36	0.18	0.75	0.498	1040
SW10-GORT-DS	River/Stream	GM	13/03/2014	7.84	0.08	0.4	136	0.107	3.21	0.181	0.95	44.6	0.513	59.1	0.005	0.12	2.64	0.559	0.75	0.48	0.18	0.75	0.775	92.5
SW12-GORT-DISC	Discharge	GM	13/03/2014	6.34	0.08	0.387	204	0.462	3.59	0.607	2.31	29.9	0.061	269	0.005	0.12	8.44	0.592	0.75	0.48	0.18	0.75	0.793	585
SW12-GORT-DS	River/Stream	GM	13/03/2014	6.43	0.08	0.438	152	0.58	3.23	0.262	1.39	45.8	2.31	63.7	0.005	0.12	3.2	0.594	0.75	0.48	0.18	0.75	1.01	263
SW14-GORT	River/Stream	GM	13/03/2014	5.89	0.08	0.385	144	0.542	2.74	0.231	1.48	38.7	2.21	50.7	0.005	0.12	3.16	0.494	0.75	0.48	0.18	0.75	0.811	245
SW1-GAR	River/Stream	GA	05/03/2014	10.4	0.08	0.06	27.3	7.38	0.704	0.541	5.87	9.5	5.14	25.5	0.005	0.676	37.6	0.195	0.75	0.48	0.18	0.75	0.12	4320
SW2-GAR	Drainage	GA	05/03/2014	5.08	0.558	0.06	21.9	66.3	0.958	2.42	11.1	9.5	137	355	0.005	0.12	52.6	0.42	0.75	2.13	0.18	0.75	0.12	17600
SW4-GAR	River/Stream	GA	05/03/2014	9	0.415	0.06	243	0.907	0.91	0.433	12.3	9.5	20.1	24.2	0.005	4.31	4.98	0.195	0.75	0.48	0.18	0.75	0.12	176
SW5-GAR	Discharge	GA	06/03/2014	1.45	2.07	0.524	21.9	30.3	2.61	6.15	8.72	19.4	0.138	480	0.005	0.317	61.5	0.195	0.75	1.58	0.681	0.75	0.647	15600
SW7-GAR	Discharge	GA	06/03/2014	1.45	0.367	0.06	61	8.92	1.16	0.361	2.21	9.5	0.946	68	0.005	0.344	21.5	0.195	0.75	0.48	0.18	0.75	0.12	5580
SW8-GAR	Drainage	GA	06/03/2014	1.45	0.08	0.499	18.3	33	1.78	1.6	5.54	111	1.01	355	0.005	0.12	81.8	0.602	0.75	3.96	0.18	0.75	0.442	25200
SW12-GAR	Drainage	GA	06/03/2014	1.45	1.34	0.656	20.9	28.8	1.96	5.34	8.04	9.5	0.32	456	0.005	0.12	57.7	0.195	0.75	1.54	0.18	0.75	0.449	13800
SW9-GAR	Drainage	GA	06/03/2014	1.45	0.08	0.587	16.6	23.4	1.61	1.23	5.95	9.5	6.07	176	0.005	0.332	39	0.618	0.75	1.63	0.18	0.75	0.527	8740
SW10-GAR	Discharge	GA	06/03/2014	1.45	0.513	0.281	21.2	24.8	1.68	2.78	3.2	9.5	2.06	226	0.005	0.12	39.7	0.195	0.75	1.7	0.18	0.75	0.271	9320
SW3-GAR	River/Stream	GA	06/03/2014	1.45	0.909	0.207	26.4	23.5	1.99	2.87	3.04	9.5	2	269	0.005	0.273	40.2	0.195	0.75	1.36	0.18	0.75	0.526	9030
SW4-SHAL	River/Stream	ShS	05/03/2014	3.45	0.296	0.06	357	0.867	1.32	0.474	5.28	26.2	3.66	83.7	0.005	10.1	13.8	0.195	0.75	0.48	0.18	0.75	0.12	127
SW5-SHAL	River/Stream	ShS	05/03/2014	26.2	0.313	0.06	315	21.4	0.695	5.39	23.7	19.4	26.3	752	0.005	1.75	53.3	0.195	0.75	0.48	0.18	0.75	0.12	8580
SW7-SHAL	River/Stream	ShS	05/03/2014	23.9	0.39	0.06	313	21.7	0.691	5.5	18.1	9.5	19.3	726	0.005	4.62	53.8	0.195	0.75	0.48	0.18	0.75	0.12	8600
SW6-SHAL	Discharge	ShS	05/03/2014	41.5	0.898	0.457	273	1.29	0.958	2.56	20.1	49.6	477	97.9	0.005	1.67	11	0.195	0.75	0.48	0.18	0.75	0.12	252
SW12-SHAL	Drainage	ShS	05/03/2014	59.8	1.59	0.06	356	0.167	0.283	0.809	1.38	29.4	76.1	146	0.005	0.456	1.68	0.195	0.75	0.48	0.699	0.75	0.12	37.7
SW10-SHAL	Drainage	ShS	05/03/2014	26.1	3	0.06	394	4.36	0.955	1.05	8.74	9.5	88	90.8	0.0213	1.04	12.4	0.195	0.75	0.48	0.18	0.75	0.12	1450
SW9-SHAL	River/Stream	ShS	05/03/2014	36.8	1.43	0.407	224	2.58	0.775	2.2	14.8	30.2	310	93.4	0.005	0.327	11.7	0.195	0.75	0.48	0.363	0.75	0.12	727
SW1-SHAL	River/Stream	ShS	05/03/2014	37.9	1.45	0.501	258	2.37	1.06	2.17	12.3	91.3	219	130	0.005	0.768	14.1	0.195	0.75	0.48	0.18	0.75	0.12	680

