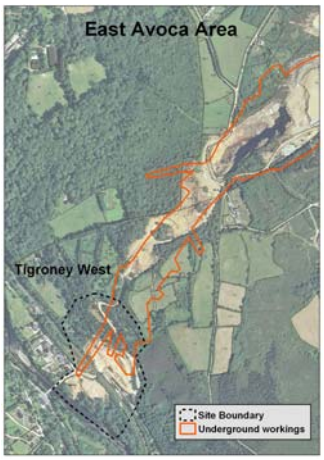
TIGRONEY WEST

Background information



Mine Name: Tigroney West

Mine District: Avoca

Alternative Names:

Elements of interest:
Pb, As, Cu, Zn, Cd

Project Prefix: AVO-

County:	**Townland:**	**Grid Reference:**
Wicklow	Tigroney West	E319899, N182135

Site Description and Environment Setting

The Tigroney West site comprises the area between Tigroney East, to the northeast, and the Avoca River to the southwest. As defined on Fig. 1, it covers 6 ha. Extant mine features (Fig. 1) include the **Williams Engine House** and its chimney (photo, right), high on the slopes at the eastern part of the site, numerous spoil heaps, the **Deep Adit**, close to the river, as well as 20th century features such as the **850 Adit** and two large ore bins. The site is bordered to the east and northeast by heathland and pasture and to the west by the Avoca River. A small housing cluster lies between part of the site and the river. The main single-track Dublin-Wexford railway and a public road run through the lower part of the site.

The **Williams Shaft**, now covered by a concrete cap, comprises an upper vertical section, from78m OD to -39m OD, and a lower inclined section that extends the to a depth of -129m OD. It was used for pumping water. It was constructed along with the engine house in the mid 19th century. The engine house and chimney have been conserved in recent years and are structurally sound. The Deep Adit (photo, left) was initially driven in the late 18th century and now extends northwest for over 800m. It drains all workings in Tigroney and Cronebane below the level of the Cronebane Shallow Adit. It is now open for several metres but thereafter completely blocked either deliberately or by collapse. Mine water discharges through a pipe in the centre of the floor that apparently was installed to bypass the blockage. The water drains via a 150m-long, 1-2m-wide channel to the Avoca River. The adit is fenced by a standard 2m-high chain-

link fence but is easily accessed via a low fence that adjoins the higher fence half-way up the railway embankment. The drainage channel, in which the water can reach a depth of 1m during periods of high flow, has a low, easily-climbed fence along part of its length. An additional entrance to the Deep Adit, known as the incline entry to Deep Adit, was recognized east of the railway during the recent site investigations (CDM 2008). The concrete block wall across the entrance is breached. Two partly blocked flatrod tunnels, one beneath the railway embankment and one beside the ore bins, originally extended eastwards to Williams shaft. The only other remaining 19th century mine features on the Tigroney West site are the low, overgrown walls of two ochre pits and the almost entirely obliterated sawmill (Fig. 1)

In late 1959 St Patrick's Copper Mines Ltd. (SPCM) began driving the 850 Adit and it reached a length of 750m by September 1962, with four small stopes developed along its length. Ore was brought out on wagons hauled by a diesel locomotive and tipped into the two large **ore bins** (photo, right) to await trucking to the mill in West Avoca. The adit is blocked by a concrete block wall but this has been breached sufficiently to allow human access. The two steel ore bins, 4.9m high on a 1.9m-high support structure (CDM 2008), and wooden crib show signs of severe corrosion and decay.

Tigroney West is covered either by spoil heaps or, in between, a thin layer of spoil (Fig. 1). Most of the spoil is in the form of three benches east of and above the railway line. The overall height is 15m (CDM2008). West of the railway line the spoil is typically less than 1m thick. The area east of the drainage channel was levelled some years ago. Table 1 presents volume estimates for the spoil heaps on the site.

