GORTDRUM MINE

Background information

Mine District: Gortdrum

Mine Name: Gortdrum

Alternative Names:

Elements of interest:
Cu, Sb, As, Ag, Hg

Project Prefix: GOR-

County:	**Townland:**	**Grid Reference:**
Tipperary	Gortdrum, Ballyryan East, Kyleagarry	E187111, N141012

Introduction

Gortdrum mine is located 2.5 km north of Limerick Junction near Tipperary town. Copper, mercury and silver were mined between 1968 and 1975. The site covers approximately 150 ha. Since closure, the large open pit has flooded and the tailings pond has been successfully revegetated. Most mine buildings, including all processing plant, have been removed. The site is privately owned and several commercial activities take place on site, including aggregate production, fish farming, cattle farming and lease of office space. Large waste heaps were created from material extracted from the open pit and the aggregate is produced on site through processing of these heaps. This activity is controlled under Section 261 of the Planning and Development Act 2000 and the site is subject to monitoring by South Tipperary County Council. Work under the HMS-IRC project was therefore largely restricted to other parts of the site.

Geology and Mineralization

The Gortdrum deposit, now worked out, was a disseminated Cu-Hg-Ag deposit in basal Carboniferous (Courceyan) limestones and shales, located beside an ENE strike-slip fault (Fig. 1). This fault, the Gortdrum Fault, brought Old Red Sandstone rocks to the southeast into contact with Lower Carboniferous limestones and shales to the northwest and was the most important control on the location of mineralization.

The deposit was 600m long by 10-180m wide and was mined exclusively by open cast. The orebody had two distinct zones (Tyler 1979): (1) the **Western ore zone** occurred in severely deformed limestone and shale in the hanging wall of the Gortdrum Fault and (2) the **Eastern ore zone wa**s in a narrow wedge of severely deformed limestones between the footwall of the Gortdrum Fault and a subsidiary fault to the south (Fig. 1). The main ore minerals were tennanite (CuO), chalcopyrite

($CuFeS_2$), chalcocite (CuS) and bornite (Cu_5FeS_4). Pb and Zn mineralization is largely absent. Tennanite and chalcopyrite dominated in the upper parts of the mine where the mineralization was hosted in thin (<5mm) veins of calcite and dolomite and in fractured limestone wallrock. Deeper in the mine, disseminated bornite and chalcocite dominated within the more ductile shaly limestone host rock. The tennanite was enriched in Hg, Ag and Sb. It typically contained 5 – 6% Hg in the upper part of the mine (0 - 25m depth) but this declined with depth to less than 1% below 75m (Steed 1986). The mean Ag+Sb content of tennanite was 21.6% (Steed 1986).

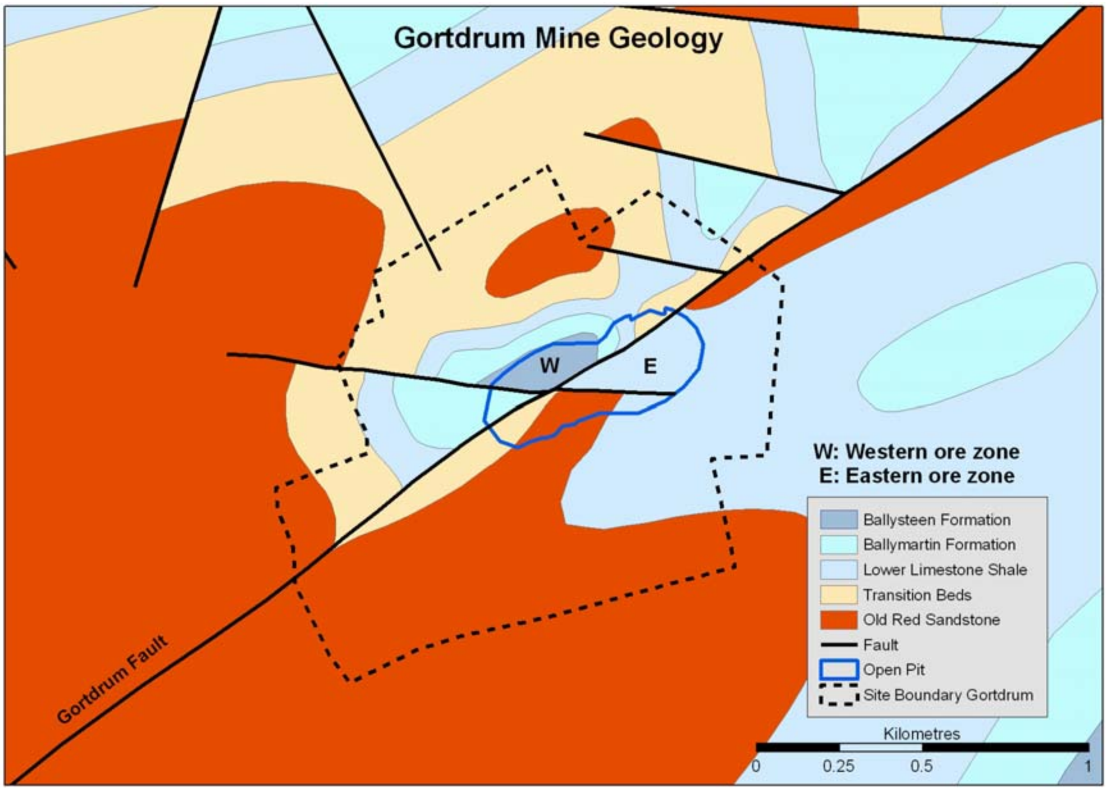

Fig 1 Geology of area around Gortdrum Mine

Mining History and Production

The Gortdrum deposit was discovered by the Lower Limestone Syndicate established by Northgate and its partners to undertake reconnaissance geochemical sampling over the Lower Carboniferous succession in Ireland. In 1962, stream sediment geochemistry showing 10-18 mg/kg THM ("total heavy metals") provided the first indications and follow-up geochemistry delineated a soil anomaly with peak values in excess of 80 mg/kg Cu over a small quarry with visible Cu-sulphide mineralization (Tyler 1979). Subsequently, an induced polarization (IP) survey was followed by drilling and in July 1966 the deposit was estimated to contain 3,810,100 tonnes of ore at 1.19% Cu and 25.1 g/t Ag (Steed 1986)

