

Department of Communications, Climate Action and Environment

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

Avoca Monitoring Report - Round 1 (2017)

Final



GWP consultants

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Section 1

Introduction

1.1 Objectives and Scope

The Department of Communications, Climate Action and Environment (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 for the first three years was defined in the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Monitoring Plan,* (Document Ref: 95735/40/DG/01, dated 26 February 2013) and sampling activities were performed in accordance with the programme and procedures set out therein.

Based on the findings of the monitoring program for the first three years, adjustments were made to the monitoring programme in 2016 which are detailed in the *Environmental Monitoring of Former Mining Areas of Silvermines and Avoca Summary Report*, (Document Ref: 95735/40/DG/25, dated 20 January 2016).

The Monitoring Report for the Avoca Mining Area presents an evaluation of the results of the field investigations carried out in March 2017. This report should be read alongside the Avoca Data Report (Document Ref: 117005/40/DG/35, dated March 2017) which contains all field observations and laboratory analytical results collected during the monitoring programme.

1.2 Background of Avoca Mining Area

The Avoca mining area is located in the eastern foothills of the Wicklow Mountains, some 55 kilometres south of Dublin. The site includes the East and West Avoca mining areas and the Shelton Abbey Tailings Management Facility (TMF) which is located approximately 8 km to the south. The Avoca River divides the East and West Avoca mine sites and runs along the base of TMF.

The Avoca Mine site was worked intermittently for approximately 250 years with the extraction of 16 Mt of copper and pyrite ore and on-site processing of concentrates. The mine went into receivership and closed in 1982. Mineral extraction left an environmental legacy that comprises three open pits, over 70 shafts and adits, numerous spoil piles and 25 mine buildings/structures. A number of spoil piles which have elevated metal levels and some pit high walls are physically unstable with the potential to collapse. In addition, unstable ground is present which has the potential for subsidence. Seeps and the water discharges from adits are acidic and metal laden. These discharges impact water quality in the Avoca River.

1.3 Catchment Description

The Avoca Mines are located within the Avoca River Catchment which includes an area of 650 km². The East and West Avoca Mines are separated by the Avoca River, which flows through the Vale of Avoca, a noted tourist attraction. To the north of the mines, the Avoca River is formed at the "Meeting of the Waters" by the confluence of the Avonbeg and Avonmore Rivers, while 6.5 km to



the south, it is joined by the Aughrim River and flows an additional 7.5 km to the sea at the fishing port of Arklow. Several smaller tributaries join the Avoca River close to the mine water discharges, including Sulphur Brook to the south of East Avoca Mines, and the Vale View and Red Road streams to the north and south respectively of West Avoca Mines.

1.4 Geology and Hydrogeology

1.4.1 Geology

The mineralised zone at Avoca is hosted in the Ordovician Avoca Formation that consists of tuffs (consolidated volcanic ash) and felsites (volcanic or extrusive igneous rocks) interbedded with slaty mudstones. The rocks trend northeast/southwest and are generally steeply-dipping to the southeast. Tight folds a few hundred metres wide are also present. The main ore zones, from which copper and pyrite (FeS₂) were extracted, occur as generally stratiform lenses up to a few tens of metres thick at the top of a sequence of tuffs and felsites.

Numerous shear zones exist and a series of north-south trending faults, one of which (the Great Fault) runs close to the Avoca River and displaces the western orebodies southward relative to the eastern ones.

There are three main ore types:

- Banded sulphides with more than 95% pyrite (FeS₂) accompanied by chalcopyrite (CuFeS₂), sphalerite (ZnS), and galena (PbS);
- Vein or disseminated ore invariably associated with silicification and containing pyrite and chalcopyrite; and
- Lead-zinc ore (galena and sphalerite) with banded pyrite.

All three ore types have minor quantities of arsenic and bismuth minerals.

The uppermost 30 to 60 m of the deposits have been oxidised. The most important minerals include iron oxides, chalcocite (Cu_2S) and covellite (CuS) together with various copper and iron oxides.

1.4.2 Hydrogeology

The bedrock is overlain by subsoils derived from glacial till and weathering of bedrock. Subsoils are thin (<2 metres) or absent on hilltops and thicker (>2 metres) along valley floors. The Avoca River valley itself comprises a thick (10-30 metres) sequence of coarse-grained alluvial sediments.

In terms of groundwater yield, the GSI classifies the bedrock in the Avoca mines area as poorly productive: PI - Poor aquifer, generally unproductive except for local zones and Pu - Poor aquifer, generally unproductive.

Overall water movement consists of three primary pathways:

 Surface runoff (overland flow). Within the mines area, surface drainage is influenced by the spoil piles and open pits on both sides of the river. The open pits collect rainwater (directly) and runoff (indirectly);



- Interflow or transition zone (flow in subsoils and/or along the top of bedrock). Near the Avoca River, interflow will enter the alluvium and the Avoca River or emerge as seeps or springs. The transition zone may be only a few metres thick, and is regarded as being more permeable or transmissive than deeper bedrock; and
- "Deep" groundwater flow at Avoca occurs in discrete fractures or fracture zones which represent zones of enhanced permeability. Deep groundwater will also be captured by underground mine workings in the mine area. Near the Avoca River, deep groundwater will also enter the alluvium.

1.5 Description of Adit Discharges

Map 1 in <u>Appendix A</u> shows the adits with active discharge that were sampled and are described in this section.

The **Cronebane Intermediate Adit** (also known as Fathom Stope 43) flows from an opening in the southeast wall of the East Avoca Pit and across the bottom of the pit forming a lake on the southwest end. Two outflow points exist within the lake (53 stope upper end and 53 stope lower end), which both discharge to the 850 Adit.

The **Cronebane Shallow Adit** discharges on the side of a hill southeast of the East Avoca Pit. The adit is believed to drain the unsaturated workings in the Cronebane and Connary areas. The discharge follows a ferricrete-lined channel which feeds into a culvert and passes under the road. Shortly after passing under the road, the discharge soaks into the ground in a low wooded area (just north of the yellow access gate).

The **Deep Adit** is located northeast of Whites Bridge and is the main mine drainage for East Avoca. The water flows from the portal into a ditch that runs semi-parallel to the Avoca River before discharging into the river. A box culvert was installed at the entrance of the Deep Adit in October 2014 as part of the Avoca Works project. The hydro-morphology of the Deep Adit channel has changed on several occasions in the period 2014-2015 with the full or partial Deep Adit flow being diverted through the Millrace at different times. From February 2016 to March 2017, the deep adit flow was discharging to the Avoca River at its normal discharge point. This was due to completed groundworks which was preventing the flow from being diverted to the Millrace channel. Figure 1 illustrates the changing hydro-morphology of the Deep Adit and Millrace area.

The **850** Adit is also located northeast of Whites Bridge. In 2009 a significant volume of water was observed issuing from the adit for the first time since more routine investigations began in 2007. This was investigated on behalf of the Department by GWP Consultants who concluded that the water flow is most likely to be due to a collapse inside the mine, diverting water from the Deep Adit to higher levels. Since the initial discharge in 2009, flow has been intermittently observed from the 850 Adit and it was added to the sampling programme in February 2014.

In October 2014, an initial survey of the 850 Adit was completed. Water was found to be backed up approximately 1 m above ground level behind an earth berm and the adit drained for approximately two days before a survey of the adit could be attempted. When the survey was completed, a drainage pipe was installed and earth berm replaced to prevent access to the 850 Adit.



As a result of remediation works onsite, the flow from the 850 Adit is now piped directly to the Deep Adit box culvert, discharging downstream of the Deep Adit portal. Flow was observed from the 850 Adit in March 2017.

The **Road Adit** is located adjacent to Rathdrum Road at the base of the Ballymurtagh landfill (formerly the Pond Lode Pit). Previously the Road Adit discharge ran alongside a ditch beside the road and then discharged to the Avoca River just downstream of the Wicklow County Council Yard Gauging Station. Since about October 2014, the Road Adit no longer flows along the road and instead goes through a pipe underneath the council yard and discharges directly into the Avoca River above the Wicklow County Council Gauging Station.

The **Spa Adit** is located in West Avoca on a hillside approximately 150 m northwest of (and approximately 40 m above) the Wicklow County Council recycling centre. The flow discharges from a break in a pipe which was observed soaking into the ground. As the loads are very low and the discharge does not flow into the Avoca or one of the tributaries within the basin, the importance of the Spa Adit is relatively low and was not sampled in March 2017.

The **Ballygahan Adit** discharges through a 100 mm (4 inch) pipe to the Avoca River over a steep bank just north of the Wicklow County Council Maintenance Yard. There are also some seeps from the river bank probably due to the pipe leaking or flow in the adit not captured by the pipe. No visible discharge was issuing from the pipe in March 2017.



Figure 1 Location of the Deep Adit Confluence Discharge (March 2017)



Section 2

Methodology

2.1 Field Sampling Methods

2.1.1 Groundwater Sampling

Eight groundwater monitoring wells were sampled on 27 and 28 March 2017. Details of groundwater monitoring locations are listed in Table 1 and illustrated on Map 2 and 3 in <u>Appendix</u> <u>A</u>.

Monitoring wells installed in the alluvium in 2007 as part of the previous study for the Department (CDM 2008) include:

- Two nested wells in the Emergency Tailings area, downgradient of the West Avoca pit and slightly side-gradient of the Ballymurtagh Landfill (MWET1, shallow, and MWET2, deep);
- Two nested wells in the Tigroney West spoil area near the Deep Adit (MWDA1, shallow, and MWDA2, deep);
- One shallow well upgradient of the Deep Adit area, near the eastern margin of the alluvial sediments (MWPF1); and
- One shallow well immediately adjacent to and downgradient of the tailings dam at Shelton Abbey (MWSA2).

The Wicklow County Council monitoring wells are as follows:

Three of the wells were installed for Ballymurtagh Landfill monitoring purposes (GW1/05, GW2/05 and SG104), which are located downgradient of the landfill (in West Avoca) and one located at the toe of the landfill (SG104).

Sample ID	Sample Type	Easting	Northing	Water Level	Field Para- meters	Sample for Lab Analysis	Owner	Depth (m- bgl)	Screen Interval (m bgl)
MWDA1	Borehole	319877	182043	Yes	Yes	Yes	Dept.	12	9.0 – 12
MWDA2	Borehole	319879	182039	Yes	Yes	Yes	Dept.	24.9	21.9 – 24.9
MWET1	Borehole	319916	181778	Yes	Yes	Yes	Dept.	10.9	7.8 – 10.6
MWET2	Borehole	319917	181781	Yes	Yes	Yes	Dept.	21	17 – 20
MWPF1	Borehole	319678	182296	Yes	Yes	Yes	Dept.	10	4.7 – 7.7
MWSA2	Borehole	321566	175292	Yes	Yes	Yes	Dept.	12.6	8.0 - 11
GW1/05	Borehole	319880	181673	Yes	Yes	Yes	WCC	31	25.0 - 31
GW2/05	Borehole	319880	181673	Yes	Yes	Yes	WCC	10	4.0 - 10
SG104	Borehole	319806	181523	Yes	Yes	Yes	WCC	26.8	-

Table 1 Location of Avoca Groundwater Monitoring Points

Groundwater samples were collected using procedures consistent with the Low Flow Groundwater Sampling Procedure (SOP 1-12) detailed in the Monitoring Plan. Groundwater was collected using



a portable submersible low-flow pump (Grundfos MP1). The static water level was recorded prior to pumping and then 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 stabilised. The results were recorded on the Groundwater Purging and Sampling Form approximately every five minutes during the purging process. The field sheets are contained in Appendix H and physico-chemical field data are summarised in Appendix A of the Data Report.

After the well was purged and stable parameters 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 exceptions to the low-flow sampling procedure were for GW2/05 where sufficient water was not present in the well and GW1/05 where a blockage exists in the well which obstructs access. These samples were collected using single use bailers, after greater than three volumes of the well had been purged (calculated as πr^2h – where r is the inner casing radius and h is the height of the water column) and the field parameters had stabilised.

Groundwater levels were measured at the nine wells using a portable electronic water level recorder. Automatic groundwater recorders have been placed in six wells and the data were downloaded. Groundwater level data are discussed in Section 6 and the data are contained in Appendix C of the Data Report.

Note that MWSA2 (Shelton Abbey) was not included in the March 2017 sampling programme, as per instructions from the Department.

2.1.2 Surface Water Sampling

Nineteen surface water locations were sampled between 27 and 30 March 2017 as listed in Table 2 and shown on Map 1 and 2 in <u>Appendix A</u>. One sampling location on the Avoca River (DS Ballygahan Adit) was removed from the monitoring programme for health and safety reasons. Additionally, the US Road Adit sampling point captures the impact of the Ballygahan Adit and seeps sufficiently. No sample was collected from Ballygahan Adit because it was dry at the time of sampling. As well, no surface water sampling was undertaken at Shelton Abbey in March 2017, as per instructions from the Department.

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 using a GPS. Photographs were taken of the surface water sampling locations (Appendix D of the Data Report). All sample locations were approached from downstream so that the underlying sediments were not disturbed. Samples were grab samples collected from a well-mixed portion of the water stream, where possible. For monitoring locations on the Avoca River, samples were collected as composite samples across the River, whereby a volume of water was collected along a transect across the



river in proportion to the river flow. Water was collected from approximately 6 to 10 locations (depending on the width of the channel) along the transect.

Samples were collected in new laboratory-provided bottles with the correct preservatives. The sample bottles that required no filtering (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.