Table 1 Area and volume of spoil heaps at Tigroney East

Waste ID	Area (m^2)	Volume (m^3)
AVO-SP01a/1b	4,491	*2,383
AVO-SP02	12,769	*10,878
AVO-SP02a	808	*1,114
AVO-SP03	542	*250
AVO-SP04	8,711	8,711

Source: HMS-IRC, modified after Gallagher and O'Connor 1997;
* LIDAR survey 2007 (CDM Report).

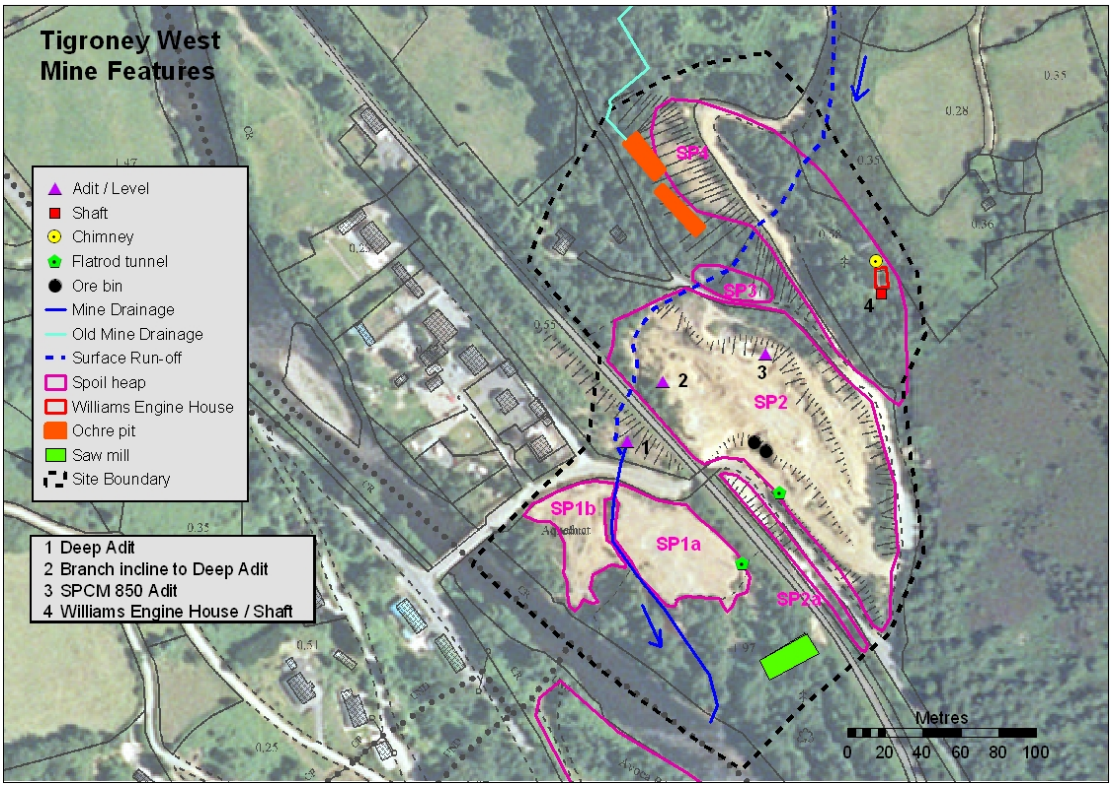


Fig. 1 Tigroney West: mine features

Geochemical assessment

1. Surface water

Surface water was sampled at a number of sources in Tigroney West (Fig. 2). These included the Deep Adit, the mixing zone where the Deep Adit discharge enters the Avoca River, surface run-off channelled into the drain that eventually joins the Deep Adit discharge channel and surface run-off generated *in situ* on the spoil beside the river (site 6 on Fig. 2). The river itself was sampled, upstream of the site, below the Deep Adit mixing zone and at another point where groundwater base flow was observed issuing to the river (Fig. 2). A local spring, known as P. Clarke's spring, rises to a metal cylinder and it was also sampled via the fitted tap. Sampling took place in November 2006, February and June 2007. In addition, CDM carried out further sampling in 2007 and 2008 for the Avoca Feasibility Study. Not all sites were sampled during each period. Tables X.2 and X.3 summarize the results for selected parameters.