Gortdrum Mines Ltd. was established in 1964 and commenced overburden stripping and construction of a concentrator in 1967 (Tyler 1979). Production began in late 1967 but by early 1968 problems were encountered with mercury contamination of the copper concentrates. A mercury recovery (calcining) plant was subsequently constructed and commissioned in 1969.

Total production over the lifetime of the mine is estimated (Tyler 1979) to be 34,737 tonnes Cu, 82,704 kg Ag and 271,029 kg Hg. At the original grade of 1.19% Cu, this implies over 3.5 million tonnes of ore were mined.

Site Description and Environmental Setting

The site is surrounded by relatively flat farmland, primarily used as cattle pasture. A number of houses lie close to the boundaries of the site but the density of housing in the immediate area of the site is generally low. Several streams drain the area with the most significant one flowing north along the western boundary of the site (Fig. 2).

The site today has four main components (Fig. 2): (1) the TMF, now revegetated and in use by the land-owner as a cattle pasture; (2) the open pit, a 90m deep lake used for fish farming; (3) large waste heaps and stockpiles on the northern side of the open pit lake, now serving as source material for aggregate production, and (4) the old mine processing area in the southeast corner of the site, containing the remains of processing buildings and the mercury plant siltation pond. This area also contains the old mine office, now converted into a dwelling for the land-owner. In addition, some building on the eastern edge of the side are being used by local businesses.

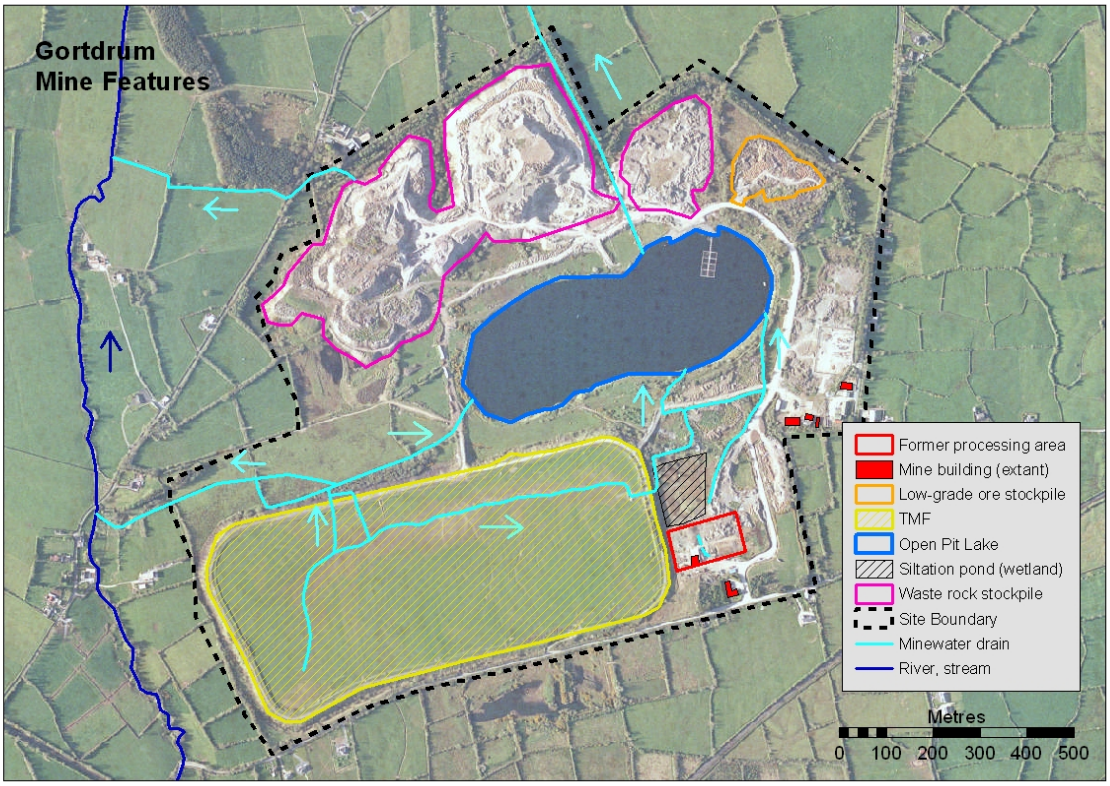

Fig 2 Gortdrum: extant mine features

The large waste heaps on the northern part of the site constitute part of a working "quarry" site and thus were not the subject of detailed study under HMS-IRC. The aggregate production is controlled by South Tipperary County Council under Section

261 of the Planning and Development Act 2000 and, therefore, monitoring of the site for dust and other potential nuisances is routinely carried out. Work under the HMS-IRC project focused on the old processing area and the TMF (solid waste XRF) as well as on-site surface water drains and off-site discharges to local water courses (Fig. 2). Stream sediment samples were collected along the river system that flows north along the western boundary of the site. However, the large waste heaps or stockpiles on the northern part of the site were included in the HMS-IRC Site Scoring process. Their chemistry was modelled using *in-situ* XRF analyses made on a limited number of aggregate samples. Table 1 gives the estimated area and volume for each solid waste heap in Gortdrum (Fig. 2), as used in the scoring system.