Site Name	Sample Site Description	Easting	Northing	Flow Measurement Method	Sample collected?	
Site T1	Avoca River Location (Upstream of Whites Br.)	319239	182805	Flow Meter - Marsh McBirney (Avonbeg) and Float method with depth profile from bridge (Avonmore)	Yes	
Upstream (US) of Whites Bridge	Avoca River Location (between Site T1 and Whites Br.)	319584	182389	Equal to flow recorded at Whites Bridge GS	Yes	
Whites Bridge	Avoca River Location (at Whites Br.)	319773	182066	Equal to flow recorded at Whites Bridge GS	Yes	
Whites Bridge Gauging Station GS (10044)	Avoca River Location (90m downstream of Whites Br.)	319843	182015	Automatic recorder - Whites Bridge GS (Data from EPA)	Yes	
Downstream (DS) Deep Adit	Avoca River Location (Downstream of Deep Adit confluence on the Avoca River)	319951	181922	Equal to flow recorded at Whites Bridge GS	Yes	
Downstream (DS) of Millrace	Avoca River location (Downstream of contaminated Millrace area)	320016	181796	Equal to flow recorded at Whites Bridge GS (less Deep Adit discharge)	Yes	
Upstream (US) of Ballygahan Adit	Avoca River Location (Upstream of Ballygahan Adit discharge)	319936	181633	Equal to flow recorded at Wicklow County Council Maintenance Yard GS (less Road Adit discharge)	Yes	
Upstream (US) of Road Adit	Avoca River Location (Upstream of Road Adit Discharge on the Avoca River)	319942	181532	Equal to flow recorded at Wicklow County Council Maintenance Yard GS	Yes	
Wicklow Co. Co. Maintenance Yard Gauging Station GS	Avoca River Location	319939	181445	Automatic Recorder - Wicklow County Council Maintenance Yard GS (Data from EPA)	Yes	
Site T5	Avoca River Location (Abandoned Coal Yard)	319972	181114	Equal to flow recorded at Wicklow County Council Maintenance Yard GS	Yes	
Avoca Bridge	Avoca River (Upstream of Avoca Bridge)	320372	179932	Float method	Yes	
850 Adit	Adit Discharge (at Deep Adit box culvert)	319850	182123	Bucket and stopwatch method	Yes	

Table 2 Location of Surface Water Monitoring Points



Site Name	Sample Site Description	Easting	Northing	Flow Measurement Method	Sample collected?
Deep Adit	Adit Discharge (at portal)	319850	182123	Flow Meter	Yes
Deep Adit Confluence	Adit Discharge (before entering Avoca River)	319896	181986	Flow Meter	Yes
Road Adit	Adit Discharge (at portal)	319858	181512	Measured from permanent flume	Yes
Road Adit Confluence	Adit Discharge (before entering Avoca River)	319942	181513	Flow Meter	Yes
Cronebane Intermediate Adit	Adit Discharge	320320	182749	Flume	Yes
Cronebane Shallow Adit	Adit Discharge	320268	182646	Flume	Yes
Ballygahan Adit	Adit Discharge	319940	181610	No Flow	No

Water quality indicator parameters were monitored during sampling by collecting them directly from the stream or discharge when possible, using a multi-parameter probe. 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 eleven locations (see Table 2) 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. Data were obtained from the EPA for the existing automatic recorders at Whites Bridge GS (EPA station 10044) and Wicklow County Council Maintenance Yard GS (EPA Station 10045) and projected to seven locations. 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. The methods used included using a portable flume (for small discharges), a Marsh McBirney meter (flow meter) to measure flow velocities and depths at regular intervals across the streams by wading, and for very small discrete discharges, a stop watch and calibrated volume container were used.

The Float Method was used when it was unsafe to wade into the river. It is the least accurate method but it provides a reasonable estimate. This method requires the measurement and calculation of the cross-sectional area of the channel as well as the time it takes an object to "float" a designated distance. The water depth was measured from a bridge at regular intervals (approximately 8 locations). The float was released into the channel upstream from the beginning of the section and measured the amount of time it takes the "float" to travel the marked section. This was repeated at least three times and the average time calculated.

2.1.3 Field QA/QC Samples

In accordance with the QA/QC Protocols set out in the Monitoring Plan, the following field QA/QC samples were collected (also see Table 3):

- 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:
 - Two 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 materials (SRMs) containing known concentrations of 18 metals were shipped blind to ALcontrol laboratory (the SRM certificate is contained in Appendix G of the Data Report).
- One water blank was collected of the DI water during the sampling event. An additional filtration blank using DI water was collected in order to try to quantify any contamination caused by the filtration procedure.

Sample IDs for the field QA/QC samples are listed in Table 3. The duplicate samples are an independent check on sampling and laboratory precision. The standard reference material is an independent check on laboratory accuracy. The decontamination blank is 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).



Sample ID	QA/QC Sample Type	Description
AVGD01.9	GW Duplicate	Duplicate of MWET1
		DI water (Lennox Lab Supplies: Batch No: 701-5715)
AVDB01.9	GW Decontamination blank	Pumped through groundwater pump after final decon at
		site MWET1)
AVSD01.9	SW Duplicate	Duplicate of US Road Adit
AVSD02.9	SW Duplicate	Duplicate of Cronebane Intermediate Adit
		DI water (Lennox Lab Supplies: Batch No: 701-5715) poured
AVDB02.9	SW Decontamination blank	over SW composite sample bottle after final decon at US
		Ballygahan Adit
AVSR01.9	Standard Reference Material	Water ERA "Trace Metals" Lot #P256-740D
AVSR02.9	Standard Reference Material	Water ERA "Trace Metals" Lot #P256-740D
	Filtration blank	Deionised water filtered onsite (Lennox Lab Suppliers. Batch
VVB01.9		No: 701-5715)
	Water blank	Deionised water (Lennox Lab Suppliers. Batch No: 701-
VVDU2.9		5717)

Table 3 Field QA/ QC Sample IDs and Descriptions

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 of sample collection. Samples were stored appropriately so they remained representative of the time of sampling. Sufficient ice packs and ice were 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. Samples were packed so that no breakage would occur. Signed COCs are provided in Appendix E of the Data Report.

2.3 Laboratory Sample Analysis

Analysis of water samples was undertaken 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, ammoniacal nitrogen as N, sulphate and dissolved metals including AI, Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, V and Zn.

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.



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 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:

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

where: %R

%R=Percent recoveryA=Measured value of analyte (metal) as reported by the laboratoryT=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:

Б

RPD = -(1)	$\frac{\mathbf{D}_1 - \mathbf{L}}{\mathbf{D}_1 + \mathbf{D}_2}$	$\frac{v_2}{x \ 0.5} \ x \ 10$	0
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. DI water blanks and DI filtration blanks were also analysed. 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 3 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 3 for sample IDs). Analyses of these samples were used to evaluate the adequacy of the sampling equipment cleaning or decontamination procedure;
- Standard Reference Material (SRM): Two certified water SRMs were sent blind to the laboratory (Sample IDs AVSR01.9 and AVSR02.9) to evaluate laboratory accuracy. The certified SRM was supplied by ERA Certified Reference Materials and was Lot #P256-740D (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.
- One water blank was collected of the DI water during the sampling event. An additional filtration blank using DI water was collected in order to try to quantify any contamination caused by the filtration procedure.



3.2 Results of Field QA/QC Samples

3.2.1 Duplicates

Three duplicate samples (one groundwater sample and two surface water samples) were generated in the field and sent blind to ALcontrol for analysis. Table 4 provides the results of the 15 metals for the three duplicate samples and the calculated RPD between each pair of samples. Note if both the original and duplicate results were less than the limit of detection (LOD) then the RPD was zero. In addition, if one of the values was less than the LOD, the LOD value is used to calculate the RPD.

All of RPD values were significantly below 50% (typically less than 10%) and the RPDs for the key parameters ranged from 0.7 to 6.6% for aluminium, 0.6 to 4.5% for copper, 2.2 to 4.4% for manganese and 1.2 to 2.5% for zinc which is considered very good. The highest reported value of the duplicate pair is selected for interpretive use in Section 4 therefore providing a conservative evaluation.

Dissolved Metal	LOD (µg/l)	MWET 1	AVGD0 1.9	% RPD	US Road Adit	AVSD0 1.9	% RPD	Crone- bane Inter. Adit	AVSD0 2.9	% RPD
Aluminium	<2	80000	82800	3.4	145	144	-0.7	63800	59700	-6.6
Antimony	<0.16	<0.96*	<0.96*	0	<0.16	<0.16	0	<0.96*	<0.96*	0
Arsenic	<0.51	3.33	<3.06*	-8.5	<0.51	0.517	1.4	10.6	10.8	1.9
Barium	<0.2	3.32	3.44	3.6	4.7	4.87	3.6	9.24	9.01	-2.5
Cadmium	<0.08	22	21.3	-3.2	0.252	0.314	21.9	96.5	96.8	0.3
Chromium	<1.2	6.81	6.95	2.0	<1.2	<1.2	0	<7.2*	<7.2*	0
Cobalt	<0.15	131	132	0.8	0.37	0.385	4.0	82.9	86	3.7
Copper	<0.85	6590	6550	-0.6	10.9	11.4	4.5	3430	3510	2.3
Iron	<19	59.1	56.8	-4.0	0.117	0.125	6.6	62.4	58.3	-6.8
Lead	<0.1	5.49	5.61	2.2	1.93	2.02	4.6	1170	1200	2.5
Manganese	<0.76	5360	5480	2.2	22.3	23.3	4.4	2150	2220	3.2
Molybdenum	<0.62	<3.72*	<3.72*	0	<0.62	<0.62	0	<3.72*	<3.72*	0
Nickel	<0.44	62.3	66.3	6.2	0.753	0.786	4.3	43.3	45.4	4.7
Vanadium	<1.3	743	820	9.9	<1.3	<1.3	0	<1.3	<1.3	0
Zinc	<1.3	7190	7280	1.2	96.5	98.9	2.5	27300	27700	1.5

Table 4 Duplicate Pair Reported Values (µg/I) and Calculated % RPD

Notes:

Bold indicates an exceedance in the Duplicate RPD acceptance criteria

*The LOD was raised due to a dilution that was carried out on the sample.

3.2.2 Decontamination Blanks

Two 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 5 provides the results of the 15 metals for the two decontamination blank samples, the DI water blank and filtration blank samples and the associated laboratory method blank samples. The majority of reported concentrations were below the limits of detection. Most metals were analysed by ICP-MS to achieve the lowest possible detection limits. The limits of detection ranged from 0.02 to 2 μ g/l except for iron with a detection limit of 19 μ g/l.

Detections were observed for six dissolved metals ranging from 0.117 to 2.77 μ g/l. Two of the metals (aluminium and zinc) detected in the decontamination blanks were also detected in the DI



water filtration blank (WB01.9). The levels of detections in the decontamination blanks were similar to those found in the DI water filtration blank. Relatively low concentrations of dissolved antimony, copper, lead and molybdenum were also found in the decontamination blanks but not the DI water blanks.

None of the parameters which were detected in the decontamination blanks but not detected in the DI water blank samples were greater than ten times the detection limit; In AVDB01.9, copper (1.33 μ g/l) and in AVDB02.9, antimony (1.41 μ g/l), lead (0.117 μ g/l) and molybdenum (1.39 μ g/l). Additionally, none of the reported values which were detected in both the DI water blank samples and the decontamination blank were greater than ten times the detection limit. All of the detections were less than the assessment criteria outlined in Section 4; therefore, these low concentrations in the blanks do not affect interpretation of results. Overall, the decontamination procedures employed in the field were adequate.

To assess the level of field cross contamination, the concentrations in the decontamination blanks were compared with the concentration in the preceding environmental samples. In AVDB01.9, aluminium (2.77 μ g/l) was 0.003% of the preceding sample and copper (1.33 μ g/l) and zinc (1.73 μ g/l) were 0.02%, respectively. In AVDB02.9, dissolved lead (0.117 μ g/l) was 9% of the preceding sample. Dissolved antimony (1.41 μ g/l) and molybdenum (1.39 μ g/l) were below the detection limit in the preceding sample lab cross contamination.

The results from the laboratory instrumentation blank were obtained from ALcontrol to determine if any contamination occurred within the laboratory (Table 5). Dissolved molybdenum was detected in the method blank (1.71 μ g/l) for Sample Batch 160904-11 and was similar to the concentration in the decontamination blank sample (1.39 μ g/l).

Overall, the decontamination procedures were adequate and blank samples do not indicate any cross-contamination in the field and therefore all the results are considered acceptable and can be used for their intended purposes.

Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.9 (µg/l)	Water Blank WB02.9 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank AVDB01.9 (μg/l)	Laboratory Method Blank (µg/l)	Decon blank AVDB02.9 (μg/l)	Laboratory Method Blank (µg/l)
Sample batch:		170330-75		170330-75		160904-11		
Aluminium	<2	2.42	<2	<2	2.77	<2	<2	2.54
Antimony	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	1.41	<0.16
Arsenic	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51	<0.16	<0.51
Barium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.51	<0.2
Cadmium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.2	<0.08
Chromium	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<0.08	<1.2
Cobalt	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<1.2	<0.15
Copper	<0.85	<0.85	<0.85	<0.85	1.33	<0.85	<0.15	<0.85
Iron	<19	<19	<19	<19	<19	<19	<0.85	<19
Lead	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.117	<0.1
Manganese	<0.76	<0.76	<0.76	<0.76	<0.76	<0.76	<0.76	<0.76
Molybdenum	<0.62	<0.62	<0.62	1.36	<0.62	1.36	1.39	1.71

Table 5 Water Blank and Decontamination Blank Reported Values and Laboratory Method Blanks (µg/l)



Dissolved Metal	LOD (µg/l)	Filtration Blank WB01.9 (µg/l)	Water Blank WB02.9 (µg/l)	Laboratory Method Blank (μg/l)	Decon blank AVDB01.9 (µg/l)	Laboratory Method Blank (µg/l)	Decon blank AVDB02.9 (µg/l)	Laboratory Method Blank (µg/l)
Sample batch:		170330-75		1703	30-75	160904-11		
Nickel	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44
Vanadium	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3
Zinc	<1.3	1.44	<1.3	<1.3	1.73	<1.3	<1.3	<1.3

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 in the lab method blank that was also detected in a field water or decontamination blank in the same batch

3.2.3 Standard Reference Materials

As previously discussed, two certified water SRMs were sent blind to the laboratory (Sample IDs AVSR01.9 and AVSR02.9) to evaluate laboratory accuracy. The ALcontrol laboratory reports are provided in Appendix F of the Data Report. Table 6 summarises the SRM results and provides the calculated %R values for the 15 requested metals.

