

# LEINSTER COALFIELD

## Background information

**Mine District:** Leinster Coalfield

**Mine Names:** Clogh, Deerpark, Flemings, Kilgory, Modubeagh, Rossmore, Sally's Bridge, The Rushes, Wolfhill

**Elements of interest:**

As, Cu, Ni, Pb, Zn, SO<sub>4</sub>, acidity

**Project Prefix:** LCF-

**County:**  
Kilkenny, Laois, Carlow

**Townland:**  
Various

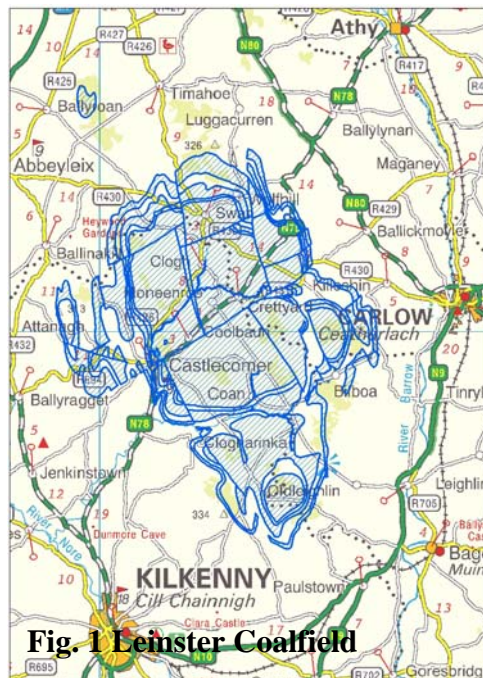
**Grid Reference:**  
E257000, N179000



## Introduction

The Leinster Coalfield underlies the Castlecomer Plateau in counties Carlow, Kilkenny and Laois (Fig. 1). The plateau hills are underlain by a remnant of the Upper Carboniferous Coal Measures (hatched area, Fig. 1) that are also preserved in the Slieve Ardagh Coalfield, 30 km to the southwest.

The Castlecomer Plateau forms a distinct, flat-topped upland area when approached from the east. It is bounded to the east by the River barrow and to the west and southwest by the River Nore. Within the plateau the land comprises rolling hills incised by two rivers that flow south and west to join the River Nore near Kilkenny. The land is predominantly grassland, mostly used as cattle pasture. Castlecomer is the most significant settlement in the area but both Kilkenny and Carlow are within 10km of the edge of the coalfield. There has been substantial recent development of single housing within the coalfield and near the villages on its peripheries.



**Fig. 1 Leinster Coalfield**

Organized coal mining has taken place in the Leinster Coalfield since at least the early 17<sup>th</sup> century when the local landowner, Wandesforde, opened his first seam (Walsh 1999). The earlier mining has not left many traces. Traces of bell pits can be discerned through the coalfield and at Holly Park there is a well-preserved chimney. However, there is nothing like the 19<sup>th</sup> century mining heritage displayed in the Slieve Ardagh coalfield. The larger-scale mining of the 20<sup>th</sup> century has left behind some mine buildings of significant heritage value as well as numerous adits and shafts. Mining in the 20<sup>th</sup> century also had a significant impact on the landscape, with several large opencast excavations developed.

## Geology and Mineralization

The Leinster Coalfield is hosted by an outlier (younger rocks surrounded by stratigraphically underlying older rocks) of Upper Carboniferous sandstones, siltstones and shales that sit on the surrounding Lower Carboniferous limestones. The coal seams are within the Westphalian or Coal Measures sequence, the uppermost part of the Upper Carboniferous succession. Unlike the steeply folded Westphalian succession in the Slieve Ardagh coalfield, the strata in the Leinster Coalfield dip gently towards the centre of the plateau to form a basin-like structure. The succession is a 300m-thick sequence of sandstone, siltstones and shales interbedded with coal seams and fireclays (Tietzsch-Tyler *et al.* 1994; Higgs and O'Connor 2005). At least eight coal seams have been identified in the coalfield. The most widespread and economically important seam was the No. 2 seam or Marine Band seam (0.31m thick), located in the lowermost Moyadd Coal Formation (Fig. 2; Higgs and O'Connor 2005). In the western part of the coalfield, this seam is split, with the lower leaf called the Skehana seam. The Skehana seam, a high-grade anthracite with low sulphur content, was extensively worked in the Deerpark colliery, for example. The No. 2 seam was worked extensively in the east and northeast part of the coalfield (Higgs and O'Connor 2005) but appears to be largely absent from the southern part of the coalfield, i.e. south of the Coolbaun Fault (Fig. 2). The Moyadd Coal Formation is overlain by the Clay Gall Sandstone Formation which in turn is succeeded by the uppermost Coolbaun Formation. The Coolbaun Formation hosts the remaining coal seams, including, in ascending order, Wards seam (0.2 – 0.3m), the Jarrow seam (0.23 – 0.31m) and the Three Foot Coal (0.91m). The remaining sequence is poorly known but contains three thin seams (Higgs and O'Connor 2005).

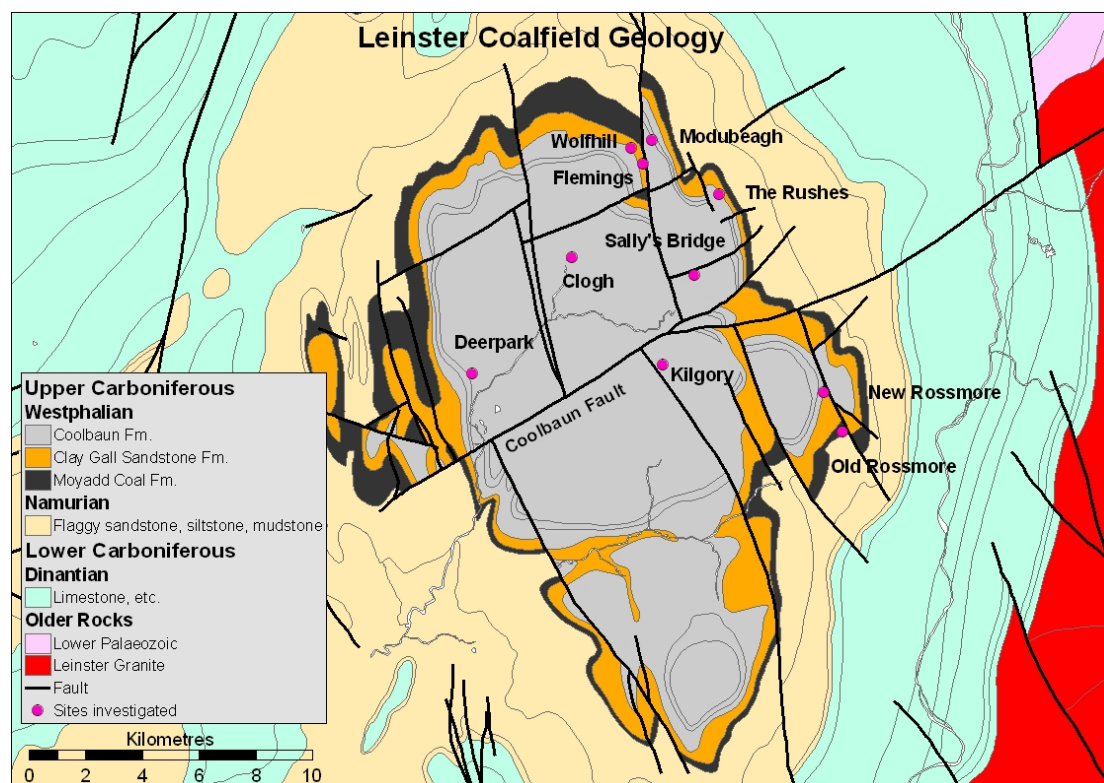


Fig. 2 Leinster Coalfield: general geology

The coal in the Leinster Coalfield, like that of Slieve Ardagh, is entirely anthracite, but the quality varies significantly among the seams (McArdle 1992). Table 1 summarizes the data for the main seams in the coalfield. High sulphur content ( $\geq 4\%$ ) is a feature of all but the Skehana seam and Three Foot Coal, the latter all but worked out as it was the first major seam to be exploited in the 18<sup>th</sup> century when mining began in earnest. A review of the development potential of the coalfield in the 1980s led to the conclusion that only the Marine Band had a significant quantity of coal that might be a potential future resource. However, its high content of sulphur, much of it in fine-grained pyrite not readily removed by washing, is a significant obstacle to development (McArdle 1992).