Table 1 Area and Volume of spoil heaps Gortdrum mine

Waste ID	Area (m^2)	Volume (m^3)
GOR-SP01	894	179
GOR-SP02/3	1028	666
GOR-SP04	848	424
GOR-TA01	348,439	3,348,077
GOR-SLT01	12,120	12,120
GOR-AGR01	169,732	1,254,412
GOR-AGR02	101,839	938,289
GOR-AGR03	37,769	141,764

Geochemical Assessment

1. Surface Water

Surface water sampling was carried out in both winter (December 2006) and summer (June 2007) seasons at a total of 7 sites (Fig. 3). The precise sampling location at some sites varied between winter and summer. Site W001 is the only upstream site and the only site outside the mine boundary. Most surface water on the mine site is directed via drainage channels to the Open Pit lake. However, water discharging from the site was sampled at two locations, W009 and W010. Table 2 summarizes the data for selected elements.

Some broad conclusions can be drawn from the data. The pH values are generally alkaline, reflecting the limestone bedrock. There is no risk of AMD at Gortdrum. EC values appear high in some cases but they are correlated with total ion concentration (e.g. Ca and SO_4) and not metal contents. Samples W002, W003 and W004 are TMF discharge / run-off and for the most part have the highest metal (Cu, Sb, As, Hg) concentrations in both winter and summer. Exceptions are the Open Pit Lake winter sample (W007), which had relatively high Cu and As, and the waste heap / stockpile leachate sample (W009) which in summer had high Sb and As (Table 2). In winter, the site of W009 was flooded: the sample was taken from a ponded area and the seasonal difference in concentration probably arises from this. In summer, three samples were taken from the Open Pit Lake to test variability. Results for most elements were almost identical for the three samples. A notable exception was total As concentration, for which one analysis gave 140 µg/l as opposed to 25 µg/l for the other two analyses. Small amounts of dissolved Hg are present in water sourced from the TMF but other samples returned values at or below the detection limit. (Dissolved Hg is described here instead of total Hg for which the detection limit (25 µg/l) is too high to detect the presence of Hg.) The measured concentrations of Sb, As and Hg in surface water within the Gortdrum are the highest recorded in the HMS-IRC project. Many of the samples exceed the draft EC standards for surface water (EC 2007).

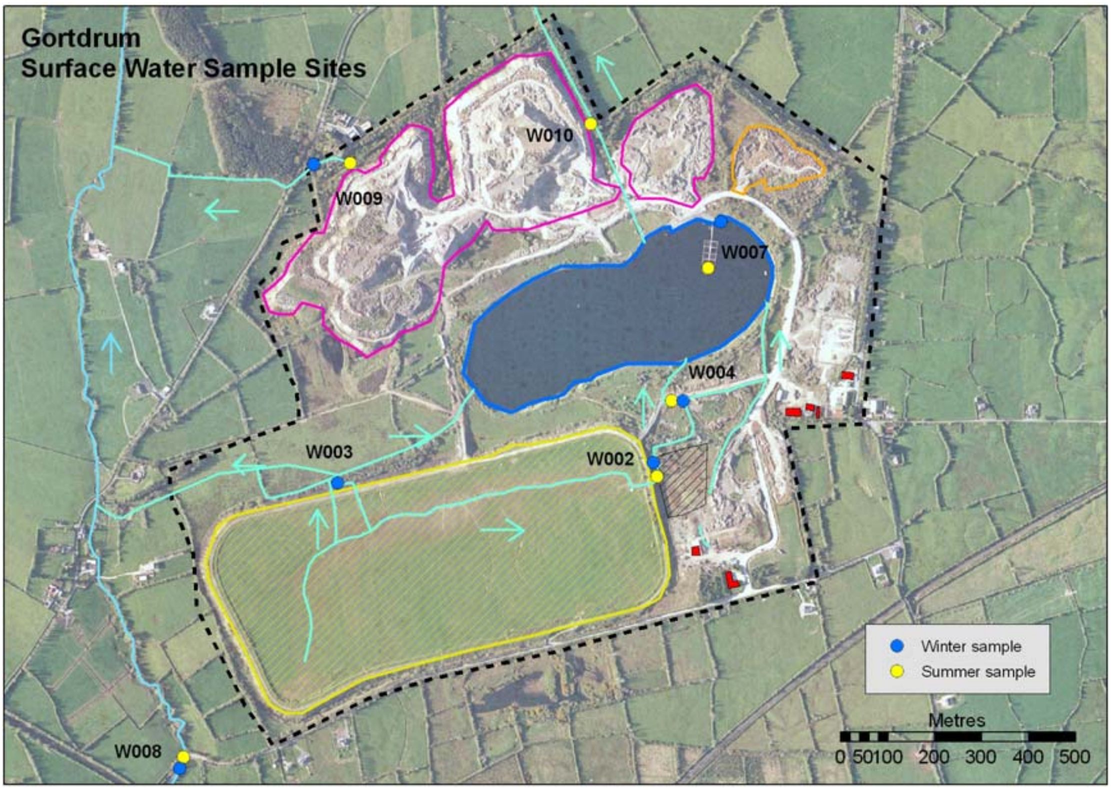

Fig. 3 Surface Water Sample sites, Gortdrum

Table 2 Gortdrum surface water samples

	pH	EC mS/cm	Cu(tot) µg/l	Sb(tot) µg/l	As(tot) µg/l	Hg (diss) µg/l	SO_4(tot) mg/l
Winter							
W002	8.17	0.27	479	2	33	0.22	12
W003	8.18	0.30	233	48	71	0.33	48
W004	7.76	0.37	121	21	91	0.38	36
W007	8.08	0.45	165	35	88	<0.05	81
W008	7.71	0.41	<1.0	<1.0	2	<0.05	12
W009	7.50	0.61	15	10	19	0.06	70
Summer							
W002	7.02	0.79	160	280	80	0.1	273
W004	7.39	0.81	130	120	25	0.24	161
W007*	8.7	0.45	25	25	63	<0.05	73
W008	8.04	0.63	25	70	25	0.05	20
W009	7.91	1.61	25	310	120	0.05	791
W010	6.90	1.37	36	20	15	0.05	442