Reported values for the majority of the metals were within the acceptable ranges. Dissolved aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, manganese, molybdenum, nickel and zinc are in excellent agreement with the certified value (%R ranged from 93 to 109%).

One of the reported values for dissolved antimony (113%), lead (111%) and vanadium (77%) were outside the acceptable range, however the corresponding reported values for the second SRM sample were within acceptable ranges and therefore the interpretation of the results is not affected. Both of the reported values for dissolved iron were low at 80 and 84%, respectively, which fall outside the expected range. This indicated that there may be bias (low) in the result for iron and any use of these values should be noted with this observation.

Note that dissolved vanadium for AVSR02.9 was reported as 10,100 μ g/l in the corresponding Data Report (Document Ref: 95735/40/DG/35, dated March 2017). This value was subsequently determined to be the diluted value rather than the neat result and is therefore incorrect. The correct result for dissolved vanadium is 1,740 μ g/l as detailed in Table 6.

Dissolved	Certified Value	Acceptan	ce Limits	AV/SR01 9		A\/SR02 9	
Metal	(μg/l)	(μg/l) Lower Upper (μg/l) (%) (%)		(μg/l)	% R	(μg/l)	% R
Aluminium	1630	87	114	1720	106	1730	106
Antimony	814	87	111	852	105	920	113
Arsenic	254	87	111	254	100	277	109
Barium	827	91	109	877	106	846	102
Cadmium	256	89	106	256	100	267	104
Chromium	870	91	109	900	103	862	99
Cobalt	413	93	111	429	104	383	93
Copper	587	90	109	607	103	610	104
Iron	545	90	111	438	80	459	84

Table 6 SRM Reported Values (μ g/I) and Calculated % R



Dissolved	Certified Value	Acceptance Limits		۸\/SR01 9		AV/SR02 9	
Metal	(μg/l)	Lower (%)	Upper (%)	(μg/l)	% R	(μg/l)	% R
Lead	413	90	110	460	111	416	101
Manganese	793	92	109	832	105	784	99
Molybdenum	577	90	109	572	99	591	102
Nickel	531	91	109	543	102	544	102
Vanadium	1640	91	107	1260	77	1740	106
Zinc	1770	90	110	1790	101	1680	95

Notes:

Bold indicates an exceedance in acceptance limits

3.3 Laboratory QA/QC Samples

3.3.1 ALcontrol

ALcontrol undertakes 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;
- Instrumental 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. None of the sample holding times were exceeded. ALcontrol provided the associated analytical quality control samples (AQC) data. The percentage recovery results for the AQC samples that were analysed with the regular environmental samples were checked against the individual lower control and upper control limits. Several of the AQC samples exceeded the upper control limit as detailed in Appendix F of the corresponding Data Report. ALcontrol advised that the AQC samples have two limits, a warning limit and a failure limit. Tests which exceed the failure limit are immediately re-run but tests that exceed the warning limit can still be reported. The test only fails automatically if there



are multiple warning limit exceedances. Laboratory analysts check the individual cases where the warning limit is exceeded and report the results if they are satisfied with all other factors involved.

3.4 Summary of Data Checks

3.4.1 Field physico-chemical Versus Laboratory Data

Table 7 summarises the field and laboratory results for pH and provides the calculated %RPD values between the two results. 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 pH were good at less than 39.9%. 85% of samples had calculated %RPD values of less than 20%. Field pH is more representative of actual conditions and is used for interpretive purposes. Recordings of pH in the field are typically lower than the laboratory due to carbon dioxide degassing during transport or within the laboratory itself. Overall, the %RPDs between the field and laboratory data are considered satisfactory.

	рН	pH Field	% RPD		
Sample Description	pH Units				
Avoca Bridge	6.82	5.94	-13.8		
DS Deep Adit	6.96	5.91	-16.3		
DS Millrace	6.8	5.87	-14.7		
Site T1	6.94	4.63	-39.9		
Site T5	6.75	5.89	-13.6		
US Ballygahan Adit	6.99	6.35	-9.6		
US Road Adit	6.91	6.12	-12.1		
US Whites Bridge	7.05	5.07	-32.7		
Whites Bridge	7.12	6.06	-16.1		
Whites Bridge GS	7.01	5.62	-22.0		
Wicklow Co. Maintenance Yard GS	6.73	6.32	-6.3		
850 Adit Confluence	3.14	2.73	-14.0		
Cronebane Intermediate Adit	2.97	2.94	-1.0		
Cronebane Shallow Adit	2.88	2.62	-9.5		
Deep Adit	3.4	3.34	-1.8		
Deep Adit Confluence	3.35	2.78	-18.6		
Road Adit	4.26	4.19	-1.7		
Road Adit Confluence	4.35	4.27	-1.9		
MWDA1	3.17	2.87	-9.9		
MWDA2	4	3.65	-9.2		
MWPF1	5.14	4.11	-22.3		
SG104	3.04	2.76	-9.7		
GW1/05	3.81	3.65	-4.3		
GW2/05	3.82	3.63	-5.1		
MWET1	3.58	3.41	-4.9		
MWET2	5.99	6.09	1.7		

Table 7 Field physico-chemical data and Laboratory Reported Values and Calculated % RPD

Notes:

Bold indicates an exceedance in acceptance limits



Section 4

Results and Evaluations

This section provides a statistical summary of the analytical results for groundwater and surface water 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 8 provides a summary of the reported dissolved concentrations of the eight groundwater samples. Included in the table are the minimum, maximum, mean and standard deviation (SDEV). Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2	8	7	1 (<12*)	809,000	148,000	271,000
Antimony	<0.16	8	1	0.08	1.2	-	-
Arsenic	<0.51	8	7	0.26	44.2	9.03	14.4
Barium	<0.2	8	8	1.46	20.4	8.2	6
Cadmium	<0.08	8	8	0.24	302	64.8	100
Chromium	<1.2	8	3	0.6	23.5	6.27	7.29
Cobalt	<0.15	8	8	0.52	717	194	219
Copper	<0.85	8	7	0.43 (2.55*)	57,100	11,500	18,800
Iron	<19	8	8	76.9	95,300	38,100	44,200
Lead	<0.1	8	8	0.37	47.9	9.36	16
Manganese	<0.76	8	8	17.7	35,500	13,100	13,500
Molybdenum	<0.62	8	2	0.31	4.19	2.46	-
Nickel	<0.44	8	8	3	266	80	82.2
Vanadium	<1.3	8	0	0.65	0.65	-	-
Zinc	<1.3	8	8	42.9	124,000	31,000	41,900

Table 8 Summary of Dissolved Metal Concentrations in Groundwater

Notes:

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

* LOD was raised due to a dilution that was carried out on the sample. Where there were detections the maximum reported value was presented as the maximum value.

Dissolved aluminium, copper, iron, manganese and zinc were found in significantly high concentrations in the majority of groundwater samples. The shallow well MWPF1 located upgradient of the Deep Adit area, near the eastern margin of the alluvial sediments had the lowest concentrations of dissolved metals. However, MWET2 had the lowest concentration of dissolved aluminium (<12 μ g/l) and copper (<5.1 μ g/l). SG104 had the highest concentrations of aluminium (109,000 μ g/l), copper (57,100 μ g/l), nickel (266 μ g/l), zinc (124,000 μ g/l) and arsenic (44.2 μ g/l).



MWDA2 had the highest concentration of iron (95,300 μ g/l) and MWET2 had the highest concentration of dissolved manganese (35,500 μ g/l). Dissolved arsenic was detected in all groundwater samples with the exception of MWPF1.

4.1.2 Surface Water Sample Results

Surface water samples were collected for two major categories: the first includes mine adit discharges and the second includes the Avoca River. Table 9 provides a summary of the reported results of the seven adit discharge samples and Table 10 provides a summary of the dissolved metals of the 11 river samples. Included in the tables are the minimum, maximum, mean and standard deviation (SDEV). Where the reported values were below the detection limit, the values were substituted with a value of half the limit of detection. The highest reported value of the field duplicate pair was used where applicable.

	-				-		
Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2	7	7	9,960	351,000	95,100	117,000
Antimony	<0.16	7	0	0.08 (0.48*)	0.08 (0.88*)	-	-
Arsenic	<0.51	7	7	8.28	40.1	16.3	11.5
Barium	<0.2	7	7	8.16	18	12.2	4.12
Cadmium	<0.08	7	7	7.64	246	81.4	80.2
Chromium	<1.2	7	0	0.06 (3.6*)	0.06 (6.6*)	-	-
Cobalt	<0.15	7	7	83.7	246	118	58.3
Copper	<0.85	7	7	232	7,040	2,640	2,630
Iron	<19	7	7	16,900	133,000	76,700	42,800
Lead	<0.1	7	7	300	1,680	977	515
Manganese	<0.76	7	7	2,220	9,240	5,230	3,180
Molybdenum	<0.62	7	0	0.31 (1.86*)	0.31 (3.41*)	-	-
Nickel	<0.44	7	7	34.3	132	53.9	35
Vanadium	<1.3	7	0	0.65	0.65 (7.15*)	-	-
Zinc	<1.3	7	7	7,960	111,000	38,100	35,300

Adit Discharges

 Table 9 Summary of Dissolved Metal Concentrations in Adit Discharges

Notes:

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

* LOD was raised due to a dilution that was carried out on the sample.

Dissolved aluminium, copper, iron, manganese and zinc were found in significantly high concentrations in all of the adit discharges. The Cronebane Shallow Adit had the highest concentrations of dissolved metals including aluminium (351,000 μ g/l), copper (7,040 μ g/l), iron (133,000 μ g/l), nickel (132 μ g/l) and zinc (111,000 μ g/l). Significant concentrations of arsenic were recorded at all sampling locations ranging from 8.28 μ g/l at the 850 Adit to 40.1 μ g/l at Cronebane Shallow Adit. No detections were recorded for antimony, chromium, molybdenum and vanadium. No samples were collected from the Ballygahan Adit because it was not discharging water in March 2017.



Dissolved Metal	LOD (µg/l)	Number	Number of Detections	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)	SDEV
Aluminium	<2	11	11	52.4	167	123	44.5
Antimony	<0.16	11	0	0.08	0.08	-	-
Arsenic	<0.51	11	3	0.26	0.59	0.34	0.15
Barium	<0.2	11	11	4.66	6.33	5.03	0.46
Cadmium	<0.08	11	8	0.04	0.59	0.26	0.19
Chromium	<1.2	11	0	0.6	0.6	-	-
Cobalt	<0.15	11	7	0.08	0.89	0.43	0.31
Copper	<0.85	11	9	0.43	16	8.5	5.71
Iron	<19	11	11	56.8	513	194	154
Lead	<0.1	11	11	0.67	4.05	2.08	1.19
Manganese	<0.76	11	11	7.15	59.1	27.7	19.1
Molybdenum	<0.62	11	1	0.31	1.14	-	-
Nickel	<0.44	11	11	0.69	1.04	0.83	0.12
Vanadium	<1.3	11	0	0.65	0.65	-	-
Zinc	<1.3	11	11	17	228	100	75

Avoca River

Table 10 Summary of Dissolved Metal Concentrations in Surface Water

Notes:

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

* LOD was raised due to a dilution that was carried out on the sample.

Dissolved metals were detected upgradient of the mining area at Site T1 with concentrations of aluminium at 52.4 μ g/l, iron at 56.8 μ g/l, manganese at 7.36 μ g/l and zinc at 17.2 μ g/l.

Between Site T1 and US Whites Bridge (365m upstream of the bridge) no significant increases in dissolved metals were recorded. A slight increase in dissolved metals was recorded at Whites Bridge (at the bridge) which is typically the first sampling location along the Avoca River within the mining area where increases in metals concentrations are recorded. Concentrations of aluminium, copper and zinc were 67.6 μ g/l, 1.28 μ g/l and 21.9 μ g/l, respectively.

Along the Avoca River the concentrations of dissolved metals were variable; the highest dissolved aluminium (167 μ g/l) and copper (16 μ g/l) were recorded at US Ballygahan Adit. The highest dissolved cadmium (0.591 μ g/l) and zinc (228 μ g/l) were recorded at DS Millrace. Concentrations of dissolved manganese (59.1 μ g/l) and iron (513 μ g/l) were highest at WCC Maintenance Yard GS (downstream of the Road Adit discharge).

These findings are discussed further in Section 5 which provides an analysis of dissolved metal loadings.

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 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 11. 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 11).

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 Avoca mining area was determined to be 31 mg/l CaCO_3 (CDM, 2008) and the appropriate ecological assessment criteria are highlighted in bold in Table 11.

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

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

The two main receptors to groundwater in the Avoca mining area 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 discussed for surface water were utilised for screening purposes for groundwater (Table 11 and Table 12).

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
рН	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. Only relevant to surface water
Arsenic	μg/l	25	-	S.I. No. 272 of 2009	
Cadmium	μg/I	≤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 Class 5: ≥200 mg CaCO3/l)
Chromium	μg/l	3.4	-	S.I. No. 272 of 2009	
Copper	μg/I	5 or 30	-	S.I. No. 272 of 2009	5 μg/l applies where the water hardness measured in mg/l CaCO3 is < 100:

Table 11 Surface Water and Groundwater Assessment Criteria for Biological Elements



Parameter	Unit	AA	MAC (or 95%ile)	Source	Description
					30 μg/l applies where the water hardness > 100 mg/l CaCO3.
Lead	μg/l	7.2	-	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 st	andards:				
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

Bold indicates the selected assessment criteria for ecological health

Table 12 Surface Water and Groundwater Assessment Criteria for Drinking Water

Parameter	Unit	Parametric value
рН	pH units	>6.5 to <9.5
Conductivity	mS/cm	2.5
Ammonium	mg/l	0.3
Sulphate	mg/l	250
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
Nickel	μg/l	20



4.1 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.