Table 2: Deep Adit discharge, seasonal variation

	Pb (tot) µg/l	Zn (tot) µg/l	Cu (tot) µg/l	As (tot) µg/l	Cd (tot) µg/l	Cr (tot) µg/l	Acidity Mg/l $CaCO_3$
Deep Adit Nov 2006	2113	49310	1471	<1	148	109	934
Deep Adit Feb 2007	1483	37950	1416	<1	139	4	960
Deep Adit Jun 2007	1272	39130	1154	<1	105	3	910
Deep Adit Feb 2008 (CDM)	1540	na	1320	<50	120	<50	930

There is little seasonal variation in the chemistry of the Deep Adit discharge (Table 2). Gray (1995) reported similar findings for Zn, Fe and Cd but suggested that Cu concentration in the Deep Adit could be linked to flow rate.

The Deep Adit discharge and surface run-off are all characterized by low pH (2.2 – 3.3), high acidity and high metal concentrations. Table 3 compares the results for all sites sampled in Tigroney West. The data are for November 2006, with the exception of the upstream site (sampled in June 2007) and the surface run-off site (February 2007). The Deep Adit discharge has high metal concentrations and high acidity, though they are lower, with the exception of Pb, than those of the Cronebane Shallow Adit. However, the latter discharge appears to eventually return into the underground workings and presumably emerges via the Deep Adit. The flow rate of the Avoca River was high in November 2006 and the result is strong dilution of the adit discharge within the mixing zone. With lower river water levels in summer 2007 the dilution was much less and metal concentrations in the mix zone are considerably higher (Table 4). The "surface drainage" referred to in Table 3 is the water than runs off the mine site in the area of Tigroney East, up-gradient of Tigroney West, before flowing into a channel that joins with the Deep Adit discharge a few metres below the adit mouth. This run-off had high metal contents also, notably Cu, though the composition is quite variable to judge by the results of February 2007 sampling when Cu concentration was 2300 µg/l, as opposed to 8,266 µg/l in November 2006.

Table 3: Data for surface water, Tigroney West*

	Pb (tot) µg/l	Zn (tot) µg/l	Cu (tot) µg/l	As (tot) µg/l	Cd (tot) µg/l	Cr (tot) µg/l	Acidity Mg/l $CaCO_3$
Deep Adit (1)	2113	49310	1471	<1	148	109	934
Deep Adit channel (3)	2021	48870	1457	<1	150	5	900
Deep Adit mix zone (4)	40	997	41	<1	3	5	17
Surface drainage (2)	394	1057	8266	1	37	19	466
Surface run-off (Feb 07) (6)	92	1454	4725	1	5	8	316
Base flow mix zone (5)	11	131	29	<1	<1	37	7
Avoca River u/s (Jun 07) (7)	5	162	97	<1	<1	12	6
Avonmore River	4	58	<1	1	<1	3	8
Spring (8)	3	82	12	<1	<1	3	10

*Samples taken in November 2006 unless stated otherwise;
numbers in brackets = sample sites, Fig. 2

That surface run-off can contain quite significant metal concentrations is confirmed by the sample collected in February 2007 during heavy rainfall from spoil close to the river, which contained 4725 µg/l Cu and 1454 µg/l Zn. The base flow mixing zone, where contaminated groundwater issues from the spoil in the bank of the river below water level, had 131 µg/l Zn and 11 µg/l Pb, suggesting some impact on the river water composition. Two upstream river water samples are included in Table 3. That from the Avoca River was taken just upstream of the Tigroney West site (Fig. 2), and showed somewhat elevated metal contents, notably for Pb and Cu. This sample was taken in Summer 2007 when river water level was considerably lower and dilution effects much reduced. The river at this point is affected to some degree by the contaminated Vale View stream that discharges into the river over 100m upstream of the site and possibly by base flow along the eastern bank. A sample taken in the

Avonmore River, 100m above the Meetings (Table 3) and approximately 1.3 km upstream of Tigroney West, had low levels of all elements except Zn.