**Table 1 Leinster Coalfield seam quality and resources**

Seam	Height, m	Calorific Value kcal/kg	S %	Ash %	Sub-economic resources, Mt
<b>Three Foot Coal</b>	0.91	7300	1.9	4.6	-
<b>Jarrow</b>	0.23–0.31	6700	4.0	8.7	1.06
<b>Wards</b>	0.2–0.3	4600	7.2	36.9	0.21
<b>Skehana</b>	0.33	7300	07	6.5	1.88
<b>Marine Band</b>	0.31	6900	4.0	11.0	12.51

From McArdle (1992)

## Mining History and Production

The earliest workings in the Leinster Coalfield were on the shallower seams and the first recorded workings were on the Three Foot Coal, the thickest and one of the best quality coal seams in the district (Table 1), which was found within a small area in the central part of the coalfield (Higgs and O'Connor 2005). This seam was found at depths between 15 and 45m and was first exploited using bell pits (Walsh 1999). The owner of Castlecomer Estate, Wandesforde, opened his first pit in 1638. According to one estimate in 1875, the Three Foot seam produced as much as 15m tons of coal (Walsh 1999). Another estimate suggests that by the early 19<sup>th</sup> century annual output from the bell pits along the seam outcrops was 150,000 tons (GSO 1964). This was probably the most active period in the coalfield.

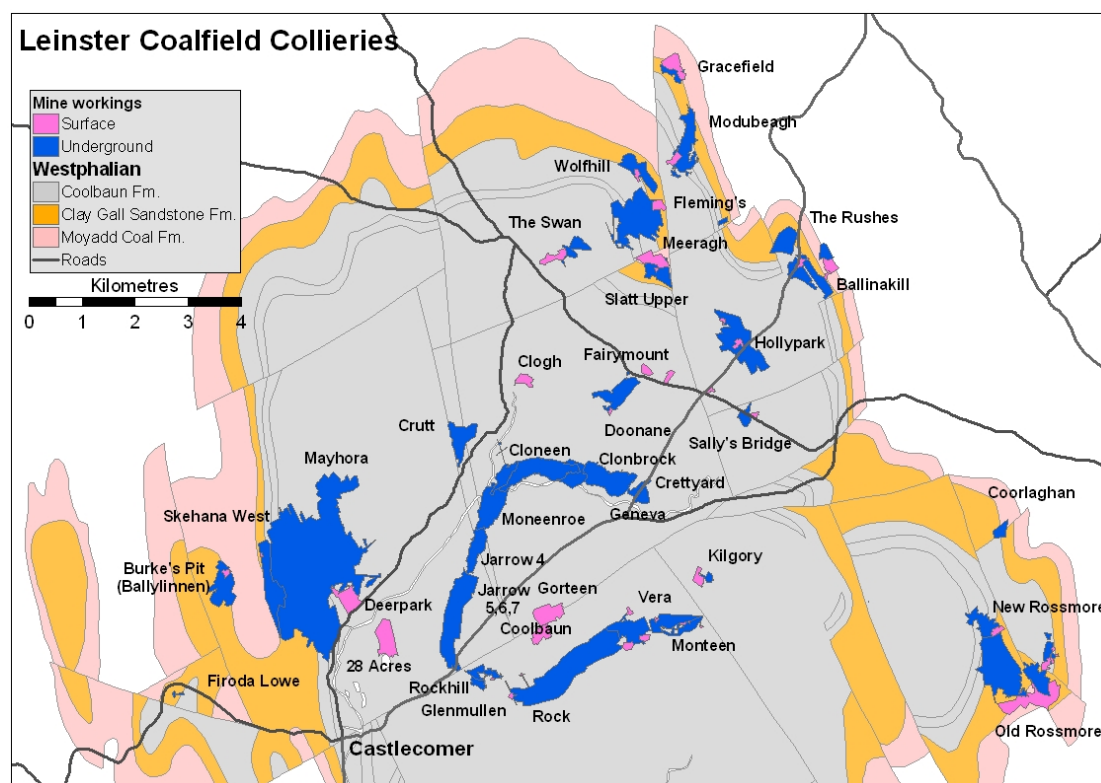
The Three Foot Coal was almost worked out by 1815 and, under the Wandesfordes, deeper exploration using shafts led to the discovery of the Jarrow seam near Clogh (Fig. 2), at a depth of around 75m (Walsh 1999). This horseshoe-shaped seam, located in the centre of the coalfield, was extensively worked by both opencast and deep mining (Higgs and O'Connor 2005). Though typically up to 0.31m thick, in places it thickens to 0.91m where inferior material was apparently added to the seam within an ox-box-like channel (Higgs and O'Connor 2005). This "Jarrow Channel" was famous for the assemblage of amphibian fossils recovered in the 19<sup>th</sup> century (Tietzsch-Tyler *et al.* 1994).

The discovery in 1914 of the Skehana seam at Skehana, west of Deerpark, ultimately led to the opening of the Deerpark colliery in 1924. This colliery, owned by the Prior Wandesfordes, was to be the main centre of mining in the coalfield until its closure in 1969. Other mines in operation in the same period included Flemings in Wolfhill, Irish Coal Mines Ltd. in Hollypark and Kilgory, Rossmore Collieries in Rossmore and Crettyard's in both Doonane (underground) and Clogh (opencast). In the early

1960s, annual output in the coalfield amounted to around 80,000 t with most of it coming from Deerpark (GSO 1964). After Deerpark's closure, only small mining operations took place in the Leinster Coalfield, notably at Rossmore where a few thousand tonnes were mined annually underground and from several opencasts in the 1970s and 1980s (British Mining Consultants 1982).

## Site Descriptions and Environmental Settings

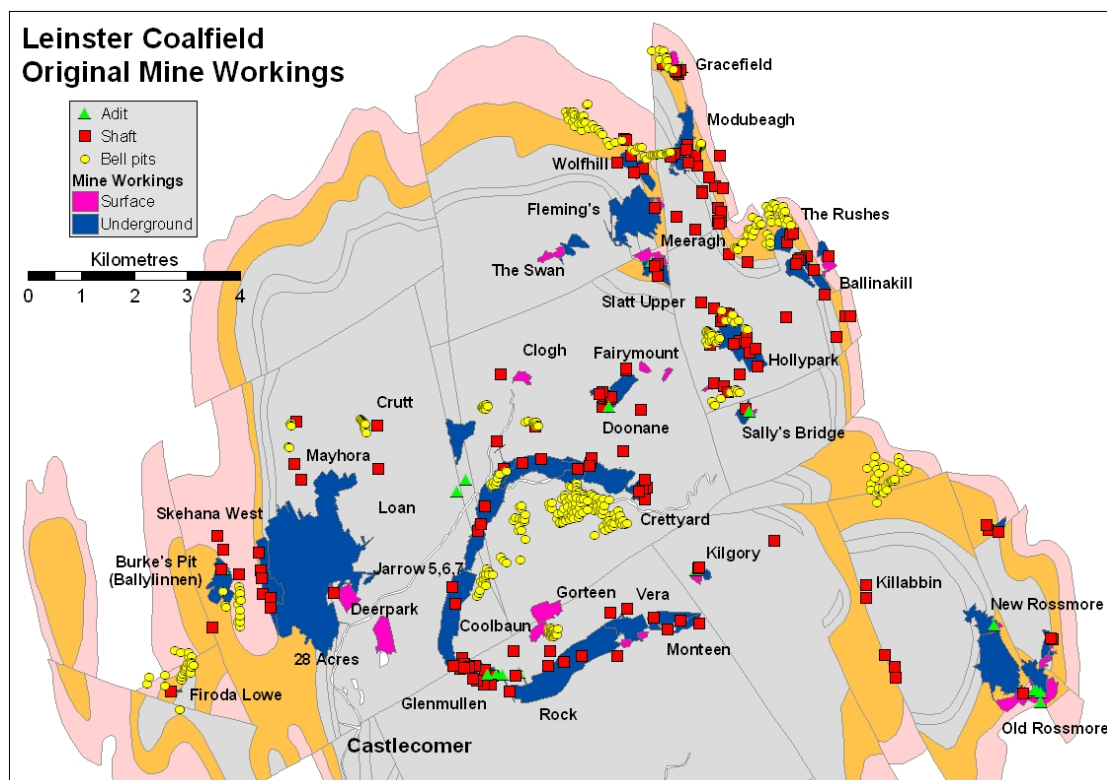
There were numerous collieries in the Leinster Coalfield. Those for which the location is known are shown on Fig. 3. In selecting sites in the coalfield for investigation as part of the HMS-IRC project, the main criterion considered was the presence of either solid or liquid mine waste on the site. Many of the collieries shown on Fig. 3 no longer have any significant surface expression, the land having been reclaimed for farming or other use. The main sites investigated were Old Rossmore, Kilgory, Deerpark, 28 Acres, Clogh, Fleming's and Modubeagh. In addition, some water samples were taken at Monteen, Doonane and The Rushes. Natural wells and springs were sampled throughout the coalfield where identified.