Table B-2 in <u>Appendix B</u> highlights the exceedances of the assessment criteria. Where exceedances of the ecological assessment criteria exist, 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 exceeded both the ecological and human health criteria and these results are highlighted in pink. The results and exceedances are discussed in this section.

4.1.1 Groundwater Assessment

Monitoring wells

The pH was found to be acidic in the majority of groundwater samples with results ranging from 2.8 to 6.1 (field). All exceeded the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria, except one location (MWET2) which only exceeded the criteria for human health with a pH of 6.1. The specific conductance ranged from 0.152 to 7.859 mS/cm with the lowest conductivity located at MWPF1 and the highest at SG104. The specific conductance exceeded the human health criteria (2.5 mS/cm) at MWET2 and SG104.

Sulphate levels greatly exceeded the criteria for human health of 250 mg/l in all of the monitoring wells with values ranging from 748 to 9,040 mg/l. One exception was at MWPF1 where sulphate was below the human health assessment criteria with a value of 32.8 mg/l. Ammonia exceeded both the ecological (0.14 mg/l) and human health (0.3 mg/l) assessment criteria in four monitoring wells with concentrations ranging from 0.582 to 2.35 mg/l.

The dissolved metal concentrations were elevated in the majority of the monitoring wells with numerous exceedances of ecological, human health criteria or both, particularly for aluminium, cadmium, copper, iron, manganese, nickel and zinc (Table B-2 in <u>Appendix B</u> includes the full listing). There were seven detections of dissolved arsenic, only SG104 with a result of 44.2 μ g/l exceeded both the human health criteria (10 μ g/l) and ecological assessment criteria (25 μ g/l).

The dissolved aluminium and copper concentrations at MWET2 (deep) (<12 and <5.1 μ g/l) were significantly lower than at MWET1 (shallow) which had concentrations of 82,800 and 6,590 μ g/l, respectively. MWET1 exceeded both the ecological and human health criteria for aluminium (1,900 and 200 μ g/l) and copper (5 and 2,000 μ g/l). This could be explained by the apparent confined nature of MWET2 (heads in MWET2 are higher than in MWET1) and also because MWET1 is screened directly beneath the Emergency Tailings deposits.

The bedrock monitoring well GW1/05 showed higher dissolved metal concentrations than its nested, shallow alluvial well GW2/05. For example, dissolved copper was 8,100 μ g/l in GW1/05 and 7,960 μ g/l in GW2/05. Both monitoring wells exceeded the ecological and human health criteria for copper (5 and 2,000 μ g/l). In GW1/05 and GW2/05, levels of dissolved aluminium (68,900 and 49,300 μ g/l), cadmium (26.2 and 16.2 μ g/l), manganese (5,740 and 3,910 μ g/l) and nickel (59.5 and 39.9 μ g/l) exceeded both the ecological assessment criteria and human health assessment criteria respectively.

The groundwater in the shallow well at the Deep Adit area (MWDA1) showed higher dissolved metal concentrations of aluminium and copper (144,000 and 9,610 μ g/l) than at MWDA2 (deep)



which had concentrations of 29,000 and 2,590 respectively. However, both wells still exceeded the criteria for ecological and human health for aluminium and copper. Both monitoring wells exceeded the ecological and human health criteria for cadmium (77.5 and 71.5 μ g/l), manganese (9,560 and 11,700 μ g/l) and nickel (87.2 and 102 μ g/l). As well, the human health criteria of 200 μ g/l for iron is exceeded in both wells (>25,000 and 95,300 μ g/l). As discussed, iron is not an important parameter for human health.

SG104 had the highest levels compared to the other monitoring wells, of dissolved copper (57,100 μ g/l), cadmium (302 μ g/l) and nickel (266 μ g/l), exceeding the ecological and human health criteria. Dissolved cobalt (717 μ g/l), lead (47.9 μ g/l) and zinc (124,000 μ g/l) were also highest in SG104 and exceeded the ecological health criteria.

The well located upgradient of the Deep Adit area and at the eastern margin of the alluvial aquifer, MWPF1, had significantly lower metal concentrations than the other wells. However, the human health assessment criteria for dissolved aluminium (200 μ g/l) was exceeded with a value of 252 μ g/l and the ecological assessment criteria for dissolved copper (5 μ g/l) and dissolved barium (4 μ g/l) was exceeded with values of 35.3 and 9.42 μ g/l, respectively.

4.1.2 Surface Water Assessment

Adit Discharges

The pH was found to be acidic in all adit discharges with results within the range of 2.62 to 4.27 pH (field) which exceeded the acceptable ranges for ecological (4.5 to 9 pH units) and human health (6.5 to 9.5 pH units) criteria. The specific conductance ranged from 1.271 to 3.358 mS/cm. There was one exceedance of the human health criteria (2.5 mS/cm) at the Cronebane Shallow Adit.

Elevated sulphate and ammonia were found at all of the adit discharge locations. Sulphate levels greatly exceeded the criteria for human health of 250 mg/l in all of the adit discharges with values ranging from 651 to 2,820 mg/l. Ammonia was detected in all of the adit discharges ranging from 0.223 mg/l (850 Adit) to 6.29 mg/l (Road Adit). Concentrations of ammonia exceeded the ecological criteria (0.14 mg/l) and the human health criteria (0.3 mg/l) in all of the adit discharge locations with the exception of the 850 Adit, Deep Adit and Deep Adit Confluence which exceeded the ecological criteria.

The dissolved metal concentrations were high in all of the adit discharges. Numerous exceedances of ecological, human health criteria or both exist for the majority of metals analysed including dissolved aluminium, cadmium, copper, iron, manganese, lead, nickel and zinc (Table B-2 in <u>Appendix B</u> includes the full listing).

Dissolved zinc ranged from 7,960 to 111,000 μ g/l which exceeded the ecological assessment criteria of 50 μ g/l. Dissolved aluminium ranged from 9,960 to 351,000 μ g/l which exceeded both the ecological (1,900 μ g/l) and human health (200 μ g/l) criteria. The concentrations of dissolved copper exceeded the ecological assessment criteria (5 μ g/l) in all of the adit discharges and also the human health (2,000 μ g/l) criteria in the Cronebane Shallow Adit (5,480 μ g/l), Cronebane Intermediate Adit (3,430 μ g/l), 850 Adit (4,660 μ g/l) and the Deep Adit confluence (2,190 μ g/l).

Dissolved cadmium (ranging from 7.64 to 246 μ g/l) and dissolved cobalt (ranging from 82.9 to 246 μ g/l) exceeded both the ecological (0.45 μ g/l) and human health (5 μ g/l) criteria. Dissolved lead ranged from 300 to 1,680 μ g/l which exceeded both the ecological (7.2 μ g/l) and human health (10



 μ g/l) criteria. Dissolved nickel ranged from 34.3 to 132 μ g/l which also exceeded both the ecological and human health criteria of 20 μ g/l.

Dissolved arsenic was detected in all of the adit discharges, ranging from 8.28 to 40.1 μ g/l. Concentrations in the Cronebane Intermediate Adit (10.6 μ g/l), Road Adit (118 μ g/l) and Road Adit Confluence (19.5 μ g/l) exceeded the human health criteria of 10 μ g/l. Concentrations in the Cronebane Shallow Adit exceeded the criteria for human health (10 μ g/l) and ecological health (25 μ g/l) with a recorded value of 40.1 μ g/l.

Dissolved iron and manganese were also high in all adit discharges. Iron ranged from 16,900 to 133,000 μ g/l, exceeding the human health assessment criteria of 200 μ g/l at every location. Manganese ranged from 2,150 to 9,240 μ g/l which exceeded the criteria for human health (50 μ g/l) and the ecological assessment criteria (1,100 μ g/l) in all adit discharges. Note that iron and manganese are not important criteria for human health (see Section 4.2.1).

There were no detections recorded in any of the adit discharges for dissolved antimony, chromium, molybdenum and vanadium.

Avoca River

Table 13 provides a summary of the reported values for river sampling locations in the Avoca Mining area that exceeded the relevant ecological and human health assessment criteria. The pH was found to be below the human health (6.5 to 9.5 pH units) criteria for the majority of rivers and streams ranging from 4.63 to 6.35 pH (field); however, all values were within acceptable ranges for ecological health (4.5 to 9 pH units). The specific conductance was well within the criteria for human health of 2.5 mS/cm ranging from 0.066 to 0.094 mS/cm. No exceedances were recorded on the Avoca River for ammonia and sulphate.

The dissolved metal concentrations in the Avoca River were low in comparison to the groundwater and the adit discharges; however, several exceedances of both ecological and human health criteria occurred. Dissolved copper exceeded the ecological criteria (5 μ g/l) at all Avoca River locations from DS Deep Adit to the Avoca Bridge, with results ranging from 11.3 to 16 μ g/l. The highest dissolved copper concentration was recorded at US Ballygahan Adit. Similarly, dissolved zinc exceeded the ecological assessment criteria (50 μ g/l) from DS Deep Adit on the Avoca River to Avoca Bridge with results ranging from 76.3 to 228 μ g/l. Dissolved cadmium exceeded the ecological assessment criteria (0.45 μ g/l) at DS Deep Adit (0.52 μ g/l) and DS Millrace (0.591 μ g/l).

Dissolved iron exceeded the human health assessment criteria of 200 μ g/l at one location downstream of the Deep Adit confluence and three locations downstream of the Road Adit confluence with concentrations ranging from 221 to 513 μ g/l. Dissolved manganese exceeded the criteria for human health (50 μ g/l) at Site T5 (55 μ g/l) and Wicklow County Council Maintenance Yard GS (59.1 μ g/l). Note that iron and manganese are not important criteria for human health (see Section 4.2.1).

Dissolved aluminium, arsenic, lead and nickel were below the ecological and human assessment criteria at all monitoring locations on the Avoca River. Additionally, no detections were recorded for dissolved antimony, chromium, and vanadium.



Cadmium Copper Manganese **Date Sampled** pH (field) Iron (diss.filt) Zinc (diss.filt) (diss.filt) (diss.filt) (diss.filt) pH Units μg/l μg/l μg/l μg/l μg/l **Sample Description** Units 4.5 to 9 0.45 5 1100 50 **Ecological Criteria** 2000 50 Human Health Criteria 6.5 to 9.5 5 200 29/03/2017 Site T1 0.425 4.63 0.04 56.8 7.36 17.2 **US** Whites Bridge 29/03/2017 5.07 0.425 0.04 58.4 7.15 17 Whites Bridge 29/03/2017 1.28 6.06 0.04 76.9 9.1 21.9 29/03/2017 4.36 Whites Bridge GS 5.62 0.119 85.5 11.2 30 12 DS Deep Adit 29/03/2017 5.91 0.52 193 26.9 202 DS Millrace 29/03/2017 5.87 13.4 0.591 221 30.5 228 US Ballygahan Adit 29/03/2017 6.35 16 0.262 26 76.3 99.6 US Road Adit 6.12 29/03/2017 11.4 0.314 23.3 98.9 125 Site T5 29/03/2017 5.89 11.6 0.305 405 55 134 29/03/2017 Wicklow Co. Maintenance Yard GS 6.32 11.3 0.321 513 59.1 146 Avoca Bridge 29/03/2017 5.94 11.3 0.348 305 48.6 130

Table 13 Summary of Reported Values for Rivers and Streams and the Surface Water Assessment Criteria

Notes

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

Metals are dissolved

Section 5

Flows, Loads and Trend Analysis

5.1 Surface Water Flows

Two EPA stream flow gauges exist on the Avoca River near the mine site, Whites Bridge GS (EPA station 10044) and the Wicklow County Council Maintenance Yard GS (EPA Station 10045). The Whites Bridge GS is located 90 m downstream of the bridge and just upstream of the confluence of the Deep Adit discharge. The Wicklow County Council Maintenance Yard GS is downstream of the Deep Adit and was previously just upstream of the Road Adit confluence. As previously discussed and shown on Map 3 in <u>Appendix A</u>, the new discharge location for the Road Adit to the Avoca River (Road Adit Confluence) is upstream of the Wicklow County Council Maintenance Yard GS.

The flow data from 30 August 2016 to 31 March 2017 for Whites Bridge GS is reproduced in Figure 2 and that for Wicklow County Council Maintenance Yard GS in Figure 3. The figures show the measured flows ranged from 51 m³/s during high flow to approximately 2-3 m³/s during low-flow. The flashy nature of the river shows a rapid response to rainfall. The median flows for this period of approximately 7.64 m³/s at Whites Bridge GS and 7.40 m³/s at Wicklow County Council Maintenance Yard GS are lower than the long-term median of approximately 8.5 m³/s and 9.1 m³/s respectively, which reflects the relatively low levels of rainfall during the monitoring period. Flow in late September/early October was particularly low with a baseline flow of approx. 2.6 m³/s at Whites bridge GS and 2.5 m³/s at Wicklow county Council Maintenance Yard GS which is close to the 95%-ile flow (low flow) of approximately 2 m³/s at both stations.

The river appears to respond similarly at both gauging stations as can be observed from the peaks in both figures. A discussion of the differences in flow rates between the two gauges is provided in Section 6.4.3 Surface Water Flow Data at the EPA Gauging Stations.



Figure 2 Mean Daily Flow (m³/s) at Whites Bridge (Station 10044) from 30 August 2016 to 31 March 2017.