Table 4: Data for Avoca River – Deep Adit mixing zone, summer 2007

	Pb (tot) µg/l	Zn (tot) µg/l	Cu (tot) µg/l	As (tot) µg/l	Cd (tot) µg/l	Cr (tot) µg/l	Acidity Mg/l $CaCO_3$
Deep Adit (1)	1272	39130	1154	<1	105	3	910
Deep Adit channel (3)	1227	38710	1188	<1	102	5	855
Deep Adit mix zone (4)	237	8306	323	1	22	5	115

Numbers in brackets = sample sites, Fig. 2

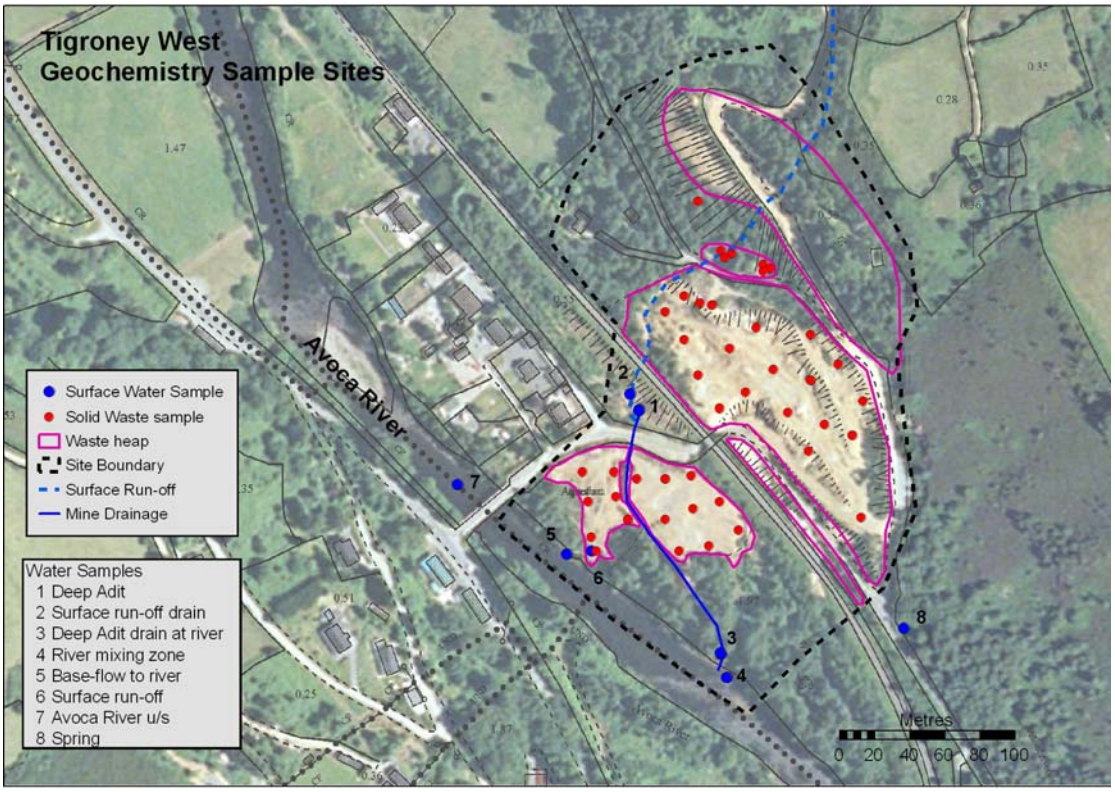


Fig. 2 Tigroney West: Geochemical sampling sites

Measured flow rates for the Deep Adit discharge were 24.1 l/s (February 2007) and 13.7 l/s (June 2007). Using the corresponding chemical analysis, the metal discharge rates can be computed (Table 5). Gray (1995) measured Deep Adit flow rates and concentrations on a monthly basis in 1994 / 1995 and computed mean monthly metal discharge rates of 151 kg/day for Fe, 117 kg/day Zn and 8.1 kg/day Cu, much higher than those suggested by the more limited HMS-IRC analyses.. The mean flow rate measured by Gray (1995) was 17.2 l/s. The much higher metal discharge rates measured by him, compared to HMS-IRC concentrations, reflect significantly higher concentrations of metals measured in the mine water.

Table 5: Metal discharge rates, Deep Adit: seasonal variation (HMS-IRC)

	Pb kg/day	Zn kg/day	Cu kg/day	Fe kg/day	Cd kg/day
February 2007 (24.1 l/s)	3.1	79.0	2.9	40.3	0.3
June 2007 (13.7 l/s)	1.5	46.3	1.4	23.9	0.1

2. Groundwater

One spring was sampled for the project (Table 2). Somewhat elevated Zn (84 µg/l) and Cu (12 µg/l) suggest the possibility of some impact from the mineralization. Two leachate samples, one a composite of samples from SP01, the other from SP02 (Fig. 1), had high levels of dissolved Cu (997 - 1498 µg/l), Pb (393 – 1122 µg/l) and Zn (1457 – 1501 µg/l) and somewhat elevated Ni (17 – 22 µg/l) and Cd (4.2 – 4.9 µg/l). The potential for contamination of groundwater by leachate from waste heaps is clear. CDM bored two wells through the spoil heap SP01 and measured very high levels of metals in the groundwater (6520 - 18030 µg/l Cu, 60 – 160 µg/l Pb and 27300 – 59960 µg/l Zn).