**Fig. 3 Locations of known collieries in the Leinster Coalfield**

The geochemistry of the Leinster Coalfield district is considered as a whole in the geochemistry section (below) rather than on a site-by-site basis. Individual site descriptions in this section review the main features of each site examined. Fig. 4 shows all the shafts, bell pits and adits originally compiled from the various historic sources available. As is clear from this, the Leinster Coalfield district has been intensively explored and exploited. Of the many shafts, bell pits and adits shown on Fig. 4, however, only a small proportion can be seen today. Most have been filled in or covered by subsequent land reclamation. In contrast, the illustration of

underground workings probably understates their actual extent because of the unavailability in some cases of suitable colliery plans for compilation purposes.



**Fig. 4 Leinster Coalfield: distribution of original mine features**

## 1. Rossmore

### Mine Names:

Old Rossmore  
New Rossmore

### Alternative names:

### Townland:

Rossmore

### Grid Reference:

E266429, N173935 (Old)

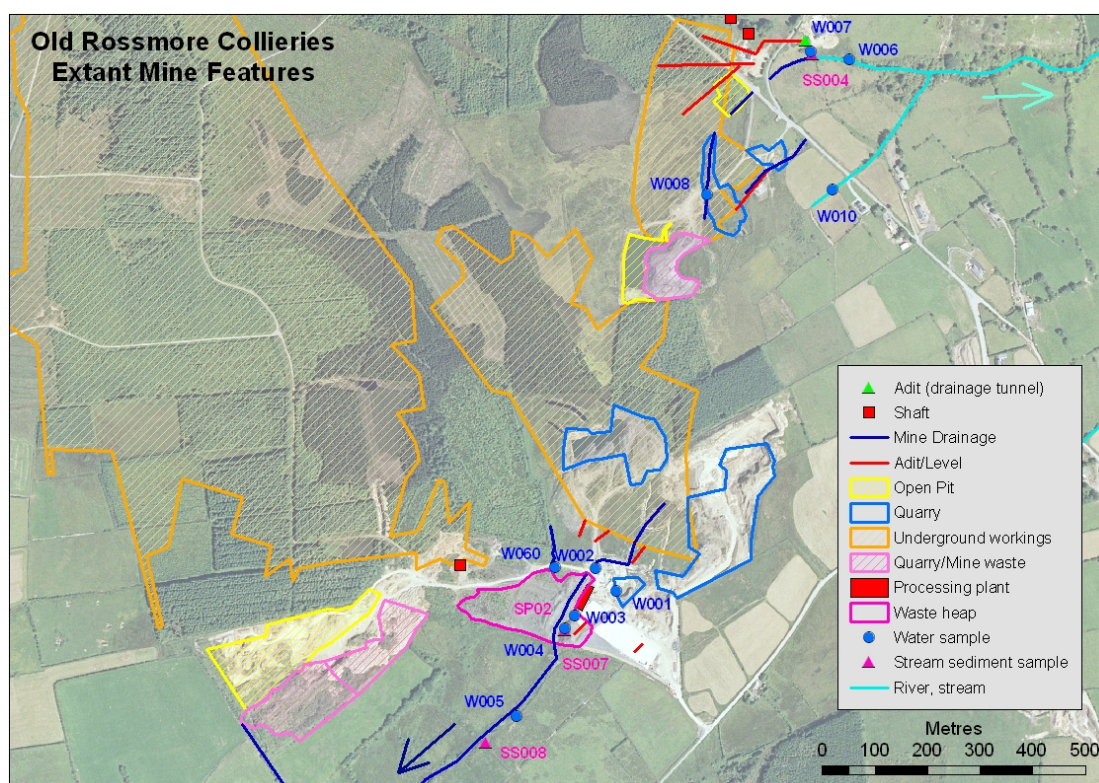
E265645, N174985 (New)



There are two mine sites at Rossmore, on the eastern edge of the coalfield, around 5km southwest of Carlow. Old Rossmore (c. 40 ha) was worked from the 1930s until the 1980s, both by underground and opencast methods. New Rossmore (photo, left), 1km to the northwest, was developed from a decline in the 1970s and 1980s. Both mines exploited the No. 2 seam or Marine band. New Rossmore was not investigated geochemically for the HMS-IRC project. The site covers 2.5 ha and contains some derelict buildings and processing plant, including mine offices, a large shed, a loading gantry,

conveyor and weighbridge. A waste heap with steep, 8m-high faces, appears to contain spoil extracted when excavating the decline rather than colliery waste.

The Old Rossmore site covers around 40 ha and was the main mine site at Rossmore. The site has been extensively worked and most of the surface comprises bare rock and waste. Not all of the excavations were a consequence of coal mining. The site was also extensively quarried for sandstone, especially in recent years. The two largest open pits shown on Fig. 5 were originally worked for coal in the 1980s but have recently been further worked for sandstone, especially the large Cheswell opencast in the extreme southwest of the site. Several large accumulations of solid waste cover parts of the site. Most of the colliery waste appears to be in the waste heap SP02 (Fig. 5; photo, right), which contains a higher proportion of coal-rich waste than the rest. This heap was analysed by *in-situ* XRF analyses as part of the geochemical assessment. The remaining heaps contain a high proportion of quarry waste and have not been included in HMS-IRC site scoring. There are few traces of the underground workings. Two shafts in the north are still traceable as 0.5 – 1.0m-deep hollows while a third, in the south, is covered by aggregate and appears secure (Fig. 5). In the north, one adit discharges a steady flow of mine water to a local watercourse (beside sample site W007, Fig. 5). There are no extant mine buildings. A derelict, rusting washing and screening rig is the only remnant of processing plant (see photo, top of this site report).



**Fig 5 Old Rossmore: mine features**



Apart from the colliery waste, the main focus for geochemical investigation on the site was the surface water. This includes drainage from surface waste, the adit discharge referred to above, standing water in a small quarry and water from a spring that issues downgradient of the mine (W010, Fig. 5). The small quarry is a steep-sided excavation in the southern part of the site with a permanent body of low-pH water

(W001, Fig. 5; photo, left). Though apparently a sandstone quarry, this excavation may be hydrologically connected to the underground workings because the chemistry of the water in it is typical of coal mine water.

Two streams drain the site, one to the east and the other to the southwest. The latter is essentially generated from the surface drainage on the Rossmore site. The stream to the east is fed both by the spring and the adit discharges (Fig. 5). In summer 2007, the spring was dry.

## 2. Kilgory

**Mine Name:**

Kilgory

**Townland:**

Kilgory

**Grid Reference:**

E260027, N175988

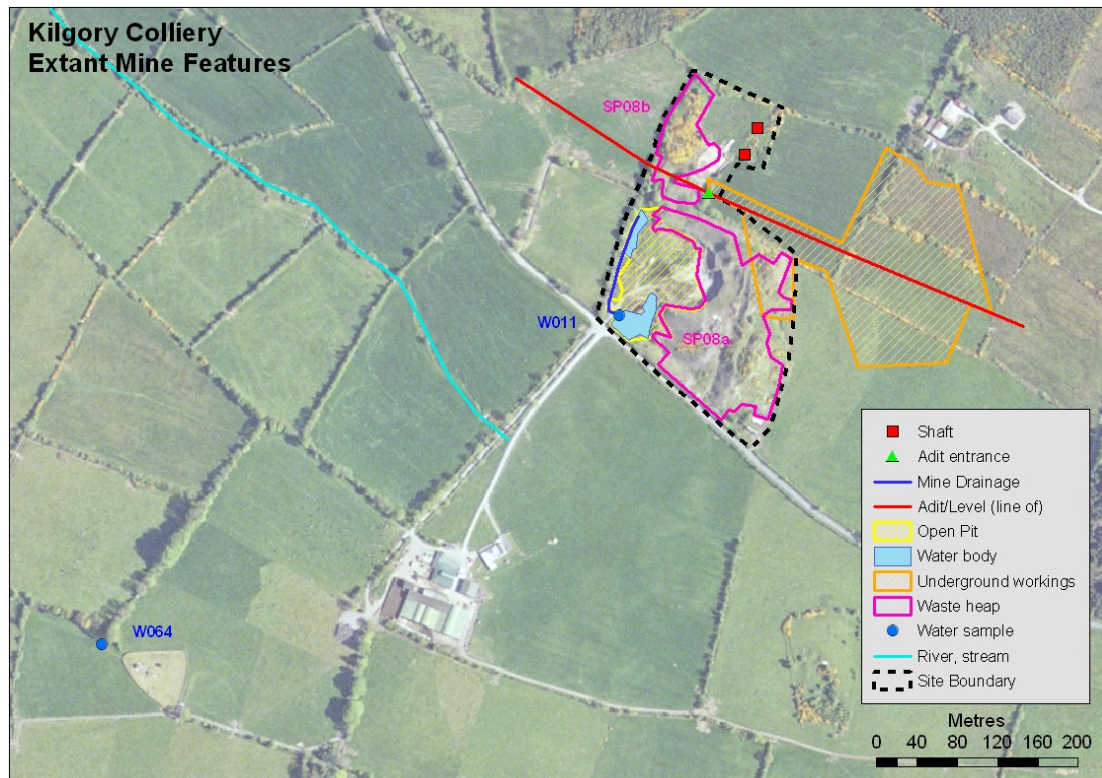


The Jarrow seam was mined at Kilgory both by underground and opencast methods. Irish Coal Mines Ltd. operated the underground mine from the 1940s until 1952. Robert McGregor and Sons (I) Ltd., in one of its first ventures in the Leinster Coalfield, excavated the opencast from 1967 until the early 1970s.