* Mean of 3 readings

The apparent lack of any major discharge from the mine site to local water courses minimizes concerns about surface water quality at Gortdrum. The location W010 (Fig. 3) is thought to be the overflow outlet for the Open Pit lake. It drains north and joins the stream that runs northwards along the western boundary of the mine site. When sampled in June 2007, the flow did not exceed 1 l/s (visual estimation). Apart from sulphate, the water is not particularly enriched in mine-related chemicals and in this its chemistry is similar to that of the upper part of the Open Pit lake itself (Table 2). The leachate emerging from the base of the stockpile / waste heap (GOR-AGR01) in the northwest corner of the mine (W009) also had a low flow rate in summer 2007. It could not be traced beyond the wooded area into which it discharges and seems to have seeped into the ground. The high concentration of Sb and As in this water may be of some concern in the context of down-gradient groundwater sources. Stream sediment analysis (below) further suggests that there is minimal, if any, downstream impact by mine-related chemicals on the river that flows north along the western boundary of the site.

2. Groundwater

No groundwater was sampled at Gortdrum for the HMS-IRC project. Leachate tests were carried out on three composite samples from the former processing area and the TMF. The leachate from the two processing area samples had elevated Sb (87, 61 µg/l), Cu (38, 2597 µg/l), As (14, 1 µg/l) and Hg (0.23, 0.37 µg/l). The very high Cu in one leachate sample reflects the original Cu-rich material. The leachate derived from the TMF sample had 11 µg/l As but other elements were not present in significant concentrations. The leachate test must be considered in the context of the results of the analysis of an actual leachate sample from the TMF, i.e. the sample taken at location W003, which had much higher concentrations of dissolved and total metals (Table 2). Moreover, the stockpile / waste rock leachate sampled from location W009 in summer 2007 also had high metal concentrations. In all, therefore, both the laboratory leachate tests and the samples of actual leachate from Gortdrum indicate that solid waste has the potential to contaminate groundwater in the area.

3. Stream Sediments

Stream sediment samples were taken at a total of five sites, upstream and downstream of the mine (Fig. 4). The concentrations in stream sediment samples of elements of interest, such as Cu, Sb and As are generally low by comparison with other mine sites in the country. Hg, Ag and Sb, all important components of the ore, were not detected in any stream sediment analysis. Detection limits for these elements are of the order of 20–40 mg/kg.

Cu and As were detected in all samples. Cu ranges from 38 to 84 mg/kg, As from 31 to 49 mg/kg. Sample SS004, taken downstream of the confluence with the stream carrying the Open Pit Lake overflow, had the highest Cu and As (84 and 49 mg/kg, respectively), yet SS001, taken upstream of all apparent mine influences, had virtually the same Cu content, 81 mg/kg. Sample SS003, from a stream flowing eastward toward the mine, had the lowest Cu and As. While it is possible to suggest that SS004 provides some evidence for mine-related impact on stream sediments at Gortdrum, stream sediments downstream of other Cu mines in Ireland typically have much higher Cu concentrations. Median Cu in stream sediments sampled at Avoca is 257 mg/kg and at Allihies it is 1246 mg/kg. Stream sediments were instrumental in the discovery of the Gortdrum mineralization. Concentrations up to 80 mg/kg Cu were found in the streams north of the mine site. The concentrations revealed by this study are of similar order and suggest that mining has not led to any significant contamination of streams sediments at Gortdrum.