3. Stream sediments

Details of stream sediment sampling and analyses are contained in the Avoca District report. Two samples taken immediately adjacent and downstream of the Tigroney West site had measured Cu between 280 and 443 mg/kg, Pb 181 – 314 mg/kg, Zn 151 – 267 mg/kg and As 48 – 53 mg/kg.

4. Solid Waste

Six separate waste heaps have been defined for the Tigroney West site (Fig. 1) (Gallagher and O'Connor 1997). Field XRF analyses (n = 42) were carried on four of these heaps in June 2007 (Fig. 2). In Table 6, the concentration of Pb and other elements of interest are compared to those for other spoil samples at Avoca. Median concentrations of Pb, As, Cu and Zn are significantly higher than median values for the remainder of analysed spoil in Avoca. Fig. 3 illustrates the high proportion of measured concentrations that fall within the upper quantile. These high values may reflect Tigroney West's role as a stockpile site for ore being processed in the 19th century or shipped to West Avoca in the 20th. Tigroney West's proximity to the river means that the potential direct contribution of spoil heaps on the site to the contaminant load in the river is likely to be greater than that of spoil heaps elsewhere in East Avoca.

Table 6: Summary statistics, field XRF analyses of solid waste, Tigroney West

mg/kg	Pb	As	Sb	Cu	Zn
n	42	42	42	42	42
Minimum	886	156	0.0	173	0.0
Maximum	43934	2940	552	4372	3795
Mean	10081	949	94	1133	393
Median	8240	835	0.0	826	214
Median rest Avoca spoil (n=188)	2315	591	0.0	391	83