Figure 3 Mean Daily Flow (m³/s) at Wicklow County Council Maintenance Yard (Station 10045) from 30 August 2016 to 31 March 2017

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 14 presents a summary of the results from the flows measured in March 2017 at the time of sampling. All flow measurements on the main river channel were performed on the same day; this provides a true representation of hydrogeological activity in the Avoca River. Refer to Appendix B of the Data Report for details of methodologies used per site and associated calculations.

The measured flow at the Deep Adit of 13.6 l/s is considered a low flow as past records for the Deep Adit range from approximately 10 to 37.5 l/s. The measured flow at the 850 Adit was 7.5 l/s. Note that the 850 Adit discharges to the Deep Adit box culvert and therefore, the flow discharging from the box culvert (21.1 l/s) contains the Deep Adit and 850 Adit discharge.

The flow was also measured at the Deep Adit Confluence prior to it discharging to the Avoca River and the measured flow was 14.65 l/s which is considerably less than the flow at the Deep Adit/850 Adit confluence (21.1 l/s). Additionally, the surface water drainage channel which joins the historic 850 channel, upgradient of the northwest culvert and railway line, was flowing (estimated <1 l/s) during sampling of the Deep Adit Confluence. The drainage channel was discharging to the Deep Adit channel, downgradient of the Deep Adit box culvert. However, the flow had ceased during sampling of the Deep Adit (portal). The apparent loss of flow between both sampling locations is likely due to infiltration along the Deep Adit ditch. Additionally, the Deep Adit sampling location is not ideal for measuring flow because it is not properly channelised and the measurement should be considered an estimate.

The flow was measured at the Road Adit and the measured flow was 17.39 l/s. Past records for the Road Adit range from approximately 6 to 58 l/s (CDM, 2008). The flow was also measured at the Road Adit Confluence prior to the adit discharging to the river and the measured flow was 19.16 l/s. The difference in flow is likely due to two different flow measurement methods being employed.



Site Name	Flow m ³ /s	Flow l/s	Date	Notes
Avoca Bridge	10.35	10,430	29/03/2017	
DS Deep Adit	8.49	8,471	29/03/2017	
DS Mill Race	8.49	8,468	29/03/2017	
Site T1	11.7	11,660	29/03/2017	
Site T5	8.93	8,930	29/03/2017	
US Ballygahan Adit	8.88	8,883	29/03/2017	
US Road Adit	8.97	8,971	29/03/2017	
US Whites Bridge	8.39	8,385	29/03/2017	
WCC Maintenance Yard	8.93	8,930	29/03/2017	
Whites Bridge	8.45	8,450	29/03/2017	
Whites Bridge GS	8.45	8,450	29/03/2017	
Cronebane Inter. Adit	0.007	6.75	30/03/2017	
Cronebane Shallow Adit	0.0001	0.10	30/03/2017	
Deep Adit	0.014	13.6	30/03/2017	
Deep Adit Confluence	0.015	14.7	30/03/2017	
Road Adit	0.017	17.4	30/03/2017	
Road Adit Confluence	0.019	19.2	30/03/2017	
850 Adit	0.008	7.5	30/03/2017	
Ballygahan Adit	-	-	29/03/2017	No Flow

Table 14 Surface Water Flow	v Value Measured in March 2017
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5.2 Loading Analysis

5.2.1 Loading Analysis Methodology

Mass loads (kg/day) were calculated for the Avoca River, the adits, and tributaries using measured flow and concentration data, as follows:

Load (kg/day) = [C (μ g/L) * F (L/day)] / 1,000,000,000 μ g/kg

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 15 aid with the interpretation of the loading of sulphate and dissolved aluminium, copper, iron, lead and zinc to the Avoca River.

It is recommended that while reading the following sections, the *Avoca River Tracer Study Report* (Document Ref: 95735/40/DG/31, dated December 2016) is consulted, particularly with regard to the location and source of diffuse groundwater contamination to the Avoca River.



				Sulp	hate	Aluminium		Copper		Iron		Lead		Zinc	
Sample Description	Date Sampled	Flow I/s	pH Units	μg/l	kg/day	μg/l	kg/day	μg/l	kg/day	μg/I	kg/day	μg/I	kg/day	μg/I	kg/day
Avoca Bridge	29/03/2017	10350	5.9	10900	9750	156	140	11.3	10.1	305	273	2.69	2.41	130	116
DS Deep Adit	29/03/2017	8490	5.9	9000	6600	149	109	12	8.8	193	142	3.94	2.89	202	148
DS Millrace	29/03/2017	8490	5.9	9800	7190	152	111	13.4	9.83	221	162	4.05	2.97	228	167
Site T1	29/03/2017	11700	4.6	1000	1010	52.4	53	0.425	0.43	56.8	57.4	0.764	0.77	17.2	17.4
Site T5	29/03/2017	8930	5.9	11100	8560	153	118	11.6	8.95	405	312	2.44	1.88	134	103
US Ballygahan Adit	29/03/2017	8880	6.4	4500	3450	167	128	16	12.3	99.6	76.4	1.35	1.04	76.3	58.5
US Road Adit	29/03/2017	8970	6.1	3500	2710	145	112	11.4	8.84	125	96.9	2.02	1.57	98.9	76.6
US Whites Bridge	29/03/2017	8390	5.1	1000	725	59.1	42.8	0.425	0.31	58.4	42.3	0.674	0.49	17	12.3
Whites Bridge	29/03/2017	8450	6.1	1000	730	67.6	49.4	1.28	0.93	76.9	56.1	1.24	0.91	21.9	16
Whites Bridge GS	29/03/2017	8450	5.6	1000	730	95.3	69.6	4.36	3.18	85.5	62.4	1.07	0.78	30	21.9
WCC Maintenance Yard	29/03/2017	8930	6.3	12800	9880	154	119	11.3	8.72	513	396	2.6	2.01	146	113
850 Adit	30/03/2017	7.5	2.7	657000	427	76100	49.5	4810	3.13	16900	11	959	0.62	24500	15.9
Cronebane Inter. Adit	30/03/2017	6.8	2.9	651000	380	63800	37.2	3430	2	62400	36.4	1170	0.68	27300	15.9
Cronebane Shallow Adit	30/03/2017	0.1	2.6	2820000	24.4	351000	3.03	7040	0.06	133000	1.15	1040	0.01	111000	0.96
Deep Adit	30/03/2017	13.6	3.3	882000	1030	80000	93.8	431	0.51	62300	73	1680	1.97	46900	55
Deep Adit Confluence	30/03/2017	14.7	2.8	773000	978	74900	94.8	2190	2.77	39200	49.6	1350	1.71	40200	50.9
Road Adit	30/03/2017	17.4	4.2	1180000	1770	10000	15	232	0.35	114000	171	300	0.45	7960	12
Road Adit Confluence	30/03/2017	19.2	4.3	1180000	1950	9960	16.5	245	0.41	109000	180	310	0.51	8310	13.8

Table 15 Summary of Measured Flows and Concentrations and Calculated Loads of Sulphate and Dissolved Metals in kg/day in the Adits and Avoca River

Loading from Adit Discharges

The Deep Adit had aluminium, copper and zinc loads of 93.8, 0.51 and 55 kg/day and the Road Adit had loads of 15, 0.35 and 12 kg/day, respectively. The Road Adit had sulphate and iron loads of 1,770 kg/day and 171 kg/day, respectively. Calculated loads for the Deep Adit were lower at 1,030 kg/day and 73 kg/day, respectively.

The flow from the Cronebane Intermediate Adit ultimately discharges to the 850 Adit, through the Copse Shaft, approximately 600 m from the entrance of the adit. In March 2017, there was a slight increase in flow between both monitoring points (6.8 to 7.5 l/s). Accordingly, there was an increase in sulphate (380 kg/day to 427 kg/day), aluminium (37.2 kg/day to 49.5 kg/day) and copper (2 kg/day to 3.13 kg/day). Dissolved iron load decreased from 36.4 kg/day to 11 kg/day which is likely due to oxidation and precipitation within the mine workings. Both monitoring locations had similar loads of dissolved lead (0.68 and 0.62 kg/day, respectively) and zinc (15.9 and 15.9 kg/day, respectively). Compared to the 850 Adit, the Deep Adit had higher loads of aluminium (93.8 kg/day and 49.5 kg/day), iron (73 kg/day to 11 kg/day), lead (1.97 kg/day and 0.62 kg/day), zinc (55 kg/day and 15.9 kg/day) and sulphate (1,030 kg/day and 427 kg/day). The reverse was true for dissolved copper whereby the 850 Adit had a load of 3.13 kg/day and the Deep Adit had a load of 0.51 kg/day.

To determine if there was any apparent loss of sulphate or metals loading along the Deep Adit channel, the flow and loading results were combined for the Deep Adit and 850 Adit portal samples and compared with the measured loads at the Deep Adit confluence (Table 14). The recorded flow was lower at the Deep Adit Confluence which is likely due to the difficulties in measuring the flows because the discharge was dispersed and flowing several different directions. Also, there is likely infiltration occurring in the channel. There was a decrease in the calculated mass load of sulphate and metals as follows: sulphate (1457 kg/day to 978 kg/day), aluminium (143 kg/day to 94.8 kg/day), copper (3.64 kg/day to 2.77 kg/day), iron (84 kg/day to 49.6kg/day), lead (2.59 kg/day to 1.71 kg/day) and zinc (70.9 kg/day to 50.9 kg/day). Decreases in loads are likely due to precipitation and the loss of flow which can be attributed to both the difficulties in measuring the flow and from infiltration along the Deep Adit channel.

The Cronebane Shallow Adit was of minor importance in terms of dissolved metals loads to the Avoca River due to both absence of surface flow to the river and low loads (low flow). Calculated loads were 3.03 kg/day for aluminium, 0.06 kg/day for copper and 0.96 kg/day for zinc. Ballygahan Adit was dry at the time of sampling.

Avoca River Loadings

Background Loadings

Background loads upstream of the Avoca Mining Area of metals were present which is evident from the calculated loads at Site T1. The dissolved metal loads at Site T1 were 53 kg/day for aluminium, 0.43 kg/day for copper, 57.4 kg/day for iron, 0.77 kg/day for lead and 17.4 kg/day for zinc. Note flow may be overestimated at Site T1 because of heavy rainfall in the intervening time between sampling and measuring flow. Additionally, due to high flow conditions at Site T1, flow measurements were collected upstream on the Avonmore and Avonbeg Tributaries and subsequently projected to Site T1. Figure 4 and Figure 5 graphically show the calculated loads of dissolved aluminium, iron, zinc and copper respectively at each location along the Avoca River from Site T1 upstream of the mining area to Avoca Bridge (see also Map 1 and 3 in <u>Appendix A</u>). Composite samples were collected where possible at monitoring locations along the Avoca River.



400 380 360 340 320 300 280 **Ae** 260 240 loads in 220 200 **Weasured** 160 140 ٠ 120 ٠ ۲ ٠ 100 80 60 40 20 0 Site T1 **US** Whites Whites Whites DS Deep Adit DS Millrace US US Road Adit Wicklow CC Site T5 Avoca Bridge Bridge GS Bridge Bridge Ballygahan Maintenance Adit Yard GS Avoca River Location (Upstream to Downstream) Dissolved Aluminium Dissolved Iron ▲ Dissolved Zinc

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Figure 4 Calculated Loads of Dissolved Aluminium, Iron and Zinc (kg/day) in the Avoca River in March 2017



Figure 5 Calculated Loads of Dissolved Copper (kg/day) in the Avoca River in March 2017

Whites Bridge

At sampling location US Whites Bridge which is located approximately 365m upstream of the bridge, there is a slight decrease in dissolved metal loads compared to Site T1 which is likely due to the overestimation of flow at Site T1. Further downstream at Whites Bridge there is an increase with loads of dissolved aluminium at 49.4 kg/day, iron at 56.1 kg/day, zinc at 16 kg/day and copper at 0.93 kg/day. There was a further increase in dissolved aluminium (69.6 kg/day), copper (3.18 kg/day), iron (62.4 kg/day) and zinc (21.9 kg/day) loads, 90 metres downstream at Whites Bridge GS. Dissolved lead loads decreased slightly from 0.91 kg/day at Whites Bridge to 0.78 kg/day at Whites Bridge GS.

Deep Adit Discharge and Contaminated Millrace Area

The DS Deep Adit location on the Avoca River is downstream of the Deep Adit discharge (Deep Adit Confluence sample) and a significant section of the contaminated Millrace area. Therefore, the calculated loads at DS Deep Adit assesses the impact of the Deep Adit discharge and the level of diffuse flow and groundwater contribution from the contaminated Millrace area and Deep Adit spoils. As indicated in Figure 4 and Figure 5, a significant increase in loads occurs at DS Deep Adit compared to the upstream sampling location (Whites Bridge GS) with increases in aluminium (69.6 kg/day to 109 kg/day), copper (3.18 kg/day to 8.8 kg/day), iron (62.4 kg/day to 142 kg/day), lead (0.78 kg/day to 2.89 kg/day) and zinc (21.9 kg/day to 148 kg/day). Similarly, sulphate loads increased by 5,870 kg/day.

Taking into account the calculated dissolved metal loads at the Deep Adit Confluence the loading results at DS Deep Adit would be expected to be lower for copper (5.95 kg/day), iron (112 kg/day), lead (2.49 kg/day) and zinc (72.8 kg/day). The additional dissolved metal load indicates that the contamination of the alluvial material in the Millrace area are a secondary source of diffuse load to the Avoca River. Note that the contaminated Millrace area located parallel to the Avoca River extended further downstream than the DS Deep Adit sampling location and therefore an additional sampling location was introduced (DS Millrace). Dissolved metal loads at the DS Millrace sampling location increased for aluminium (111 kg/day), copper (9.83 kg/day), iron (162 kg/day), lead (2.97 kg/day) and zinc (167 kg/day). Increases between DS Deep Adit and DS Millrace are likely due to further diffuse groundwater contamination from the Millrace area.