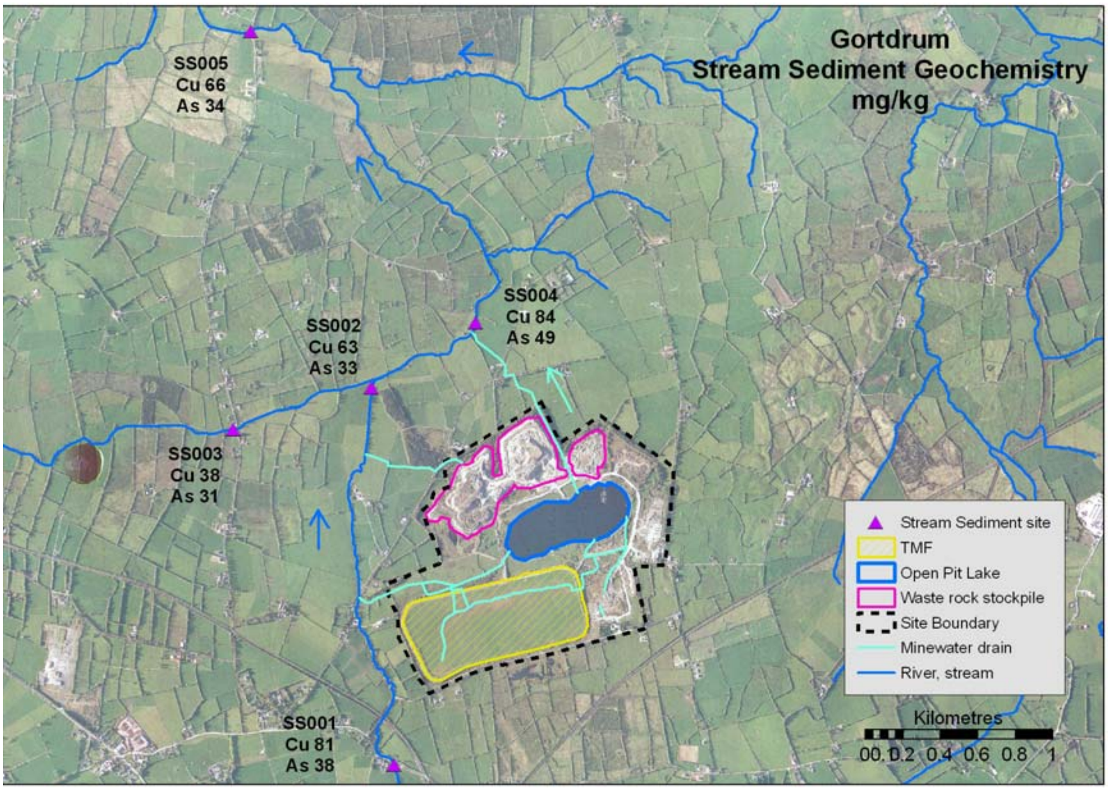

Fig. 3 Stream Sediment Geochemistry, Gortdrum

4. Solid Waste

The solid waste analysed came from the old processing area (24 samples), the TMF (55 samples), the mercury plant siltation pond (29 samples) and the stockpiles / waste rock heaps now serving as a source of aggregate (5 samples) (Fig. 5). Analyses reported for the processing area and TMF are *in situ* XRF analyses. In contrast, owing to difficult field conditions, the siltation pond and aggregate samples were collected in the field and then dried and ground in the lab prior to analysis.

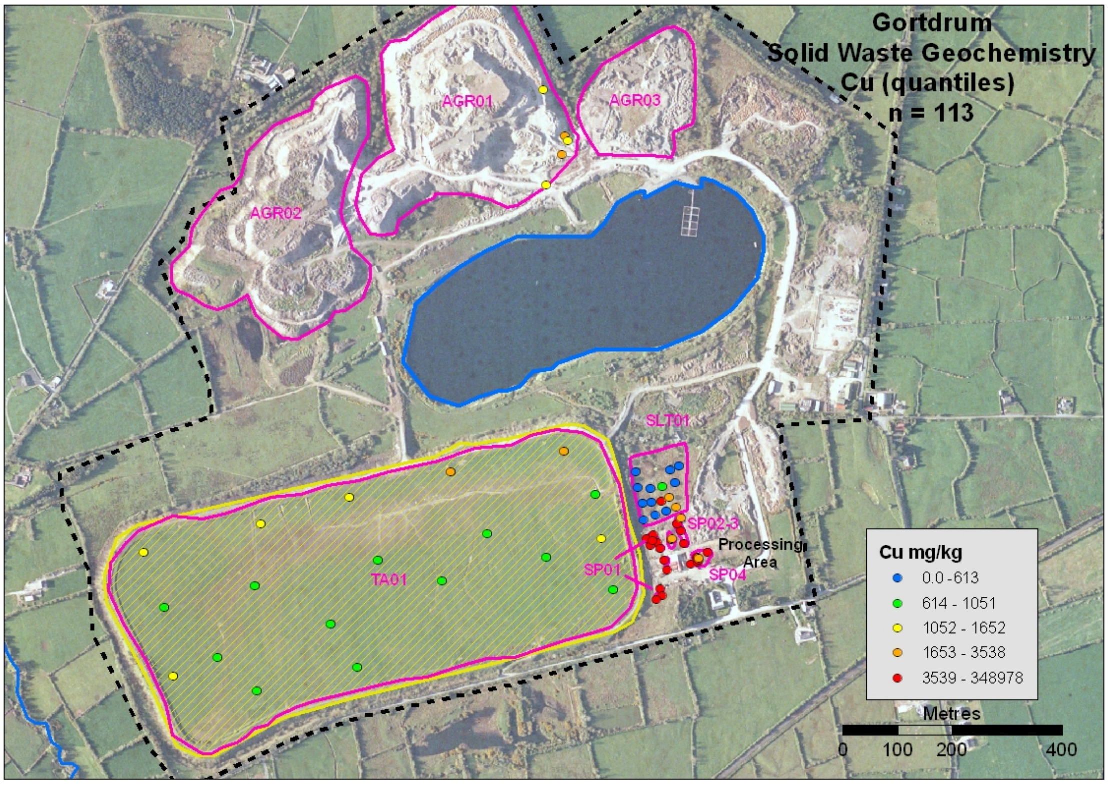

Fig. 5 Solid Waste Cu XRF analyses, Gortdrum

Fig. 5 shows the distribution of Cu in XRF analyses for all sample sites at Gortdrum. Allowing for the fact that analysis of prepared samples in the laboratory generally yields higher element concentrations than field analyses, the results nevertheless show clearly that the old processing area has very elevated Cu concentrations in solid waste relative to other sources in Gortdrum. The siltation pond, in particular, has generally relatively low Cu concentrations while the TMF samples have average to below-average Cu. Table 3 summarizes the data for the main elements of interest at Gortdrum.