The site (4 ha) consists largely of a flooded, benched open pit partly covered with and surrounded on the north and east sides by waste tips (SP08a) that rise up to 10-12 m above the surrounding farmland (Fig. 6; photo, above)). It is apparently owned by a local farmer and the pit is used as a feeding lot for a small cattle herd while the pit lake is used for breeding ducks. Various pieces of farm machinery, including a slurry spreader, were stored on the site when visited (photo, left). North of the main waste heap is a small area that includes the surface traces of the earlier underground mining.



The two shallow exploration pits or shafts have been smoothed over, one of them backfilled, and no hole is visible. A hollow several metres deep marks the site of the adit but no entrance is visible. A faint trace of the line of the adit can be seen in the field to the west. The waste heap here (SP08b) was created in the 1940s and 1950s.



**Fig. 6: Kilgory mine features**

The pit lake water was sampled as part of the geochemical assessment. Water from St. Gregory's well, 600m southwest beside an old burial ground, was also sampled. Median data for solid waste analysed elsewhere in the district were used to score the two waste heaps on the site as part of the HMS-IRC scoring system.

### 3. Deerpark

**Mine Name:** Deerpark

**Alternative Name:**

**Townland:**  
Deerpark

**Grid Reference:**  
E253417, N175583



Deerpark colliery was opened in 1924 as an extension of the Skehana colliery which first began to exploit the high-grade Skehana seam discovered in 1914. The colliery continued production until closure in 1969 and was during that period the major coal producer in the Leinster Coalfield. It is the only site in the coalfield where a range of 20<sup>th</sup>-century mine buildings and other features can still be seen.

The site covers 16 ha beside the Castlecomer – Swan road (R426) about 2km north of Castlecomer. It is part of an active farm with the land given over to cattle pasture. Immediately inside the entrance gate is the shell of the large shower block, built in 1939 and recently reroofed. A long avenue leads up towards the main adit or

decline entrance, beyond the modern farm buildings (Fig. 7). Between the entrance and the adit are what remain of the original mine buildings including a small building beside the site of the mine office, possibly an office itself, the remains of the screening plant and several large buildings that presumably served as workshops and storage. Based on a comparison with contemporary photographs (in Walsh 1999), most of these buildings retain their original roofs. They are in use as farm outbuildings. Also here are the ruins of the elevated track and landing point for mine wagons (photo, right) that were hauled on an endless ropeway from underground via the adit of decline. Here the coal was unloaded for screening in the adjacent plant from where it brought by conveyor to the stockpile in what is now the field to the southeast. From there it was loaded into rail wagons and brought to Kilkenny via Castlecomer.



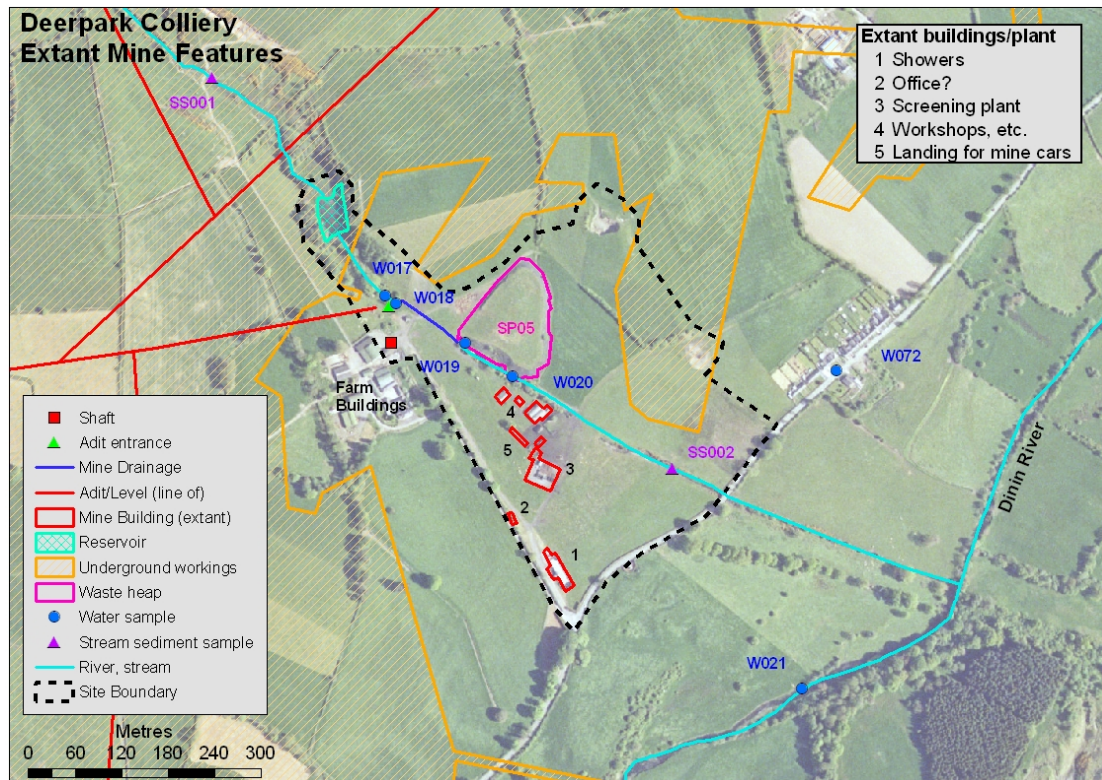
A stream runs through the centre of the site to join the Dinin River 300m southeast of the road (Fig. 7). The mine discharges a constant flow of orange-red-coloured water to the stream (photo, left) via a drainage tunnel that was installed below the entrance to the main adit or decline prior to sealing. The flow was not measured owing to the difficulty of access but Misstear *et al.* (1980) quote a discharge rate of 775,000 m<sup>3</sup>/day (9.0 l/s). A visual comparison with discharges measured elsewhere suggests it was at least 10-15 l/s during winter sampling for the HMS-IRC project. Walsh (1999) states that 600 gallons per minute (45 l/s) were pumped from

the main pumping stations during the operation of the mine and this may be a more realistic assessment of the discharge rate. A concrete block wall now forms the outer part of the adit seal (photo, below).

On the northeastern bank of the stream are the remains of Bell's Heap, a large black conical waste heap that dominated the skyline at Deerpark. It appears to have been composed mainly of slack. Most of this was removed after the mine closed, with truck-loads of slack sold to the cement factory in Limerick (Walsh 1999). There are two other mine features of note on the site. The first is the shaft, known as the New



Shaft, built by British mining engineers but never used because it was incorrectly located (Walsh 1999). It was backfilled with broken trams and slack from Bell's Heap after closure of the mine. The landowner has in recent years placed a concrete cap on it. The reservoir upstream of the adit was built in the 1940s to ensure a steady supply of water to the boiler, pumps and, later, the showers



**Fig. 7 Deerpark : mine features**

The remains of Bell's Heap is contoured and grassed over. Although solid waste is exposed on the banks of the stream *in-situ* XRF analyses were not carried out at Deerpark. Water samples were collected from the stream upstream and downstream of the adit discharge as well as from the adit discharge itself, in both winter and summer periods. The Dinin River was also sampled downstream of its confluence with the stream that flows through the mine site. Stream sediment was also sampled from this stream, upstream and downstream of the mine.