Between DS Millrace and US Ballygahan Adit, dissolved iron and zinc loads decreased from 167 to 58.5 kg/day and from 162 to 76.4 kg/day, respectively (see Figure 4) which is likely due to precipitation. In contrast, the calculated dissolved copper load increased from 9.83 to 12.3 kg/day (see Figure 5), indicating a diffuse source of dissolved copper within this river stretch.

Ballygahan Adit and Seeps

In order to assess the groundwater seeps which, discharge to the River in close proximity to the Ballygahan Adit (dry at the time of sampling), samples were collected upstream (US Ballygahan Adit) and downstream (US Road Adit). Slight increases were calculated for the following dissolved metals; iron (76.4 to 96.9 kg/day) lead (1.04 kg/day to 1.57 kg/day) and zinc (58.5 kg/day to 76.6 kg/day).

Road Adit Discharge

The Road Adit is the primary discharge from West Avoca. Upstream of the Road Adit Confluence (US Road Adit), dissolved metal loads were calculated as follows; aluminium (112 kg/day), copper (38.8 kg/day), iron (96.9 kg/day), lead (1.57 kg/day) and zinc (76.6 kg/day).



The Wicklow County Council Maintenance Yard GS sampling location is located downstream of the Road Adit discharge since October 2014. Taking into account the loadings at US Road Adit and at the Road Adit Confluence the loads would be expected to be 129 kg/day for aluminium, 277 kg/day for iron and 90.4 kg/day for zinc. However, the calculated loadings at Wicklow County Maintenance Yard GS were higher for iron (396 kg/day) and for zinc (113 kg/day). The calculated loads for aluminium were slightly lower at 119 kg/day. The increase in loads at Wicklow County Council Maintenance Yard GS can be primarily attributed to the Road Adit which discharges to the Avoca River approximately 65m upstream. The additional or unexplained increase can be attributed to diffuse groundwater flow which is consistent with the findings of a dye tracer study undertaken on the Avoca River in September 2016.

Specifically, the results of the tracer study (undertaken in low flow conditions ranging from 4-6 m³/s) found that, between downstream of the contaminated Millrace and approximately 70 m downstream of the Road Adit Confluence, 42% of the dissolved iron load and 49% of the dissolved zinc load occurring within this river stretch was due to diffuse contamination. Note that although there was a significant diffuse contribution of dissolved metals to the River, there was also a calculated loss of flow within this stretch.

Further downstream at Site T5, the calculated loads for dissolved iron and zinc were 312 kg/day and 103 kg/day, respectively. This decrease in iron and zinc between Wicklow County Council Maintenance Yard GS and Site T5 is likely due to precipitation. The measured load for aluminium was 118 kg/day which was similar to the measured load at Wicklow County Council Maintenance Yard GS.

No surface water sampling was undertaken at Shelton Abbey in March 2017.

5.3 Trend Analysis

5.3.1 Historical Trends

This section discusses concentration time trends for select locations including the Deep Adit, the Road Adit and one location on the Avoca River for selected parameters (dissolved copper, zinc and iron). The trends are shown graphically in Figure 6 (Deep Adit from October 2001 to March 2017), Figure 7 (Deep Adit from October 2001 to March 2017, excluding high values recorded in November 2001), Figure 8 (Road Adit from October 2001 to March 2017) and Figure 9 (Avoca River at Avoca Bridge from October 2001 to to March 2017).





Figure 6 Concentration trends for dissolved copper, zinc and iron within the Deep Adit Discharge (Oct 2001 to March 2017)



Figure 7 Concentration trends for dissolved copper, zinc and iron within the Deep Adit Discharge (Oct 2001 to March 2017), excluding high values recorded in November 2001





Figure 8 Concentration trends for dissolved copper, zinc and iron within the Road Adit Discharge (Oct 2001 to March 2017)



Figure 9 Concentration trends for dissolved copper and zinc at Avoca Bridge compared with the environmental quality objective (EQS) (Oct 2001 to March 2017)



The Mann-Kendall test was performed to assess statistical trends in the water quality 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 copper, zinc and iron.

The Mann-Kendall test results in the identification of a trend (if one exists) and the probability associated with the trend. Table 16 shows the possible outcomes of the Mann-Kendall trend analysis as applied to the water quality data.

Trend	P value	Trend reported as				
	p < 0.05	Decreasing				
Decreasing	0.05 <= p < 0.1	Likely Decreasing				
	p >= 0.1	No Trend				
	p < 0.05	Increasing				
Increasing	0.05 <= p < 0.1	Likely Increasing				
	p >= 0.1	No Trend				
No Trend	p = 1	No Trend				

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 analyses were conducted for all data since October 2001 because data were available for all the sample locations from that date onwards. Analyses on data since June 2007 were also carried out to determine if there were any trends in more recent data, which also eliminated the high results in 2001/2002. The Mann-Kendall test results for both time periods are presented in Table 17 and facilitate general observations about trends in the water quality of the two main adit discharges and the downstream location of Avoca Bridge.

Sample	Parameter	Octobe	r 2001 to I	March 2017	June 2007 to March 2017				
location	Parameter	P value	S value	Trend	P value	S value	Trend		
	Copper	<0.0001	-327	Decreasing	0.0432	-26	Decreasing		
Deep Adit	Zinc	0.361	-21	No Trend	0.122	-18	No Trend		
	Iron	0.0001	179	Increasing	0.473	2	No Trend		
	Copper	0.0019	-90	Decreasing	0.32	-7	No Trend		
Road Adit	Zinc	<0.0001	-126	Decreasing	0.0215	-27	Decreasing		
	Iron	0.0028	-68	Decreasing	0.0597	-21	Possibly Decreasing		
Avoca Bridgo	Copper	0.144	-52	No Trend	0.464	2	No Trend		
Avoca Bridge	Zinc	0.385	15	No Trend	0.105	-15	No Trend		

Table 17 Mann-Kendall Trend Analy	sis of data for Deep Adit,	, Road Adit and Avoca Bridge
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Notes:

The p-value is the probability that the null hypothesis is true.

The confidence coefficient is 0.95.

The results of the Mann-Kendall analysis for October 2001 to March 2017 show that dissolved copper concentrations are decreasing in the Deep Adit and there is no trend for dissolved zinc. Dissolved iron however is increasing in the Deep Adit. Dissolved copper, dissolved zinc and dissolved iron were decreasing in the Road Adit. These trends can also be inferred from Figure 6, Figure 7 and Figure 8.



The results of the Mann-Kendall analysis for June 2007 to March 2017, show that dissolved copper is decreasing in the Deep Adit. In the Road Adit, dissolved zinc is decreasing and dissolved iron is possibly decreasing.

Figure 9 displays the results for dissolved copper and zinc in the Avoca River at Avoca Bridge which is downstream of the main Avoca Mining Area, from 2001 to present. No statistically significant trend was present for dissolved zinc or dissolved copper for either the 2001-2017 period or the 2007-2017 period. The ecological assessment criteria (or EQS) are also shown on the graph for reference. Dissolved copper has been above the ecological assessment criteria of 5 μ g/l and dissolved zinc above the ecological assessment criteria of 50 μ g/l since mid-2002.

5.3.2 Seasonal Trends

Table 18 shows the seasonal variation between the concentrations of dissolved metals and the calculated loads observed between the high flow sampling events in March 2013 (R1), February 2014 (R3), February 2015 (R5), February 2016 (R7) and March 2017 (R9), and the low flow sampling events in August 2013 (R2), September 2014 (R4), August 2015 (R6) and August/September 2016 (R8). The concentrations of dissolved aluminium, copper, iron and zinc were very similar in each sampling event with a few exceptions. Dissolved copper in the Deep Adit was significantly lower in concentration in August 2013, September 2014, August 2015 and September 2016 compared with the high flow sampling, however it was also low in February 2015 when the flow in the Deep Adit was lower than the previous winter sampling events.

The concentration of dissolved iron at Avoca Bridge is quite variable and dissolved zinc is higher in concentration during the low flow sampling events than the high flow sampling events. Seasonal differences in dissolved copper concentrations at Avoca Bridge are less pronounced with values ranging from 10.8 to 14.5 kg/day in low flow conditions and from 5.24 to 18.5 kg/day during winter sampling events.

The calculated loads of dissolved aluminium, copper, iron and zinc were typically lower during low flow conditions compared to the loads calculated during high flow conditions across all three sampling sites (Table 8). Flow was particularly low in the Deep Adit and Road Adit in September 2016 (R8) and consequently, dissolved metal loads at these sites were substantially lower than the previous low flow sampling rounds. Similar low flow values recorded during the high flow sampling events at the Deep Adit in February 2015, February 2016 and March 2017 resulted in relatively low calculated loads of dissolved metals relative to the 2013 and 2014 high flow sampling events.

The flows measured at Avoca Bridge and Road Adit during the R9 2017 sampling event were lower than the flows measured during previous high flow sampling events. Accordingly, low flows resulted in the calculation of reduced dissolved metal loads.

Sample Description	Date Sampled	Flow	Aluminium		Copper		Iron		Zinc	
		l/s	μg/l	kg/ day	μg/I	kg/ day	μg/I	kg/ day	μg/I	kg/ day
Deep Adit	R1 15/03/2013	29.2	98800	249	770	1.9	88500	223	47300	119
	R2 15/08/2013	13	96700	110	184	0.21	68300	77.4	44900	50.9
	R3 27/02/2014	22.2	71600	138	1500	2.9	55800	107	35500	68.2
	R4 16/09/2014	17.5	80200	121	130	0.2	98100	148	39900	60.3

 Table 18 Seasonal Variation of Concentrations and Calculated Loads of Dissolved Metals in the Adits and at Avoca Bridge from 2013-2017



Sample		Flow	Alumi	nium	Сор	per	Iro	n	Zinc		
Description	Date Sampled	l/s	μg/l	kg/ day	μg/l	kg/ day	μg/l	kg/ day	μg/l	kg/ day	
	R5 12/02/2015	16.7	85600	123	147	0.2	64200	92	36300	52	
	R6 17/08/2015	19.5	106000	179	142	0.2	53800	90.6	46800	78.8	
	R7 15/02/2016	12.0	84500	87.9	350	0.36	79700	82.9	53800	56	
	R8 01/09/2016	10.4	68500	61.6	85.2	0.08	61300	55.1	34200	30.7	
	R9 30/03/2017	13.6	80000	93.8	431	0.51	62300	73.0	46900	55.0	
	R1 15/03/2013	28.9	14900	37.2	366	0.9	76100	190	9140	22.8	
	R2 15/08/2013	15.6	16400	22.1	335	0.45	69500	93.9	7810	10.5	
	R3 27/02/2014	56.2	15000	72.8	321	1.6	265000	1290	20100	97.6	
	R4 16/09/2014	18	15600	24.3	294	0.46	126000	196	9810	15.3	
Road Adit	R5 12/02/2015	-	12400	-	339	-	75600	-	8350	-	
	R6 17/08/2015	14.49	13300	16.7	305	0.4	65800	82.4	8290	10.4	
	R7 15/02/2016	31.5	12200	33.2	382	1.04	70400	192	8470	23.1	
	R8 01/09/2016	8.34	10900	7.85	244	0.18	51500	37.1	6300	4.54	
	R9 30/03/2017	17.4	10000	15	232	0.35	114000	171	7960	12	
	R1 20/03/2013	12000	162	167	10.8	11.2	153	158	154	159	
	R2 20/08/2013	1940*	161	27	10.8	1.81	232	38.9	301	50.5	
	R3 04/03/2014	24000	152	315	18.5	38.4	485	1010	161	334	
	R4 17/09/2014	3240	93.1	26.1	14.5	4.06	182	51	314	88	
Avoca Bridge	R5 16/02/2015	20096	246	427.1	5.24	9.10	201	349	87	151.6	
Diluge	R6 18/08/2015	3010	99.1	25.8	12.1	3.2	161	41.9	241	62.7	
	R7 16/02/2016	18400	154	245	13	20.7	230	366	122	194	
	R8 31/08/2016	3298	130	37	10.9	3.11	183	52.1	194	55.3	
	R9 29/03/2017	10350	156	139.5	11.3	10.1	305	273	130	116	

Notes:

*Unrepresentative flows resulted in an underestimate of the sulphate and dissolved metals loadings at Avoca Bridge



Section 6

Groundwater Levels and

Groundwater-Surface Water Interaction

6.1 Groundwater Levels

Groundwater levels were measured at the nine wells using a portable electronic water level recorder. Table 19 provides the measured depth to groundwater and calculated groundwater elevations. All groundwater level data are contained in Appendix C of the Data Report. The groundwater elevations varied between 26.06 to 32.67 m Ordnance Datum (OD) in the Avoca Mining Area. These groundwater elevations were between 0.28 to 1.1 metres higher than the elevations measured in August 2016. The groundwater elevations were consistent with the hydraulic gradient towards the Avoca River. MWSA2 is located downgradient of Shelton Abbey Tailings; this is in a different part of the catchment and the groundwater elevation in this area is much lower than at West and East Avoca.

Borehole Identifier	Date	Time	Depth to Groundwater (m bTOC)	Depth to Groundwater (m bgs)	Groundwater Elevation (m OD)
MWDA1	27/03/2017	12:22	6.125	5.53	26.67
MWDA2	27/03/2017	11:24	6.19	5.46	26.43
MWET1	28/03/2017	13:31	7.06	6.49	26.33
MWET2	28/03/2017	12:22	6.96	6.26	26.41*
MWPF1	27/03/2017	09:33	4.39	3.80	27.10*
MWSA2	28/03/2017	15:45	8.41	8.13	1.76*
GW1/05	28/03/2017	08:57	4.745	4.11	26.06*
GW2/05	28/03/2017	10:00	4.42	4.42	26.53*
SG104	27/03/2017	15:20	25.50	Unknown	32.67

Table 19 Measured	Groundwater	Levels and	Calculated	Elevation	March	2017
Tuble 15 Micubalea	Gioanawater	ECVCID UNIO	culculated	Licvation	i vi ai ci i	

Notes:

m is metres

OD is Ordnance Datum

bTOC is below top of casing

bgs is below ground surface

* Monitoring well elevations were based on a GPS survey and therefore may be less accurate

Automatic pressure transducers and loggers have been installed in the six wells owned by the Department. Figure 10 shows the groundwater elevations of the five wells located in the Avoca Mining Area from 28 August 2016 to 31 March 2017. Figure 11 shows the groundwater elevation at MWSA2 at Shelton Abbey Tailings Facility between 30 August 2016 and 31 March 2017.