In addition to Cu, As, Sb, Hg and Ag are significant components of the material on the processing site. The levels of Hg and As, in particular, are particularly high. Most of the material analysed on the processing site consists of fine silt-clay that forms the surface layer on the ground. Thicker heaps of solid waste also occur on the site. These consist either of spoil brought from the northern part of the site as cover, e.g. on the site of the mercury plant, or remnants of processing waste found among the remaining buildings (photo, above left). This processing waste is the source of the extremely high values recorded for some elements (34% Cu, 1.89% As, 5468 mg/kg Hg).

Table 3 Summary statistics of solid waste XRF analyses, Gortdrum

mg/kg	Cu	Sb	As	Hg	Ag
Processing Area					
n	24	24	24	24	24
Minimum	1928	0.0	195	25	0.0
Maximum	348978	4410	18924	5468	459
Median	34199	1013	2722	487	82
Mean	70427	1121	3661	819	103
TMF					
n	55	55	55	55	55
Minimum	683	0.0	14	0.0	0.0
Maximum	3538	0.0	118	16	0.0
Median	1174	0.0	50	0.0	0.0
Mean	1374	0.0	54	2	0.0
Aggregate					
n	5	5	5	5	5
Minimum	1289	0.0	194	14	0.0
Maximum	1851	81	371	19	0.0
Median	1613	65	224	15	0.0
Mean	1580	53	264	16	0.0
Siltation Pond					
n	29	29	29	29	29
Minimum	0.0	0.0	13	0.0	0.0
Maximum	4686	189	1037	73	0.0
Median	101	0.0	65	0.0	0.0
Mean	619	17	122	11	0.0

Fig. 6 shows the distribution of Hg on the site around the old processing area. The ground on the site of the former mercury plant has consistently elevated Hg values – the lower value recorded on the eastern part of this site was measured on spoil imported from the northern part of the site, presumably to ameliorate the ground.

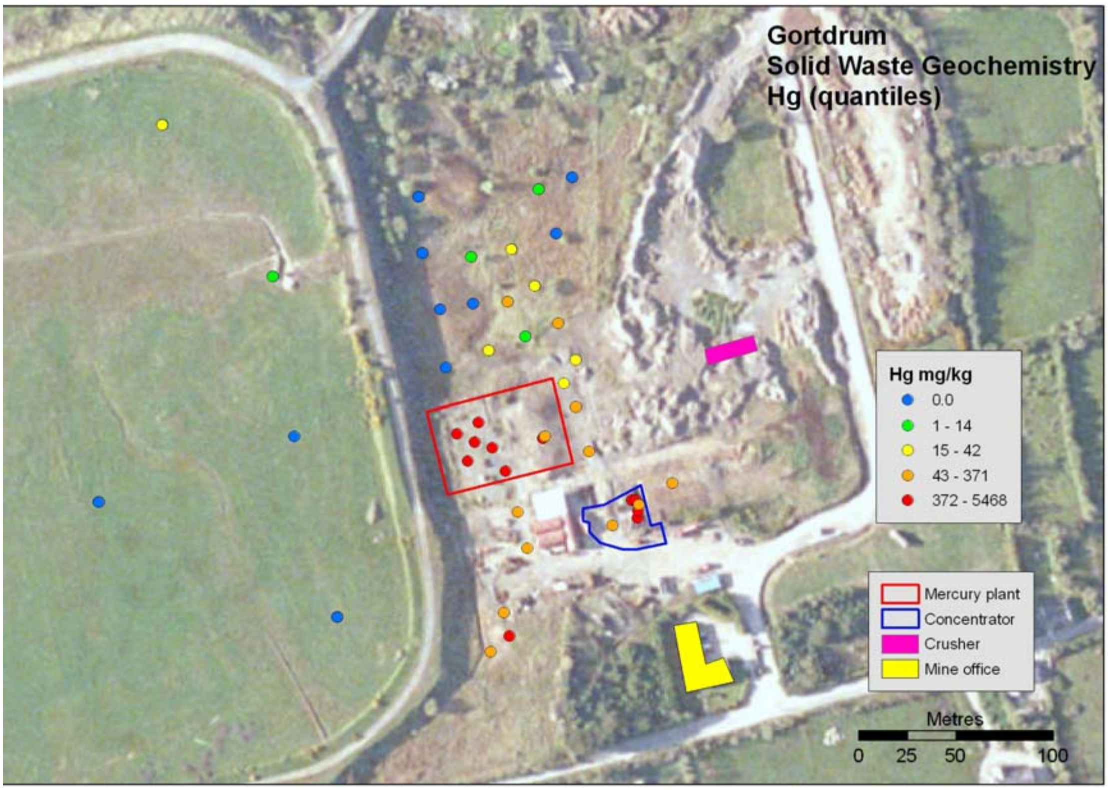

Fig. 6 Hg in solid waste, Gortdrum processing area

The TMF was drilled with an auger and analyses of tailings were carried out on the material brought to the surface from intervals of 0.5m, 3m and 5.5m below surface. A total of 55 samples were analysed from 19 different sites. Only Cu was consistently detected. Samples from 3m and 5.5m depth had similar median Cu contents (1158 and 1011 mg/kg, respectively) whereas those from near the surface had higher median value (1654 mg/kg). The difference may reflect the physical state of the samples rather than any real chemical variation. Below approximately 1m depth, the tailings were in the form of a grey, plastic mud (photo, above right), in contrast to the dry sandy material in the upper part. The high water content of the deeper tailings samples might have reduced measured concentrations of elements in the samples. Analysis of dried samples from three TMF locations did not show any systematic bias toward higher Cu concentrations for samples from any particular depth.