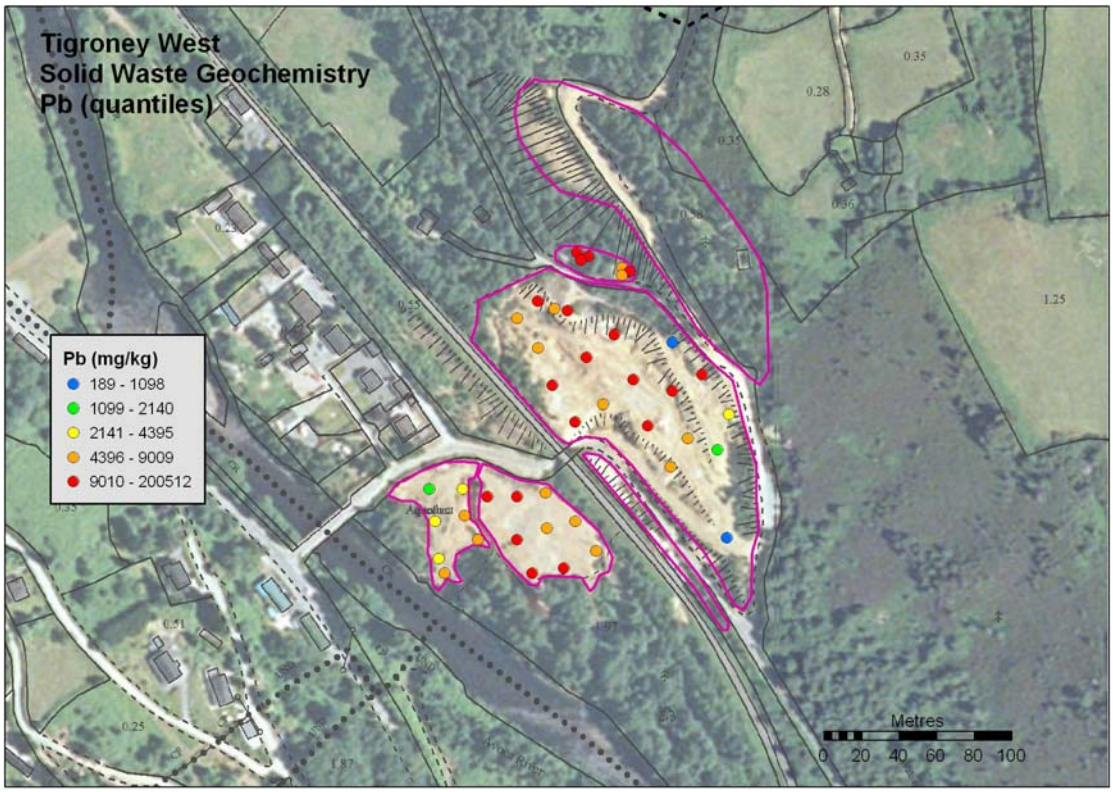


Fig. 3 Tigroney West: Solid Waste Field XRF Geochemistry: Pb
(Note that quantile values listed in Legend relate to all Avoca spoil analyses)

5. HMS-IRC Site Score

Table 7 HMS-IRC Site Score, Tigroney West

Waste	SP01	SP02	SP02a	SP03	W004*	Totals
1. Hazard Score	**46**	**79**	**36**	**45**	**1699**	**1905**
2. Pathway Score						
Groundwater	9.31	14.32	8.08	9.02	277.92	318.65
Surface Water	15.24	20.72	6.94	6.46	508.48	557.85
Air	0.30	3.59	0.04	0.03	0.00	3.96
Direct Contact	4.08	49.12	0.49	0.49	0.00	54.19
Direct Contact (livestock)						
3. Site Score	**29**	**88**	**16**	**16**	**786**	**935**

*** W004 is the Deep adit discharge**

The total site score for Tigroney West is 935 (Table 7). The Deep adit discharge accounts for over 84% of this score (Fig. 4). The solid waste heaps contribute the rest of the score, approximately in proportion to their size. The size of the Deep adit's contribution to the score, approximately 25% of the total score for the entire Avoca District, reflects the very high concentrations of metals in it, the high volume of the discharge and the greater potential impact this has on the entire range of receptors covered by the scoring system.