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

Table B-3 Comparison of Surface Water Results to Assessment Criteria for Livestock Drinking Water

Sample Description	Area	Type	Date Sampled	Dissolved solids, Total	Fluoride	Sulphate	Aluminium (diss.filt)	Arsenic (diss.filt)	Cadmium (diss.filt)	Chromium (diss.filt)	Cobalt (diss.filt)	Copper (diss.filt)	Lead (diss.filt)	Mercury (diss.filt)	Selenium (diss.filt)	Vanadium (diss.filt)	Zinc (diss.filt)
			Units	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Livestock Criteria				**1000**	**2**	**500**	**5000**	**200**	**50**	**1000**	**1000**	**500**	**100**	**10**	**50**	**100**	**24000**
SW10-SHAL	Drainage	ShS	05/03/2014	216	*0.25*	55.1	26.1	*0.06*	4.36	0.955	1.05	8.74	88	0.0213	*0.195*	*0.12*	1450
SW12-SHAL	Drainage	ShS	05/03/2014	26.3	*0.25*	*1*	59.8	*0.06*	0.167	0.283	0.809	1.38	76.1	*0.005*	*0.195*	*0.12*	37.7
SW4-SHAL	River/ Stream	ShS	05/03/2014	81.1	*0.25*	2.5	3.45	*0.06*	0.867	1.32	0.474	5.28	3.66	*0.005*	*0.195*	*0.12*	127
SW5-SHAL	River/ Stream	ShS	05/03/2014	174	1.47	87.5	26.2	*0.06*	21.4	0.695	5.39	23.7	26.3	*0.005*	*0.195*	*0.12*	8580
SW7-SHAL	River/ Stream	ShS	05/03/2014	157	1.42	87.1	23.9	*0.06*	21.7	0.691	5.5	18.1	19.3	*0.005*	*0.195*	*0.12*	8600
SW6-SHAL	Discharge	ShS	05/03/2014	100	*0.25*	13.8	41.5	0.457	1.29	0.958	2.56	20.1	477	*0.005*	*0.195*	*0.12*	252
SW9-SHAL	River/ Stream	ShS	05/03/2014	116	*0.25*	29.7	36.8	0.407	2.58	0.775	2.2	14.8	310	*0.005*	*0.195*	*0.12*	727
SW1-SHAL	River/ Stream	ShS	05/03/2014	148	*0.25*	34.3	37.9	0.501	2.37	1.06	2.17	12.3	219	*0.005*	*0.195*	*0.12*	680
SW1-SM	River/ Stream	BG	11/03/2014	30	*0.25*	*1*	3.86	0.173	*0.05*	1.2	0.082	*0.425*	13.6	*0.005*	*0.195*	*0.12*	24.2
SW2-SM-South	Discharge	BG	11/03/2014	298	*0.25*	36.9	3.58	0.299	5.18	3.6	0.165	*0.425*	1.1	*0.005*	0.477	0.848	1940
SW3-SM	River/ Stream	BG	11/03/2014	84.7	*0.25*	2.9	4.82	0.155	0.188	1.36	0.087	*0.425*	1.25	*0.005*	*0.195*	*0.12*	123
SW4-SM-Ga	River/ Stream	BG	11/03/2014	130	*0.25*	8.4	3.8	0.252	0.457	1.83	0.101	*0.425*	1.16	*0.005*	0.393	0.426	181
SW10-GAR	Discharge	GA	06/03/2014	712	*0.25*	337	*1.45*	0.281	24.8	1.68	2.78	3.2	2.06	*0.005*	*0.195*	0.271	9320
SW12-GAR	Drainage	GA	06/03/2014	722	1.91	333	*1.45*	0.656	28.8	1.96	5.34	8.04	0.32	*0.005*	*0.195*	0.449	13800
SW1-GAR	River/ Stream	GA	05/03/2014	1330	0.714	788	10.4	*0.06*	7.38	0.704	0.541	5.87	5.14	*0.005*	*0.195*	*0.12*	4320
SW2-GAR	Drainage	GA	05/03/2014	807	2.14	438	5.08	*0.06*	66.3	0.958	2.42	11.1	137	*0.005*	0.42	*0.12*	17600
SW3-GAR	River/ Stream	GA	06/03/2014	702	1.75	336	*1.45*	0.207	23.5	1.99	2.87	3.04	2	*0.005*	*0.195*	0.526	9030
SW4-GAR	River/ Stream	GA	05/03/2014	60	*0.25*	16.6	9	*0.06*	0.907	0.91	0.433	12.3	20.1	*0.005*	*0.195*	*0.12*	176
SW5-GAR	Discharge	GA	06/03/2014	694	2.37	289	*1.45*	0.524	30.3	2.61	6.15	8.72	0.138	*0.005*	*0.195*	0.647	15600
SW7-GAR	Discharge	GA	06/03/2014	634	0.958	312	*1.45*	*0.06*	8.92	1.16	0.361	2.21	0.946	*0.005*	*0.195*	*0.12*	5580
SW8-GAR	Drainage	GA	06/03/2014	1660	1.94	909	*1.45*	0.499	33	1.78	1.6	5.54	1.01	*0.005*	0.602	0.442	25200
SW9-GAR	Drainage	GA	06/03/2014	1290	1.77	681	*1.45*	0.587	23.4	1.61	1.23	5.95	6.07	*0.005*	0.618	0.527	8740
SW10-GORT-DISC	Discharge	GM	13/03/2014	787	*0.25*	402	*1.45*	0.286	0.328	2.3	0.188	1.99	0.276	*0.005*	0.438	0.498	1040
SW10-GORT-DS	River/ Stream	GM	13/03/2014	316	*0.25*	41.7	7.84	0.4	0.107	3.21	0.181	0.95	0.513	*0.005*	0.559	0.775	92.5
SW10-GORT-US	River/ Stream	GM	13/03/2014	317	*0.25*	27.3	12.4	0.506	0.107	3.66	0.228	1.02	2.65	*0.005*	0.759	0.909	58.4
SW12-GORT-DISC	Discharge	GM	13/03/2014	837	*0.25*	374	6.34	0.387	0.462	3.59	0.607	2.31	0.061	*0.005*	0.592	0.793	585
SW12-GORT-DS	River/ Stream	GM	13/03/2014	321	*0.25*	46.7	6.43	0.438	0.58	3.23	0.262	1.39	2.31	*0.005*	0.594	1.01	263
SW14-GORT	River/ Stream	GM	13/03/2014	294	*0.25*	36.2	5.89	0.385	0.542	2.74	0.231	1.48	2.21	*0.005*	0.494	0.811	245
SW17-Gort	River/ Stream	GM	11/03/2014	217	*0.25*	9.7	10.1	0.504	*0.05*	2.12	0.198	1.34	0.194	*0.005*	0.631	0.503	24.4
SW18-GORT	Drainage	GM	12/03/2014	471	*0.25*	198	*1.45*	0.544	1.02	1.91	0.203	3.7	14.4	*0.005*	0.519	0.374	437
SW19-GORT	Drainage	GM	12/03/2014	606	*0.25*	295	*1.45*	0.412	1.07	2.03	0.191	3.2	3.25	*0.005*	0.545	0.54	588
TMF Seep 1	Discharge	GM	12/03/2014	4020	2.96	2520	*1.45*	1.57	9.59	5.77	14	4.72	0.263	*0.005*	0.859	1.59	20900
SW6-MAG	River/ Stream	MG	11/03/2014	359	*0.25*	185	7.59	0.233	1.67	1.02	0.597	5.61	0.488	*0.005*	*0.195*	*0.12*	792