The siltation pond is now a partly vegetated wetland (photo, left) though the area nearest the former mercury plant is drier. The wetness of the material precluded *in situ* XRF analysis. A grab sample taken in

December 2006 close to the former outlet pipe had a measured Hg content of 595 mg/kg after drying. However, the systematic sampling undertaken in summer 2007 did not yield similarly high Hg concentrations (Table 3). Nevertheless, the siltation pond contains significant Cu and As.

No systematic sampling and analysis of solid waste was carried out in the area of the stockpile / waste rock heaps north of the open pit. This area is an active aggregate operation (photo, left) and is subject to monitoring under the terms of the relevant legislation. Five aggregate samples were collected and analysed in the lab after grinding. The results (Table 3) show that Cu, As and Hg were consistently detected in samples analysed. The levels are much lower than those encountered in the old processing area but nonetheless may be significant, particularly in the context of an aggregate operation that produces considerable quantities of dust.

5. HMS-IRC Site Score

Table 4 Site Scores for individual wastes, Gortdrum

Waste	SP01	SP02-3	SP04	TA01	AGR01	AGR02	AGR03
1. Hazard Score	**28**	**13**	**41**	**46**	**145**	**139**	**30**
2. Pathway Score							
Groundwater	0.81	0.44	0.86	0.82	7.40	7.05	1.25
Surface Water	0.27	0.11	0.43	5.22	27.95	26.60	2.88
Air	0.02	0.03	0.02	0.08	3.20	3.06	0.31
Direct Contact	0.09	0.17	0.12	1.44	15.58	15.58	1.56
Direct Contact (livestock)							
3. Site Score	**1**	**1**	**1**	**8**	**54**	**52**	**6**

Waste	SLT01	W002	W009	W010	Stream sediments	Totals
1. Hazard Score	**11**	**43**	**45**	**15**	**56**	612
2. Pathway Score						
Groundwater	0.15	1.11	3.97	0.36		24.23
Surface Water	0.44	4.90	0.32	0.23		69.35
Air	0.00					6.71
Direct Contact	0.18					34.71
Direct Contact (livestock)					22.48	22.48
3. Site Score	**1**	**6**	**4**	**1**	**22**	**157**

The total site score for Gortdrum, after applying the HMS-IRC scoring system, is 157 (Class IV). This is a very low score for a 20th-century mine with large volumes of solid waste remaining on site. By comparison, the other 20th-century mines are all

Class I sites, with scores of 2712 (Tynagh), 2545 (Silvermines) and 2438 (Avoca). The reason for the difference is the generally low concentrations of metals measured in the waste at Gortdrum, particularly metals with high relative toxicity, such as Pb and As, that are relatively abundant on other sites. While As and Hg are present in high concentrations around the old processing area, the volume of waste there is very low. It is possible that the concentrations of metals in the large-volume stockpile / waste heaps on the northern part of the site are underestimated, given the limited number of analyses carried out. However, the low concentration of metals in the original ore places a limit on metal concentrations in waste material. The composition of the ore, specifically the absence of high concentrations of Pb and other metals of high relative toxicity, would still ensure that the hazard score for these heaps remained low.

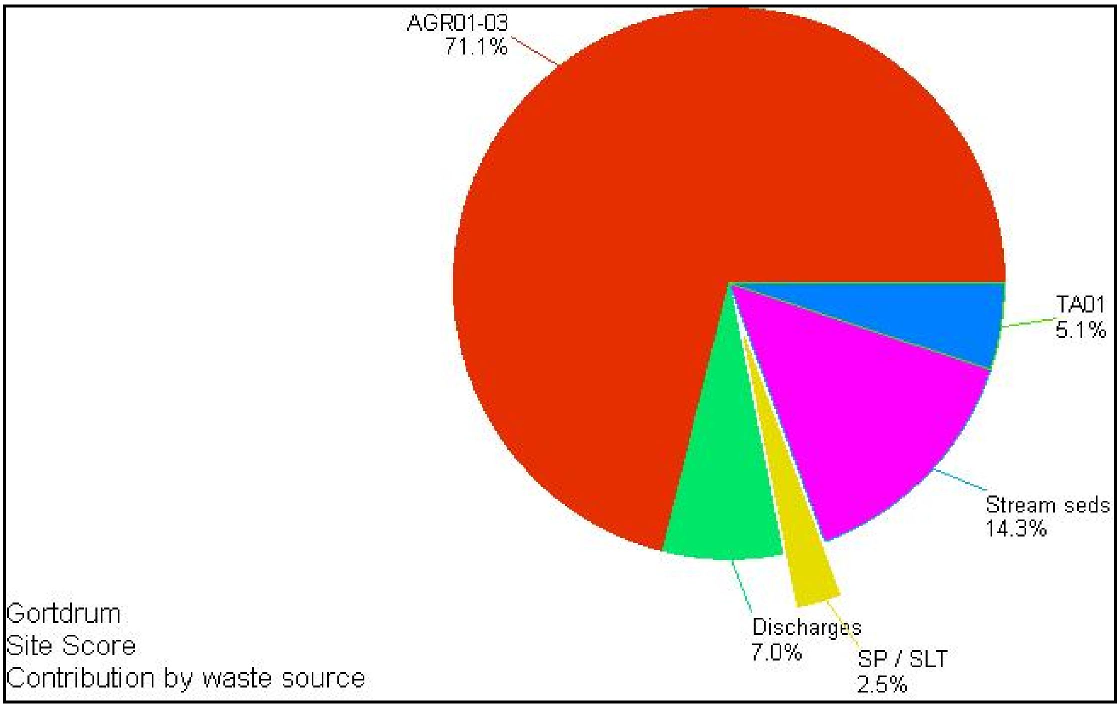

Fig. 7 Site Scores, Gortdrum, by waste source

Fig. 7 shows the site score broken down by waste type. Individual heaps among the different types have been combined to simplify the diagram. The extremely large volumes of stockplile / waste rock (total calculated volume > 2 million m^3) give it by far the largest share of the total score (71.1%). Although the tailings pond has an even larger volume than the stockpile, the very low concentration of metals in it gives it a very low share of the score (5.1% of the total). The low volume of waste at the old processing site and the low volumes of the water discharges account for the low scores from these two sources. Stream sediments have an unusually high share of the total score by comparison with other mine sites but this must be seen in the context of very low overall score. Their score reflects the presence of small concentrations (< 100 mg/kg) of elements such as Pb, As and Ni over a long length of stream.