#### **4. 28 Acres**

**Mine Name:** 28 Acres

**Alternative Name:**

**Townland:** Castlecomer Demesne  
**Grid Reference:** E254135, N174832

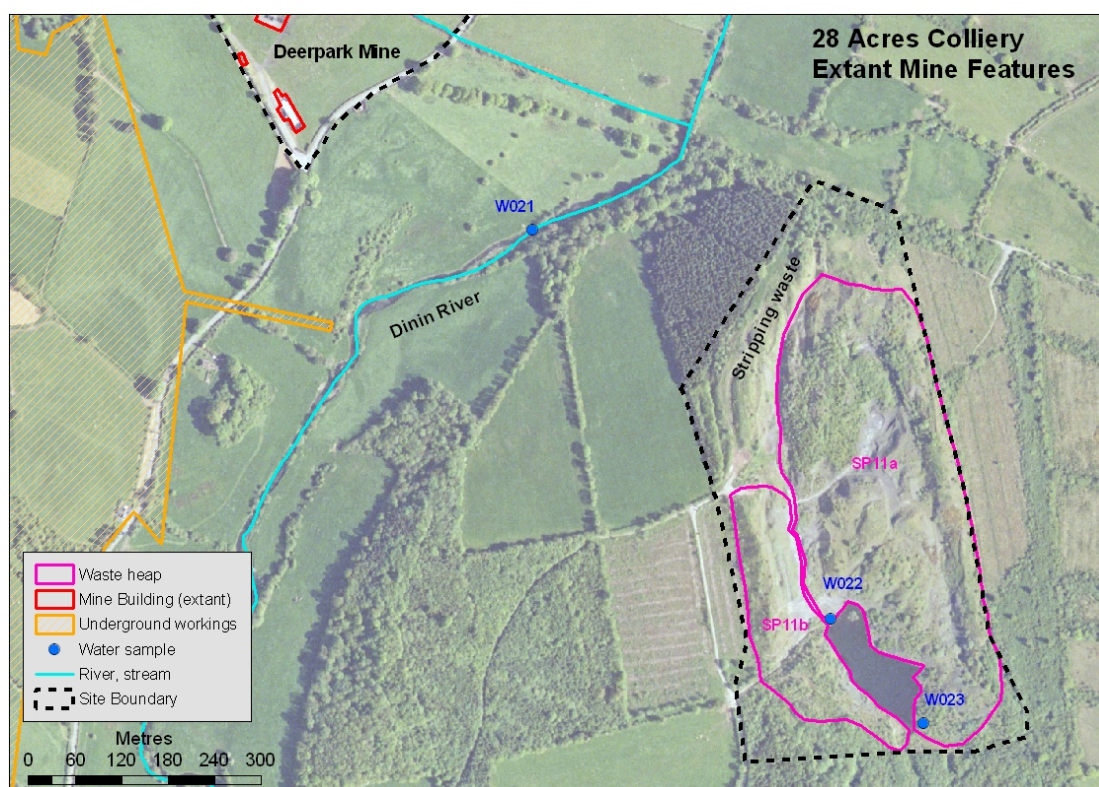


The 28 Acres site (21 ha) is a former opencast mine that was operated for several years in the early 1970s by Robert McGregor and Sons (I) Ltd. It is chiefly remarkable for the very large volumes of solid waste that occupy the site, estimated to be close to 1 million m<sup>3</sup>. The waste comprises both stripping waste and mine waste, with the latter accounting for around 890,000 m<sup>3</sup>. The stripping waste consists of glacial till with cobble-sized clasts that was removed prior to mining of the underlying bedrock. The mine waste consists mostly of shale that overlay the coal seam. It contains abundant ironstones, many in the form of nodules, but very little, if any, coal waste. The open pit is flooded and forms a small lake (photo, below

right) that is home to some ducks. The open pit lake has an area of about 8,000 m<sup>2</sup> and its volume was evidently much smaller than that of the waste that surrounds it. The 28 Acres site was used as a waste repository for other opencast mines in the area. In recent years (2001) the waste has been sold as aggregate and fill. The site lies within the northern part of what was the Castlecomer Demesne, the estate of the Wandesfordes who were centrally involved in coal mining in the around Castlecomer from the mid-17<sup>th</sup> century. The demesne is now part of the Castlecomer Discovery Park, a woodland area with recently restored fishing lakes. Some commercial forestry has been planted on the northwestern side of the site. Other land in the area around the mine site is mainly employed as cattle pasture.



Geochemical work on this site was limited to collecting water samples from two sites at either end of the open pit lake, in both winter and summer. A small drainage stream enters the lake at the southeastern corner and a c. 20mm-diameter pipe is also present here. Whether the pipe extracts water from or discharges water to the lake was not investigated. A section of older iron pipe lies abandoned beside it.



**Fig. 8: 28 Acres: mine features**

## 5. Clogh

**Mine Name:** Clogh

**Alternative Names:**

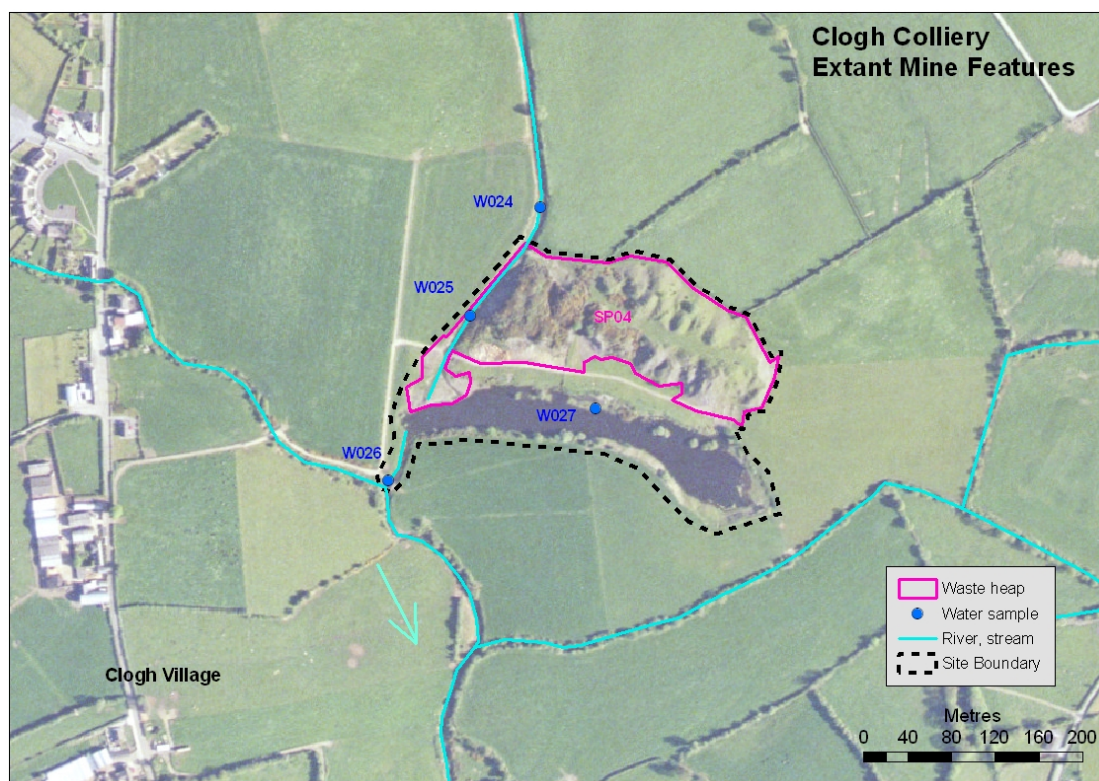
**Townland:**  
Kill; Coolnaleen

**Grid Reference:**  
E256750, N179712



The Clogh site (5.8 ha) is a former opencast mine operated by Robert McGregor and Sons (I) Ltd. between 1969 and 1972. The open pit is flooded and forms a natural-looking lake that is home to a pair of swans. The southern boundary of the lake rises steeply above the water but on the northern side the land slopes gently to the lake from the mound formed by the solid waste heaps behind. The waste heaps are well vegetated in parts by a mixture of grass, gorse and other shrubs but some of the steeper slopes are almost bare. The average height of the heap above the adjacent farmland is 10.5m and the estimated volume of the solid waste is 302,000 m<sup>3</sup>. The land around the site is exclusively grassland used for sheep and cattle pasture.

Geochemical investigation of the site was confined to analysis of water from the Dinin River tributary that flows southwards past the base of the waste heap as well as water from the pit lake (Fig. 8). The waste heap was included in the HMS-IRC Site Scoring system by applying the median composition of waste heaps analysed elsewhere in the Leinster Coalfield.