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

	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	0.818	0.263	4.68	64.7
SM04-V	0.251	0.070	2.22	43.1
SM05-V	0.573	0.122	2.98	44.7
SM06-V	1.026	0.145	5.42	44.2
SM08-V	0.494	0.105	2.93	44.8
SM13-V	0.370	0.079	2.86	34.5
SM14-V	0.259	0.109	1.79	31.0
SM15-V	0.117	0.058	1.07	27.7
SM17-V	0.206	0.081	3.50	34.5
SM19-V	0.156	0.089	1.89	31.1
SM21-V	0.708	0.117	3.32	38.7
SM22-V	0.415	0.092	3.55	40.5
SM27-V	0.117	0.075	1.31	43.2
SM28-V	0.283	0.098	2.71	31.2
SM30-V	0.180	0.061	3.00	38.8
SM31-V	0.288	0.134	1.94	43.6
SM33-V	0.337	0.062	2.99	43.0
SM34-V	0.322	0.077	3.35	35.2
SM38-V	0.281	0.066	2.50	38.2
SM40-V	1.074	0.148	9.02	39.4
SM56-V	0.232	0.094	3.59	35.0
SM57-V	0.330	0.060	2.99	44.3

xx Exceeds the Maximum Concentration in Feeding Stuff

xx Exceeds No effect level for digestion in wildlife

xx Exceeds Low effect level for digestion in wildlife