Figure 10 shows that the heads are higher in the shallow alluvium monitoring well MWDA1 with respect to its nested well-pair in the deeper alluvium MWDA2 which suggests an apparent downward hydraulic gradient between the pair. This infers that groundwater containing high concentrations of dissolved metals in the spoils, discharges into the alluvial aquifer,





Figure 10 Groundwater Elevations in the Avoca Mining Area from 30 Aug 2016 to 31 March 2017



Figure 11 Groundwater Elevation at Shelton Abbey from 30 Aug 2016 to 31 March 2017

In contrast to MWDA1 and MWDA2, the head is slightly greater in the deep well MWET2 compared to the shallow monitoring well MWET1. GW1/05 and GW2/05 are located closer to the western alluvial margin, and approximately 95 m to the south-southeast of the MWET1/ET2 well cluster. There was a marginal downward gradient between the alluvial well GW2/05 and top of bedrock (GW1/05) at this location (Table 19) in March 2017.



Data loggers were replaced in the following wells in November 2016: MWDA1, MWDA2 (Deep Adit spoils area), MWET1, MWET2 (Emergency Tailings Area) and MWSA2 (Shelton Abbey). The data logger in MWPF1 was not replaced because it was previously replaced in 2015.

6.2 Surface Water Levels

As described in Section 5.1 Surface Water Flows, there are two EPA stream flow gauges on the Avoca River near the mine site: Whites Bridge GS (EPA station 10044) and the Wicklow County Council Maintenance Yard GS (EPA Station 10045). The measured water elevations from 30 August 2016 to 31 March 2017 for Whites Bridge GS and Wicklow County Council Maintenance Yard GS are reproduced in Figure 12. Additionally, the calculated elevations of the Avoca River at the midpoint between the two automatic flow gauges are shown in Figure 12. The figure demonstrates that the river appears to respond similarly at both gauging stations.

The distance between the two gauging stations is approximately 470 metres. The measured surface water elevations were used to calculate the average gradient between the two gauges for the monitoring period, which was 0.006. Streambed characteristics and the elevations both influence the flow rates and help define any apparent losses or gains in river flow.



Figure 12 Elevation of the Avoca River at GS 10044 and GS 10045 at the Deep Adit Area from 1 September 2016 to 26 March 2017

6.3 Groundwater-Surface Water Interaction

Groundwater gradients to the Avoca River were calculated using the estimated groundwater elevations and corresponding river water elevations for the same date and time. The locations of the monitoring wells with respect to the gauging station locations on the Avoca River are shown on Map 3 in <u>Appendix A</u>. The appropriate river gauges were selected as follows:

 For MWDA1, MWDA2 and MWPF1 the river water elevation was taken from the EPA gauge located at Whites Bridge GS (GS 10044);



- MWET1, MWET2, GW1/05 and GW2/05 are approximately equidistant between the two gauges. To take account of the gradient between the two gauges, the river water elevation can be estimated using both the Whites Bridge GS (GS 10044) and the Wicklow County Council Maintenance Yard GS (GS 10045) by selecting a midpoint water level. The estimated surface water elevations for the emergency tailing area for the period 30 August 2016 to 31 March 2017 are displayed on Figure 12 (GS 10044 & GS 10045);
- For SG104 the water elevation from Wicklow Maintenance Yard County Council (GS 10045) was used; and
- The river water level at MWSA2 was unable to be determined because there are no gauges available at a nearby location.

Table 20 summarises resulting hydraulic gradient data between the monitoring well clusters and the Avoca River during the sampling event, and shows an estimated gradient from the wells to the river at the time of sample collection in March 2017. These values are similar to previous rounds in both direction and magnitude with an estimated mean gradient of 0.007, 0.001 and 0.010 for MWDA1, MWDA2 and MWPF1, respectively.

Borehole Identifier	Date	Time	Groundwater Elevation (m OD)	Water Distance to Elevation at Perpendicula Perpendicular Stream Point (m OD) (m)		Gradient
MWDA1	27/03/2017	12:22	26.67	26.39	40	0.007
MWDA2	27/03/2017	11:24	26.43	26.38	40	0.001
MWET1	28/03/2017	13:31	26.33*	25.03**	72	0.018
MWET2	28/03/2017	12:22	26.41*	25.03**	72	0.019
MWPF1	27/03/2017	09:33	27.1	26.18	44	0.010
MWSA2	28/03/2017	15:45	1.76	Not available	45	Not available
GW1/05	28/03/2017	08:57	26.06*	25.03**	74	0.014
GW2/05	28/03/2017	10:00	26.53*	25.03**	74	0.020
SG104	27/03/2017	15:20	32.67	23.75	142	0.063

Table 20 Calculated Groundwater Gradients for March 2017

* Monitoring Well elevations were based on a GPS survey and therefore may be less accurate

**Estimated elevations based on two surface water gauges

The hydraulic communication between the river and groundwater is of primary importance in reviewing potential contaminant loads to the river from diffuse groundwater flow. Where a positive hydraulic gradient from the alluvial aquifer to the river is present (i.e. the head in the aquifer is higher than in the river), the Avoca River is a net gaining river.

Hourly water level data for both gauges on the Avoca River (Whites Bridge GS (EPA station 10044) and the Wicklow County Council Maintenance Yard GS (EPA Station 10045)) were obtained for the monitoring period from the EPA. Groundwater elevation data were plotted against the recorded elevations of the Avoca River as shown in Figure 13 for the deep adit area and Figure 15 the emergency tailings area. Both figures demonstrate that there is a direct relationship between the river stage and the groundwater levels in both areas. Rises in river levels are accompanied by rises in groundwater levels.



Both figures show that there were several significant hydrological (rainfall) events which resulted in groundwater levels rising. For example, groundwater levels rose by approximately 0.8 metres between 20 January and 3 February 2017. This peak was in response to river levels which rose by up to 1.13 metres during the same event. Groundwater levels gradually increase in the deep adit area and the emergency tailings area in December 2017 and remain relatively constant during the winter and spring months (December through March). The hydraulic response to rainfall and river stage is more muted in MWET1 than in MWET2, possibly because the two wells are separated by a fine silt/clay layer at approximately 16 meters' depth, which could act as a confining layer to MWET2.

Figure 14 and Figure 16 show the calculated gradient to the Avoca River at the Deep Adit area (MWDA1, MWDA2) and the emergency tailings area (MWET1, MWET2) from 1 September 2016 to 26 March 2017 based on hourly elevation data. Both figures show that as river stages change hydraulic gradients to or from the river also change. Gradients are predominantly positive which suggests that the Avoca River is a net gaining river from the alluvium in both areas during the monitoring period. The implication is that the spoil and the alluvial areas on both sides of the river contribute contaminant load to the river. However, Figure 13 and Figure 14 show that a negative gradient occurs during periods of high flow, particularly when there was a rapid rise in water level. On 14 and 15 October 2016, a significant hydrological (rainfall) event resulted in groundwater levels rising in MWDA1 and MWDA2 by approximately 0.5 metres. A negative gradient of up to -0.018 can be observed during this period between the river and MWDA2, as shown in Figure 14. From the beginning of August to mid-December negative gradients exist for MWDA2. The minimum gradient for MWDA2 was -0.018 while the average was 0.0007. For MWDA1 which is the shallower well, a positive gradient existed for over 95% of the monitoring period. The findings indicate that shallow groundwater in the deep adit area is likely discharging to the Avoca River for the majority of the monitoring period.

For MWET1 and MWET2, only positive gradients were observed during the monitoring period with a minimum gradient of 0.002 (MWET1) and a maximum of 0.019 (MWET1). Note that the elevations are based on the GPS survey of the boreholes and the river water elevations were estimated using both the Whites Bridge GS elevation and the Wicklow County Council Maintenance Yard gauges because they are located equidistance between the gauges.





Figure 13 Comparison of Groundwater Elevation and Elevation of the Avoca River (GS 10044) at the Deep Adit Area from 1 August 2016 to 26 March 2017



Figure 14 Calculated Groundwater Gradient to the Avoca River at the Deep Adit Area from 1 August 2016 to 26 March 2017





Figure 15 Comparison of Groundwater Elevation and Elevation of the Avoca River (GS 10044 & 10045) at the Emergency Tailings Area from 1 September 2016 to 26 March 2017



Figure 16 Calculated Groundwater Gradient to the Avoca River at the Emergency Tailings Area from 1 September 2016 to 26 March 2017



6.4 Summary of Diffuse Loading

In the Avoca mining area diffuse flow discharges to the Avoca River from a combination of sources including groundwater, ditch infiltration and infiltration on spoil piles. In this section a summary of the evidence of diffuse loading to the Avoca River is provided from three sources, as follows:

- Point source and diffuse loading analysis;
- Groundwater gradients; and
- Surface water flow data at the EPA Gauging Stations.

6.4.1 **Point Source and Diffuse Loading**

The analysis of loading to the Avoca River is discussed in Section 5.2.2, Loading Results and Discussion, and can be summarised as follows using the zinc loading as an example:

- Between Site T1 to US Whites Bridge, there is a slight decrease in zinc load from 17.4 to 12.3 kg/day which is likely due to an overestimation of flow at Site T1. Between US Whites Bridge and Whites Bridge, zinc load increased from 12.3 to 16 kg/day which is a 30 % increase. The only surface water input in this segment is from Vale View (estimated to be 6.5 l/s). Historically, the Vale View tributary has discharged very low zinc loads to the Avoca River. This indicates that the increase in loading is primarily due to diffuse load;
- Between Whites Bridge and Whites Bridge GS, zinc load increases from 16 kg/day to 21.1 kg/day which is an increase of 32%. No surface water inputs exist within this river stretch and therefore, the apparent increase is primarily due to diffuse load;
- Between Whites Bridge GS and DS Deep Adit on the Avoca River, the zinc load increases significantly from 21.1 to 148 kg/day which is greater than a five-fold increase. The Deep Adit (confluence sample) contributed 50.9 kg/day of the load. The calculations indicated that there is a significant level of diffuse flow entering the river from the Deep Adit spoils and/or the contaminated Millrace area which is contributing to the zinc load of the River. Between DS Deep Adit and DS Millrace there is a 13% increase in zinc load which is likely due to additional diffuse groundwater flow from the contaminated Millrace area;
- Between DS Millrace and US Ballygahan Adit on the Avoca River, zinc loads decrease from 167 to 58.5 kg/day which is likely due to precipitation and mixing of both the Deep Adit discharge and the diffuse zinc load input from the contaminated Millrace area;
- Between US Ballygahan Adit and US Road Adit dissolved zinc increases by 31% from 58.5 to 76.6 kg/day. The Ballygahan Adit is located within this river stretch and was dry in March 2017. Groundwater seeps also exist in this area and are the likely cause of the increase in dissolved zinc;
- Between US Road Adit and Wicklow County Council Maintenance Yard GS, the zinc load increases from 76.6 to 113 kg/day which is a 48% increase. The Road Adit (confluence sample) contributed 13.8 kg/day of the load. Accordingly, 22.6 kg/day is due to diffuse groundwater flow. This increase may be partly due to incomplete mixing of the Road Adit discharge; and



 Between Wicklow County Council Maintenance Yard GS and Site T5, zinc load decreased from 113 to 103 kg/day which is a closer to the expected load downstream of the Road Adit confluence.

6.4.2 Groundwater Gradients

The groundwater gradients are predominantly positive which suggests that the Avoca River is a net gaining river from the alluvium in the Deep Adit area and the Emergency Tailings area during the monitoring period. The implication is that the spoil and the alluvial areas on both sides of the river contribute contaminant load to the river. However, negative gradients existed for the deeper groundwater well (MWDA2) in the deep adit area for a prolonged period from August to mid-December. The implication is that deeper groundwater in the deep adit area does not discharge directly to the Avoca River during and after periods of sustained low flow.

6.4.3 Surface Water Flow Data at the EPA Gauging Stations

In order to examine whether the Avoca River was a losing or gaining river between Whites Bridge GS and Wicklow County Council Maintenance Yard GS (see Map 3 in <u>Appendix A</u> for locations) the flow records were examined for the monitoring period.

Discharge measurements in open channel cross-sections are all subject to some level of error. It is not possible to predict the error but an indication can be derived from the deviation plots. The deviation plots compare the measured flow against the rating curve flow. The deviation plots were obtained from the EPA for the Whites Bridge GS and the Wicklow County Council Maintenance Yard GS. The total number of flow measurements at Whites Bridge GS was 26 and the difference between the measured flow and the flow rating curve ranged from 0.010 to 1.22 m³/s (or 0.1 to 6.7 %). The total number of flow measurements at Council Yard GS was 20 and the difference between the measured flow and the flow rating curve ranged from 0.010 to 0.418 m³/s (or 0.4 to 12.7 %).

The mean daily flow at the two stations were similar during the monitoring period with the percentage difference ranging from 0 to 12 % which is likely to be within the margin of error determined from the deviation plots. Therefore, it is not possible to draw any conclusions using the gauge data at this time as to whether the stretch of river between the two gauges is a gaining or a losing river. In the future when the rating curve is improved and the margin of error is reduced it may be possible to make a determination.

6.4.4 Diffuse Loading Conclusion

Overall the interaction between the Avoca River and groundwater is very dynamic. The quantity of diffuse loading varies along each river stretch with the greatest evidence of diffuse loading between Whites Bridge GS and DS Deep Adit and between US Ballygahan Adit and US Road Adit.