**Fig. 9 Clogh: mine features**

## 6. Fleming's

**Mine Name:** Fleming's

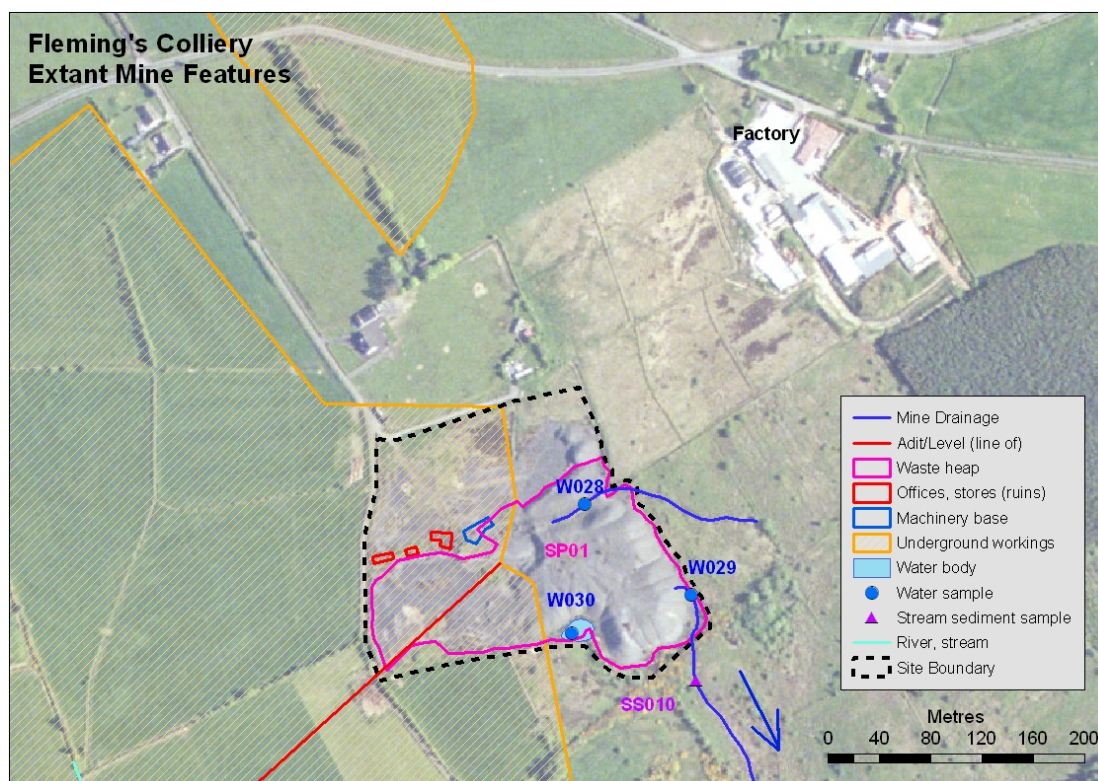
**Alternative Names:** Ballylehane

**Townland:**  
Ballylehane Upper

**Grid Reference:**  
E259273, N183006



This is one of three closely spaced sites at the northern part of the district, the others being Wolfhill and Modubeagh. Fleming's operated as an underground mine from January 1940 until April 1965. The underground workings lie southwest of the site and were reached via a decline (Fig. 10). The site covers 4.3 ha and is mainly remarkable for the large size and coal-rich nature of the waste heaps left behind (photo, right). Locals freely draw from the heaps periodically. During the course of the HMS-IRC project the northern part of the heap, visible on Fig. 10, was removed and the site levelled. The shells of several mine buildings remain on the site, along with the bases for machinery. There is no trace of the decline. The surrounding land is a mixture of pasture, to the north and west, and wetland and forestry to the east and south. A factory 200m northeast makes fireclay products.



**Fig. 10 Fleming's: mine features**

The coal waste is visibly rich in pyrite and seepage and run-off from it have low pH. Two seepages were identified and sampled in winter along with one pool formed from rainwater and possibly seepage. Only one seepage was still discharging in summer (W029) at a very low rate and the pool (W030) was dry. Detailed *in-situ* XRF analysis was also carried out on the waste heap. A sediment sample was taken from the dry drainage channel in the summer.

## 7. Modubeagh

**Mine Name:** Modubeagh

**Alternative Name:**

**Townland:** Modubeagh  
**Grid Reference:** E259562, N183878



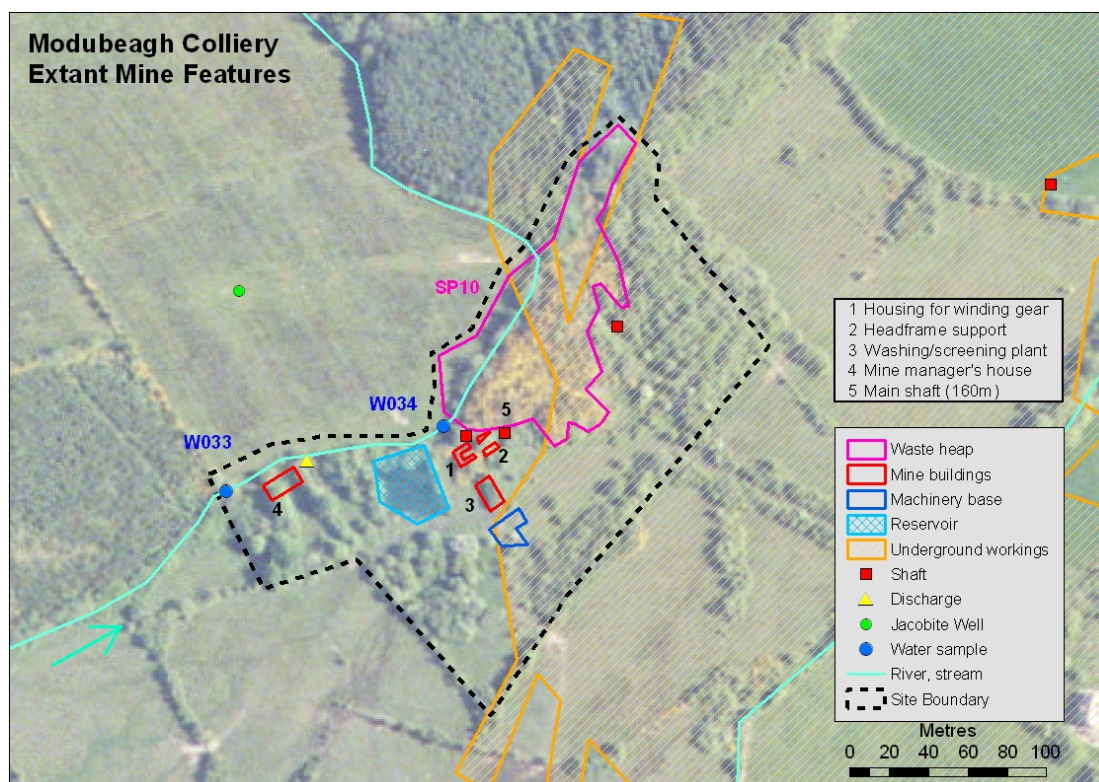
Modubeagh colliery operated from the second part of the 19<sup>th</sup> century to the early 20<sup>th</sup> century before closing in 1925 under the management of Wolfhill Collieries Ltd. The site is surrounded by grassland and some forestry but does not itself appear to be used to any great extent (Fig. 11). The extant mine features on the site are largely overgrown by gorse and brambles. Modubeagh exploited the No. 2 seam or Marine band at a depth of around 160m below surface.

The substantial waste heap has a volume of around 60,000 m<sup>3</sup>. Valar Resources assessed it in 1986 and estimated it to contain 36,000 tons with 8.4% coal. It is overgrown by gorse. The 1.25m-thick low walls (photo, right) of the most substantial surviving building are interpreted as the remains of the housing for the winding gear that operated on the main shaft lying to the east, with the 2m-high stone walls in between likely to have supported the headframe. The other buildings have been reduced to footprint level. The mine manager's house is reached via a formal, tree-lined avenue, now heavily overgrown. The reservoir is thick with vegetation, including reeds and bullrushes. It was used to supply cooling water to the pumps.



The main shaft (Fig. 11) appears as a 5m-wide and 3m-deep depression, partly screened by bushes and used recently as a dump for household appliances. Its collar collapsed in the early 1980s. This is one of the deepest shafts in the coalfield, extending to 160m below surface. It was used for pumping water and as a downcast for drawing in air. The other two shafts on the site are marked by standpipes and may have been air shafts. The shaft 160m northeast of the mine site boundary (Fig. 11) is now open after surface collapse. Water rises to between 0.75 and 2m of the surface (photo, above left).