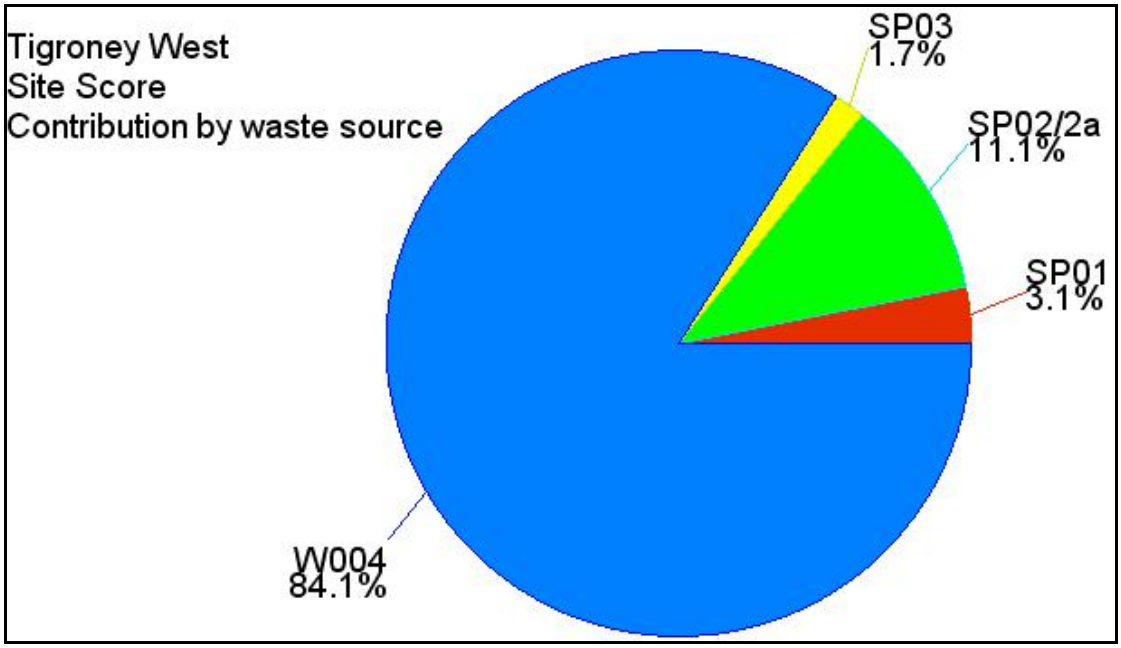


Fig. 4 Contribution of individual waste sources to Tigroney West Site Score

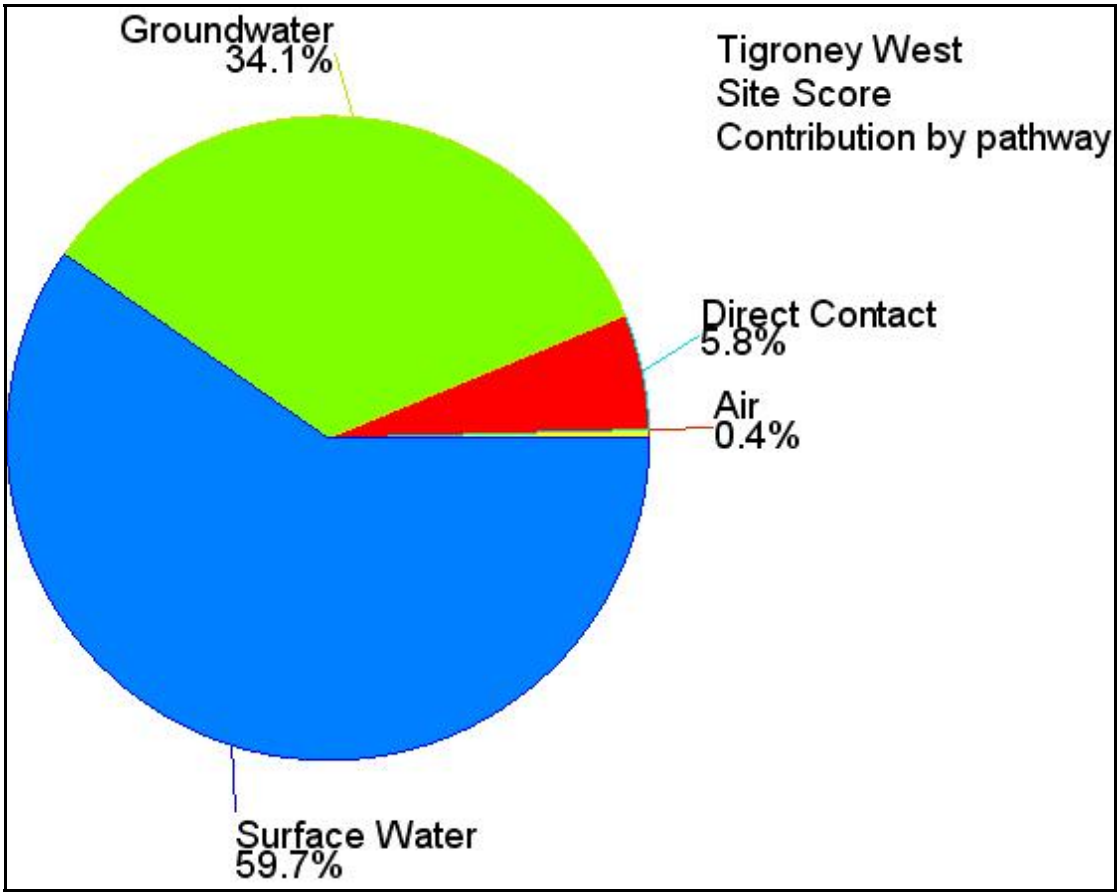


Fig. 5 Contribution of individual pathways to Tigroney West Site Score

Fig. 5 shows the contribution of the different pathways to the total site score at Tigroney West. Pathways are the routes by which receptors are exposed to the hazard. Fig. 5 shows a reversal of the situation observed in other sites in East Avoca where the groundwater pathway is typically a much greater contributor to the site score than the surface water pathway. In Tigroney West, surface water accounts for

60% of the score, groundwater little more than half that. This is a consequence not only of the Deep adit discharging directly to the Avoca River but also of the proximity of the solid waste heaps to the river. Two out of four waste heaps have a surface water pathway score exceeding that of groundwater.

6. Geochemical overview and conclusions

Concentrations of elements of interest in solid waste are generally significantly higher in Tigroney West than elsewhere on the Avoca site. Most of the waste is benched on sloping ground and run-off from it drains to the Avoca River.

The Tigroney Deep Adit drains most of the underground workings below the level of Cronebane Shallow Adit. The mine water discharged to the river has very high concentrations of Cu, Pb, Zn and elevated Cd and Cr, as well as low pH and high acidity. Dilution by the Avoca River is rapid when water levels are high; at times of low river flow, river water can contain high concentrations of Cu, Pb and Zn. The flow rate from the Deep Adit varies on a seasonal basis but metal concentrations in the discharge remain relatively unchanged so that periods of highest flow, generally the winter months, correspond to the maximum input of metals to the river. Metal discharge rates measured during the course of the HMS-IRC project ranged up to 3.1 kg/day Pb, 79 kg/day Zn, 2.9 kg/day Cu and 0.3 kg/day Cd, indicating an ongoing and significant input of metals to the Avoca River ecosystem.

Stream sediments in the Avoca River have high concentrations of Cu, Pb and Zn adjacent to and downstream of the Tigroney West site.

References

CDM (2008) Feasibility Study for management and remediation of the Avoca Mining site. Prepared for the Geological Survey of Ireland. CDM, USA.

Gray, N.F. (1995) Main adit flow and metal discharge rates. Water Technology Research, Technical Report 13, November 1995. Trinity College Dublin