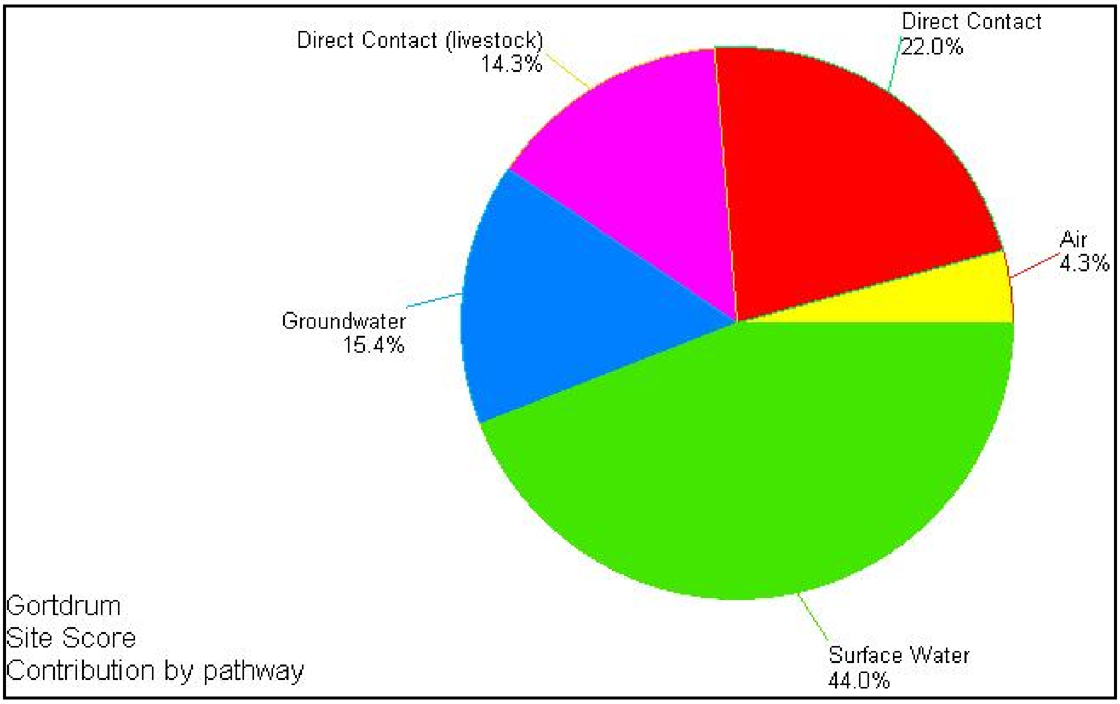

Fig. 8 Site Scores, Gortdrum, by pathway

Fig. 8 shows the contributions made to the total score by the various pathways. The stockpile / waste rock heaps dominate the overall score and the surface water pathway is the most important component of their score. Hence, the surface water pathway dominates the site score. This dominance reflects the large surface area of the stockpile / waste rock heaps and their proximity to surface drainage. The aquifer vulnerability is considered to be relatively low and as a consequence the groundwater pathway makes a relatively modest contribution to the overall score. Note that the "Direct Contact (livestock)" score in Fig. 8 is equivalent to the stream sediment score in Fig. 7.

6. Geochemical overview and conclusions

Gortdrum mine is one of the largest abandoned mine sites in the country. Very large volumes of solid waste remain on site. The Gortdrum deposit was the only one in Ireland to contain significant Hg and, as such, has significant potential risks not associated with other sites.

The ground cover in the old processing area has high concentrations of Cu, As and Hg. This area is close to the former mine office, now the site owner's dwelling, and has been in use as a storage and workshop area in the recent past. This area was gated in response to the initial survey for the HMS-IRC project and access is restricted. However, given the very high concentrations of Hg and As detected, a site-specific risk assessment should be carried out. The TMF has been successfully revegetated though bare patches have developed upon it. Cu concentrations in the tailings are low enough to allow good grass growth and As contents are much lower than those recorded in the processing area. Hg is typically below detection limit. The TMF is in general use as a cattle pasture. The former siltation pond is now a wetland and is largely waterlogged. Moreover, metal concentrations are unexpectedly low. The stockpile / waste heaps north of the open pit are now part of an aggregate extraction operation. Limited analysis suggests significant levels of metals, including As and Hg, remain in this material after extraction.

Very little water appears to flow off the site. Leachate and run-off from the TMF drain to the open pit lake. A drain takes overflow from the lake to a local water course but flow was very low when observed in summer – it may be more significant in winter. Leachate draining from spoil heaps on the northwestern end of the site appears to flow underground. Leachate generally has elevated concentrations of Cu, Sb, As and Hg, as does the lake water. There is potential for some impact on groundwater downgradient of the site.

There is no evidence for significant impact of mining on the composition of stream sediments in local streams. Metal concentrations are of a similar order to those reported from reconnaissance geochemistry prior to mining.

References

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