The stream that flows east-northeast past the northern boundary of the site rises on the hill at Wolfhill colliery to the west. It is not known to be affected by discharge from Wolfhill. However, a discharge of orange-red water enters the stream at Modubeagh close to the mine manger's house and the stream is discoloured over much of the remaining length shown on Fig. 11 (photo, right). This discharge resembles a typical ochreous mine discharge as observed, for example, at Deerpark but it emerges from the northern bank of the stream where there are no recorded underground mine workings. While typical of observed mine discharges elsewhere in the coalfield, the discharge may well get its colour from interaction between groundwater and iron-rich rocks such as ironstones, known to be common in the strata of the district. The Jacobite Well noted in the field north of the site is the source of spring water historically piped to Athy in previous centuries.



**Fig. 11 Modubeagh colliery: extant mine features**

Geochemical investigations at Modubeagh were confined to the analysis of water samples collected upstream and downstream of the discharge, both in summer and winter (Fig. 11). In addition, a sample of stream water was collected about 2.5 km downstream of the site for comparison.

## Geochemistry

Surface water, stream sediments and solid waste heaps in the Leinster Coalfield were analysed to identify possible environmental impacts related to mining. In addition, leachate tests were carried out on composite samples of solid waste.

## 1. Surface water and groundwater

Surface water and groundwater samples were collected in both winter (January and February 2007) and summer (September 2007). The surface water samples came from streams both upstream and downstream of mine sites, adit discharges, seepages and run-off from waste and from open pit lakes. Groundwater samples came from springs and natural wells throughout the coalfield. The summer water samples were part of a series of analytical batches for which total metal analyses were unsatisfactory owing to apparent cross-contamination between samples during analysis, as indicated in particular by excessively high Pb concentrations in both samples and lab blanks. For this reason, only the winter analyses are discussed below. In the case of some sites, only winter analyses are available in any case because seepages and run-off had dried out in summer. Even with this selection, caution is required because there is some evidence of cross-contamination in analyses for one winter batch. This batch included samples from Fleming's site that have relatively high concentrations of some metals, including Al and Ni. Comparison of data for lab blanks as well as dissolved element concentrations suggests cross-contamination of the total metal concentrations for some other samples in the batch.

In general, concentrations of potential contaminants were low in the Leinster Coalfield samples, with little major variation among the parameters analysed. Exceptions were samples of seepage, run-off and ponding on exposed coal/shale waste. These samples had relatively low pH, high acidity and high EC as well as significantly elevated concentrations of Al, Fe, Cu, Ni, Zn and SO<sub>4</sub>. Table 2 summarizes the data for some of these parameters for all analyses carried during the project in winter.

**Table 2 Summary statistics for all winter water samples, Leinster Coalfield**

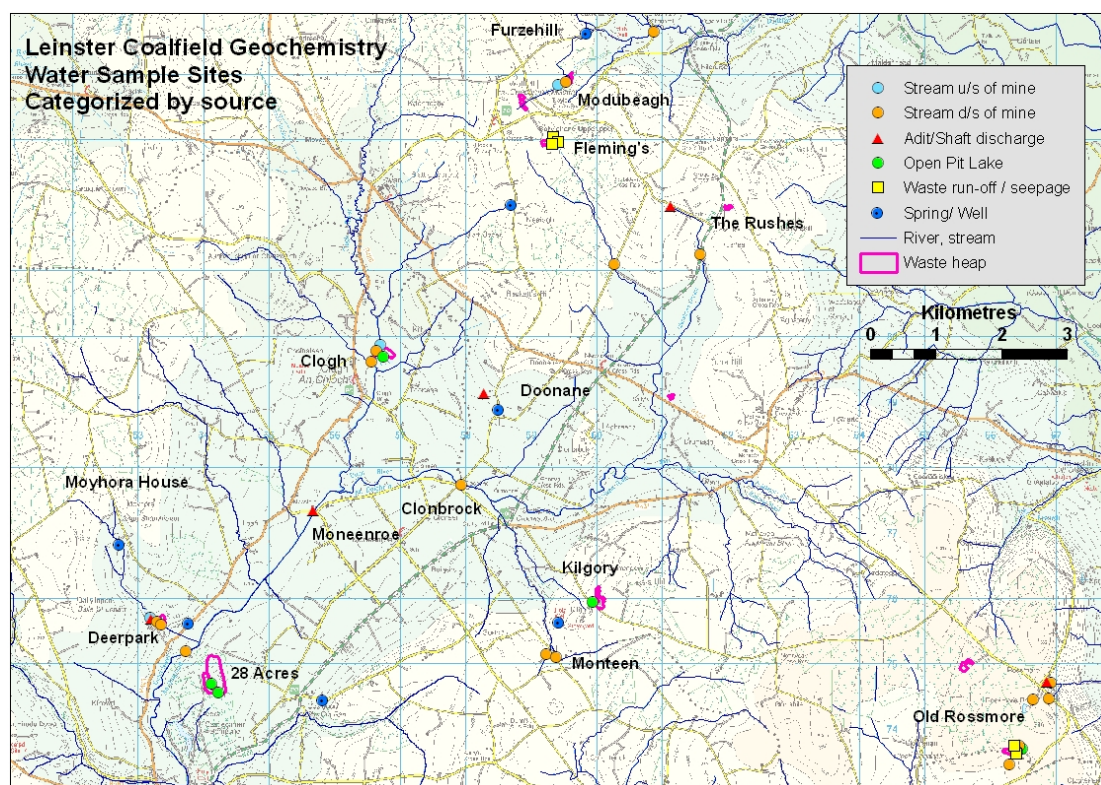
	pH	EC	Al (tot)	Cd (tot)	Cu (tot)	Ni (tot)	Zn (tot)	SO <sub>4</sub>
		mS/cm	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
<b>n</b>	43	43	43	43	61	61	61	61
<b>Minimum</b>	2.58	0.02	64	<1	3	1	14	<3000
<b>Maximum</b>	8.15	2.23	129,500	31	354	775	1544	1,773,000
<b>Median</b>	7.31	0.22	551	<1	29	11	166	15000
<b>Mean</b>	6.72	0.37	6546	1.8	39	47	219	105453

The median concentrations for specific water sources are given in Table 3 where they can be compared to standard concentrations used for the HMS-IRC project. Most samples from the Leinster Coalfield exceed the standard (drinking water) concentration for Al of 200 µg/l, even those of groundwater for which the range is 360-454 µg/l. Concentrations of Cu, Ni and sulphate are generally below standard limits while those for Zn routinely exceed them. High Cd concentrations were detected only in seepages and run-off.

**Table 3 Median concentrations, winter water samples, by source, Leinster Coalfield**

Medians	pH	EC	Al (tot)	Cd (tot)	Cu (tot)	Ni (tot)	Zn (tot)	SO <sub>4</sub>
		mS/cm	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
<b>Upstream (n=3)</b>	7.86	0.16	638	<1	31	12	150	11000
<b>Downstream (18)</b>	7.38	0.22	589	<1	31	13.5	198	17500
<b>Adit/Shaft discharge (5)</b>	6.83	0.35	454	<1	24	11	149	63000
<b>Waste run-off (5)</b>	2.78	1.48	38190	8	108	253	561	737,000
<b>Open Pit Lake (5)</b>	7.70	0.20	568	<1	29	9	198	11000
<b>Well (7)</b>	7.31	0.40	397	<1	16	2	72	11000
<b>Standard value*</b>	6.5-9.5	< 2.5	200	0.25	5 - 30	20	8 - 100	250,000

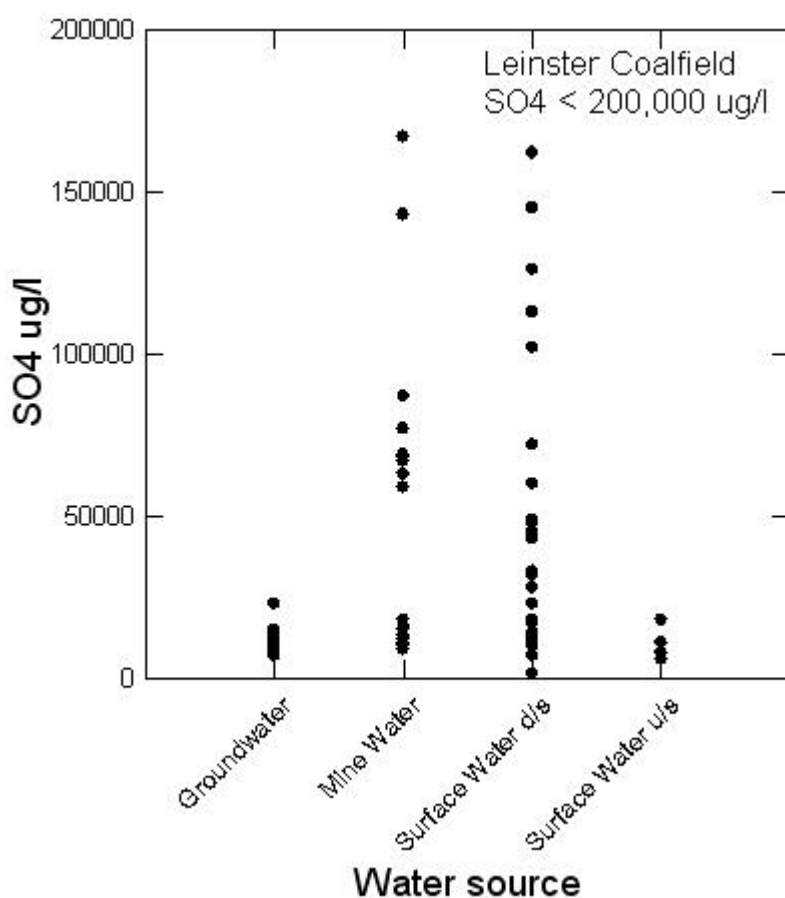
\*Standard value used for HMS-IRC. Values for Cu, Zn vary according to hardness of water