The groundwater gradients are predominantly positive which also suggests that the Avoca River is a net gaining river from the alluvium in the Deep Adit area and the Emergency Tailings area during the monitoring period. The implication is that the spoil and the alluvial areas on both sides of the river contribute contaminant load to the river. This is particularly evident in the measured zinc load results from the March 2017 sampling event, in the stretches of river between Whites Bridge and Whites Bridge GS and between Whites Bridge GS and DS Deep Adit, where the diffuse load is the primary source of zinc loading to the Avoca River. Dissolved zinc exceeded the ecological



assessment criteria (50 μ g/l) on the Avoca River from DS Deep Adit to Avoca Bridge with results ranging from 76.3 to 228 μ g/l.



Section 7

Summary and Recommendations

7.1 Summary of Findings

Eight groundwater monitoring wells were sampled and analysed in March 2017 and water levels were measured. Eighteen surface water locations were sampled with flows measured at seven of the locations and projected to an additional eleven from the EPA automatic gauges. The field QA/QC sample results were reviewed for accuracy and precision. The laboratory QC/QC samples and laboratory reports were also reviewed. Overall, the data quality is considered acceptable and the data can be used to compare to the assessment criteria and perform trend and loading evaluations.

A statistical summary of the analytical results for groundwater and surface water was prepared and results were compared to assessment criteria. Analyses of loading, concentration time trends and groundwater levels were also provided.

The overall conclusions are as follows:

- The dissolved metal concentrations were elevated in the majority of the monitoring wells and adit discharges with numerous exceedances of ecological criteria, human health criteria or both, particularly for dissolved aluminium, cadmium, copper, iron, manganese, nickel and zinc. As well, sulphate levels greatly exceeded the criteria for human health in the majority of monitoring wells.
- The shallow well MWPF1 located upgradient of the Deep Adit area, near the eastern margin
 of the alluvial sediments had the lowest concentration of dissolved metals. The highest
 concentrations of dissolved aluminium, copper, cadmium, nickel, cobalt, lead and zinc were
 recorded in SG104 (downgradient of the Ballymurtagh landfill). The highest concentration of
 dissolved iron was recorded at MWDA2, located in the Deep Adit spoils area.
- The Cronebane Shallow Adit was the adit discharge with the highest concentrations of dissolved metals including aluminium, cadmium, iron, nickel and zinc. The Cronebane Shallow Adit is of minor importance in terms of metals loads to the Avoca River, because of absence of direct flow to the river and low concentrations and/ or flows.
- In the Avoca River and tributaries, dissolved metal concentrations were low in comparison to the groundwater and the adit discharges; however, multiple exceedances of both the ecological and human health criteria occurred, namely for dissolved cadmium, copper, manganese and zinc. Dissolved copper exceeded the ecological criteria (5 μg/l) at DS Deep Adit and all river locations from DS Deep Adit to Avoca Bridge, with results ranging from 11.3 to 16 μg/l. Similarly, dissolved zinc exceeded the ecological assessment criteria (50 μg/l) at all river locations from DS Deep Adit to Avoca Bridge with results ranging from 76.3 to 228 μg/l. Dissolved cadmium exceeded the ecological assessment criteria of 0.45 μg/l at the monitoring point located downstream of both the Deep Adit discharge and the contaminated Millrace. The highest value for dissolved iron was recorded at 513 μg/l at



Wicklow County Council Maintenance Yard GS located downstream of the Road Adit discharge on the Avoca River.

- The Deep Adit, 850 Adit and Road Adit had significant dissolved metal loads which were discharging to the Avoca River. The Deep Adit had aluminium, copper and zinc loads of 93.8, 0.51 and 55 kg/day. The 850 Adit had loads of 49.5, 3.13 and 15.9 kg/day, respectively. The calculated loads for the Road Adit were lower at 15 kg/day for aluminium, 0.35 kg/day for copper and 12 kg/day for zinc.
- The results of the Mann-Kendall analysis for October 2001 to March 2017 show that dissolved copper concentrations are decreasing in the Deep Adit and there is no trend for dissolved zinc. Dissolved iron however is increasing in the Deep Adit. Dissolved copper, dissolved zinc and dissolved iron were decreasing in the Road Adit. At Avoca Bridge, no statistically significant trend was present for dissolved zinc or dissolved copper for both the 2001-2017 period and the 2007-2017 period.
- As river stages change hydraulic gradients to or from the river also change. Gradients are
 predominantly positive which suggests that the Avoca River is a net gaining river from the
 alluvium during the monitoring period. The implication is that the spoil and the alluvial
 areas either side of the river contribute contaminant load to the river. This is especially
 evident in the measured zinc load results, in the stretches of river between Whites Bridge
 and Whites Bridge GS and between White Bridge GS and DS Deep Adit where the diffuse
 load accounts for 32% and 51% respectively.

7.2 Recommendations for the Monitoring Programme

No recommendations for the monitoring programme are proposed at this time.



Section 8

References

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Appendix A

Figures









Drawn by: OC Date: 26/06/2017 Internal Project Reference: Q:\95500-95999\95735\ 40 Documents Generated\GI\$\02_GIS_Tasks\22_MonRptR9\ MXD\03_AvocaMonSWGW.mxd Source: © DCENR Lidar Survey (2007)

Surface water (Adit discharge)

Surface water (Rivers and Streams)

Groundwater (Borehole)

Scale is 1:7,000 50 100 0 _ m

Rivers

Appendix B

Analytical Data Tables and Assessment Criteria



Table B-1 Comparison of Groundwater and Surface Water Results to Assessment Criteria R9

						Specific										
						Conductanc										
				Oxygen,		е										
	_		Ammoniacal	dissolved		@ deg.C		Aluminium	Antimony	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron
Sample Description	Туре	Date Sampled	Nitrogen as N	(field)	pH (field)	(field)	Sulphate	(diss.filt)								
		Units	mg/l	% Sat	pH Units	mS/cm	mg/l	μg/I	μg/l							
		Ecological Criteria	0.14	80 to 120*	4.5 to 9	-	-	1,900	-	25	4	0.45	3.4	5.1	5	-
	Hı	uman Health Criteria	0.3	-	6.5 to 9.5	2.5	250	200	5	10	-	5	50	-	2000	200
MWDA1	GW	27/03/2017	0.612	5.6	2.87	2.324	1670	144000	0.48	7.34	5.91	77.5	23.5	140	9610	>25,000
MWDA2	GW	27/03/2017	0.586	5.5	3.65	1.56	951	29000	1.2	4.32	6.91	71.5	3.6	213	2590	95300
MWPF1	GW	27/03/2017	0.1	94	4.11	0.152	32.8	252	0.08	0.255	9.42	0.238	1.73	0.518	35.3	76.9
SG104	GW	27/03/2017	2.35	73.7	2.76	7.859	9040	809000	0.88	44.2	20.4	302	6.6	717	57100	15800
GW1/05	GW	28/03/2017	0.1	26.8	3.65	1.585	1050	68900	0.48	3.93	5.47	26.2	3.6	132	8100	1050
GW2/05	GW	28/03/2017	0.1	50.2	3.63	1.301	748	49300	0.08	1.57	1.46	16.2	0.6	92	7960	99.3
MWET1	GW	28/03/2017	0.582	8.4	3.41	1.647	972	82800	0.48	3.33	3.44	22	6.95	132	6590	59100
MWET2	GW	28/03/2017	0.1	8.5	6.09	3.245	2330	6	0.48	7.28	12.6	2.52	3.6	129	2.55	95100
Avoca Bridge	River	29/03/2017	0.1	90.4	5.94	0.081	10.9	156	0.08	0.255	4.99	0.348	0.6	0.711	11.3	305
DS Deep Adit	River	29/03/2017	0.1	84.4	5.91	0.089	9	149	0.08	0.255	4.82	0.52	0.6	0.562	12	193
DS Millrace	River	29/03/2017	0.1	86.1	5.87	0.076	9.8	152	0.08	0.255	4.84	0.591	0.6	0.607	13.4	221
Site T1	River	29/03/2017	0.1	98.4	4.63	0.066	1	52.4	0.08	0.255	6.33	0.04	0.6	0.075	0.425	56.8
Site T5	River	29/03/2017	0.1	87.6	5.89	0.082	11.1	153	0.08	0.255	4.92	0.305	0.6	0.77	11.6	405
US Ballygahan Adit	River	29/03/2017	0.1	93.7	6.35	0.072	4.5	167	0.08	0.255	5.09	0.262	0.6	0.489	16	99.6
US Road Adit	River	29/03/2017	0.1	88.7	6.12	0.075	3.5	145	0.08	0.517	4.87	0.314	0.6	0.385	11.4	125
US Whites Bridge	River	29/03/2017	0.1	97.9	5.07	0.067	1	59.1	0.08	0.592	5.21	0.04	0.6	0.075	0.425	58.4
Whites Bridge	River	29/03/2017	0.1	93.7	6.06	0.072	1	67.6	0.08	0.255	4.89	0.04	0.6	0.075	1.28	76.9
Whites Bridge GS	River	29/03/2017	0.1	97.7	5.62	0.071	1	95.3	0.08	0.255	4.66	0.119	0.6	0.075	4.36	85.5
Wicklow Co. Maintenance Yard GS	River	29/03/2017	0.1	89.7	6.32	0.094	12.8	154	0.08	0.587	4.67	0.321	0.6	0.891	11.3	513
850 Adit (Confluence)	Adit	30/03/2017	0.223	76.1	2.72	1.312	657	76100	0.48	8.28	12.5	79.9	3.6	83.7	4810	16900
Cronebane Intermediate Adit	Adit	30/03/2017	0.366	8.7	2.94	1.271	651	63800	0.48	10.6	9.24	96.5	3.6	82.9	3430	62400
Cronebane Shallow Adit	Adit	30/03/2017	0.663	62.6	2.62	3.358	2820	351000	0.88	40.1	9.27	246	6.6	246	7040	133000
Deep Adit	Adit	30/03/2017	0.282	21.6	3.34	1.377	882	80000	0.48	9.08	8.16	64.4	3.6	90.5	431	62300
Deep Adit Confluence	Adit	30/03/2017	0.271	96.5	2.78	1.352	773	74900	0.48	8.45	10.2	66.7	3.6	85.6	2190	39200
Road Adit	Adit	30/03/2017	6.29	29.6	4.19	1.91	1180	10000	0.88	18	17.7	7.64	6.6	117	232	114000
Road Adit Confluence	Adit	30/03/2017	6.02	86.7	4.27	1.912	1180	9960	0.88	19.5	18	8.36	6.6	120	245	109000

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

Table B-1 Comparison of Groundwater and Surface Water Results to Assessment Criteria R9

Sample Description	Туре	Date Sampled Units	Lead (diss.filt) µg/l	Manganese (diss.filt) µg/l	Molybdenum (diss.filt) µg/l	Nickel (diss.filt) µg/l	Vanadium (diss.filt) µg/l	Zinc (diss.filt) µg/l
		Ecological Criteria	7.2	1100	-	20	-	50
	Human Health Criteria		10	50	-	20	-	-
MWDA1	GW	27/03/2017	4.52	9560	1.86	87.2	0.65	42500
MWDA2	GW	27/03/2017	3.45	11700	1.86	102	0.65	50200
MWPF1	GW	27/03/2017	0.618	17.7	0.731	3	0.65	42.9
SG104	GW	27/03/2017	47.9	32700	3.41	266	7.15	124000
GW1/05	GW	28/03/2017	11.4	5740	4.19	59.5	0.65	9630
GW2/05	GW	28/03/2017	0.373	3910	0.31	39.9	0.65	8580
MWET1	GW	28/03/2017	5.61	5480	1.86	66.3	820	7280
MWET2	GW	28/03/2017	1.02	35500	1.86	16.3	0.65	5400
Avoca Bridge	River	29/03/2017	2.69	48.6	0.31	1.04	0.65	130
DS Deep Adit	River	29/03/2017	3.94	26.9	0.31	0.821	0.65	202
DS Millrace	River	29/03/2017	4.05	30.5	0.31	0.904	0.65	228
Site T1	River	29/03/2017	0.764	7.36	1.14	0.7	0.65	17.2
Site T5	River	29/03/2017	2.44	55	0.31	0.962	0.65	134
US Ballygahan Adit	River	29/03/2017	1.35	26	0.31	0.822	0.65	76.3
US Road Adit	River	29/03/2017	2.02	23.3	0.31	0.786	0.65	98.9
US Whites Bridge	River	29/03/2017	0.674	7.15	0.31	0.694	0.65	17
Whites Bridge	River	29/03/2017	1.24	9.1	0.31	0.798	0.65	21.9
Whites Bridge GS	River	29/03/2017	1.07	11.2	0.31	0.694	0.65	30
Wicklow Co. Maintenance Yard GS	River	29/03/2017	2.6	59.1	0.31	0.928	0.65	146
850 Adit (Confluence)	Adit	30/03/2017	959	2490	1.86	36.2	0.65	24500
Cronebane Intermediate Adit	Adit	30/03/2017	1170	2150	1.86	43.3	0.65	27300
Cronebane Shallow Adit	Adit	30/03/2017	1040	7650	3.41	132	7.15	111000
Deep Adit	Adit	30/03/2017	1680	3280	1.86	34.5	0.65	46900
Deep Adit Confluence	Adit	30/03/2017	1350	2880	1.86	34.3	0.65	40200
Road Adit	Adit	30/03/2017	300	8820	3.41	45.4	7.15	7960
Road Adit Confluence	Adit	30/03/2017	310	9240	3.41	49.8	7.15	8310

xx Exceeds Ecological Assessment Criteria

xx Exceeds Human Health Assessment Criteria

xx Exceeds both Ecological and Human Health Criteria

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

- Not analysed or no assessment criteria

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