**Fig. 12 Leinster Coalfield: water sampling sites**

The highest EC and element concentrations and lowest pH were measured in run-off and ponded water on the waste heap at Fleming's site, and to a lesser extent in two seepage / run-off samples at Old Rossmore. Other waste heaps were not similarly sampled as run-off and/or ponding were not observed during field work. However, similarly low pH, high EC and high metal concentrations should be expected in seepage and run-off from any solid waste heap that contains coal waste. Such waste can be expected to contain pyrite, either in macroscopic or microscopic form (McArdle 1992), with the potential to generate water with low pH, high acidity and high metal concentrations. The concentration of sulphate (SO<sub>4</sub>) in seepage and run-off samples (15,000 – 1,177,300 µg/l) is a direct indication of the presence of pyrite in the waste.

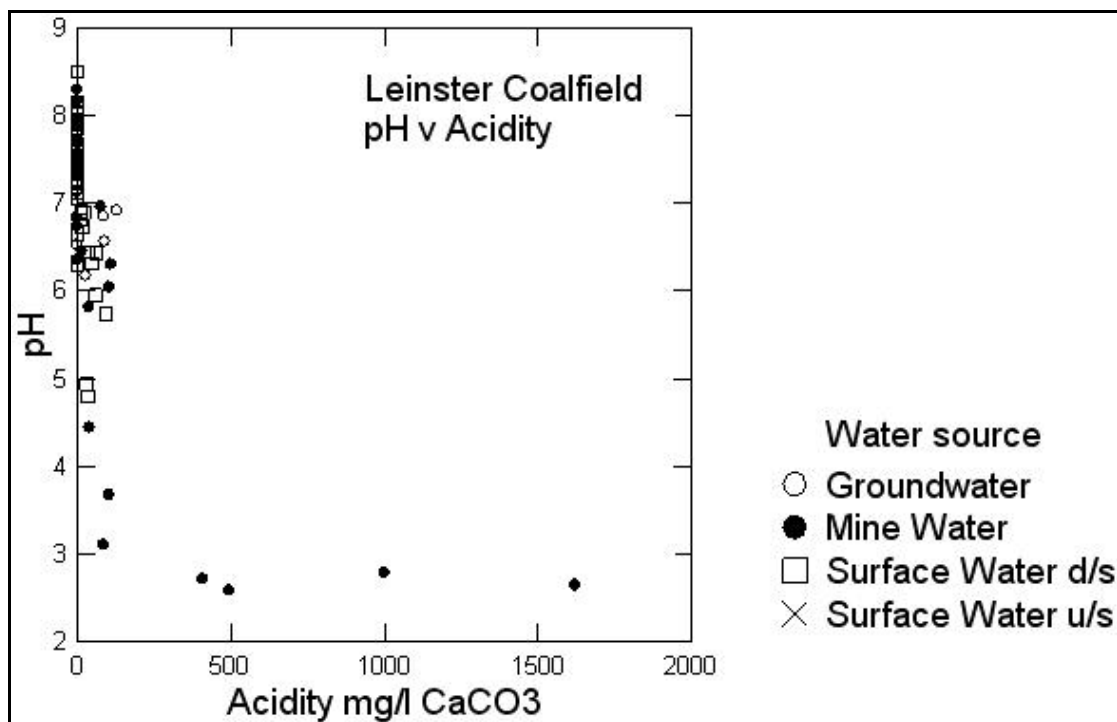
Among the various parameters measured for the HMS-IRC project, sulphate is possibly the most useful for demonstrating the impact of mine sites on water in the Leinster Coalfield because it is widely present in samples analysed and can be directly linked to coal waste. Fig. 13 shows the range in sulphate concentration as a function of water source for all samples analysed, collected in both winter and summer. In this case, adit discharges, seepages and run-off from waste heaps and open pit lake waters have been bundled together as "mine water". Only samples with  $\text{SO}_4 < 200,000 \mu\text{g/l}$  are shown to allow adequate illustration of the variation – this involves excluding data for all samples from the Fleming's site. It is clear from Fig. 13 that water in streams downstream of mines do show consistently higher concentrations of  $\text{SO}_4$  than those upstream of sites.



**Fig. 13  $\text{SO}_4$  by water source, Leinster Coalfield**

Apart from metal contamination, the most important chemical issue related to mine water discharges from coal mines worldwide is acid mine drainage (AMD) or acid rock drainage (ARD), generated as a consequence of reaction between mine water and sulphides, mainly pyrite, in the coal and its host rock. Water with high acidity generally has low pH but low-pH waters do not necessarily have high acidity. Most water analysed in the coalfield had pH greater than 7.0 and alkalinity was measured instead but for those with  $\text{pH} < 7$  the measured acidity is generally low. This reflects the general absence of significant concentrations of ions, e.g. metals, in the water. Very low pH (2.6 – 2.8) is a feature of seeps and run-off at Fleming's and some samples taken at Old Rossmore also had low pH (3.1 – 4.9), particularly the water in the small quarry near the entrance (sample W001, Fig. 5). However, of the Rossmore samples only that from the open pit had an acidity exceeding  $100 \text{ mg/l CaCO}_3$ , and the measured concentration was only  $105 \text{ mg/l CaCO}_3$ . Of all the

samples analysed from the Leinster Coalfield, only those from seeps and run-off on the coal-rich waste at the Fleming's site had truly high acidity, with concentrations ranging from 410 to 1620 mg/l  $\text{CaCO}_3$  in the four samples analysed. The general relationship between pH and acidity for all samples collected in the district is shown in Fig. 14. As is the case for the Slieve Ardagh coalfield, although low-pH, high-acidity samples can be generated under specific circumstances and in specific locations, acidity is generally not a significant factor in the Leinster Coalfield and the risk of AMD therefore appears to be low.



**Fig. 14 pH v Acidity, Leinster Coalfield**

Groundwater samples from wells and springs generally have very low concentrations of elements of interest (Table 3). In order to assess the potential for groundwater contamination as a result of leaching of solid waste heaps, leachate analyses were carried out on two composite samples of solid waste, one from SP01 at Fleming's colliery site and one from SP02 Old Rossmore. The seepage and run-off samples from Fleming's already provide an idea of the potential composition of leachate at this site and the results for the leachate test (LCH001) are in agreement with surface water analyses carried out previously in that the same elements are elevated in both. However, the measured concentrations are much higher in the water samples collected at Fleming's itself than they were in the leachate generated in the laboratory from the solid waste. . The leachte had a concentrations of 6.7  $\mu\text{g/l}$  Cd (compared to a maximum of 34  $\mu\text{g/l}$  in the field samples), 39  $\mu\text{g/l}$  Cu (compared to 344  $\mu\text{g/l}$ ), 27  $\mu\text{g/l}$  Pb (15  $\mu\text{g/l}$ ), 7  $\mu\text{g/l}$  Ni (785  $\mu\text{g/l}$ ) and 88  $\mu\text{g/l}$  Zn (1500  $\mu\text{g/l}$ ). The disparity between the concentrations in actual leachate and run-off versus the laboratory-generated leachate suggests that longer contact between water and solid waste that occurs in nature, compared to the five-minutes afforded by the leaching test, may be crucial to bringing metals into solution in this instance. At Old Rossmore, concentrations of elements of interest in the leachate are much lower than for Fleming's: 11  $\mu\text{g/l}$  Cu, 3  $\mu\text{g/l}$  Pb and 8  $\mu\text{g/l}$  Zn, with the rest below the detection limit.

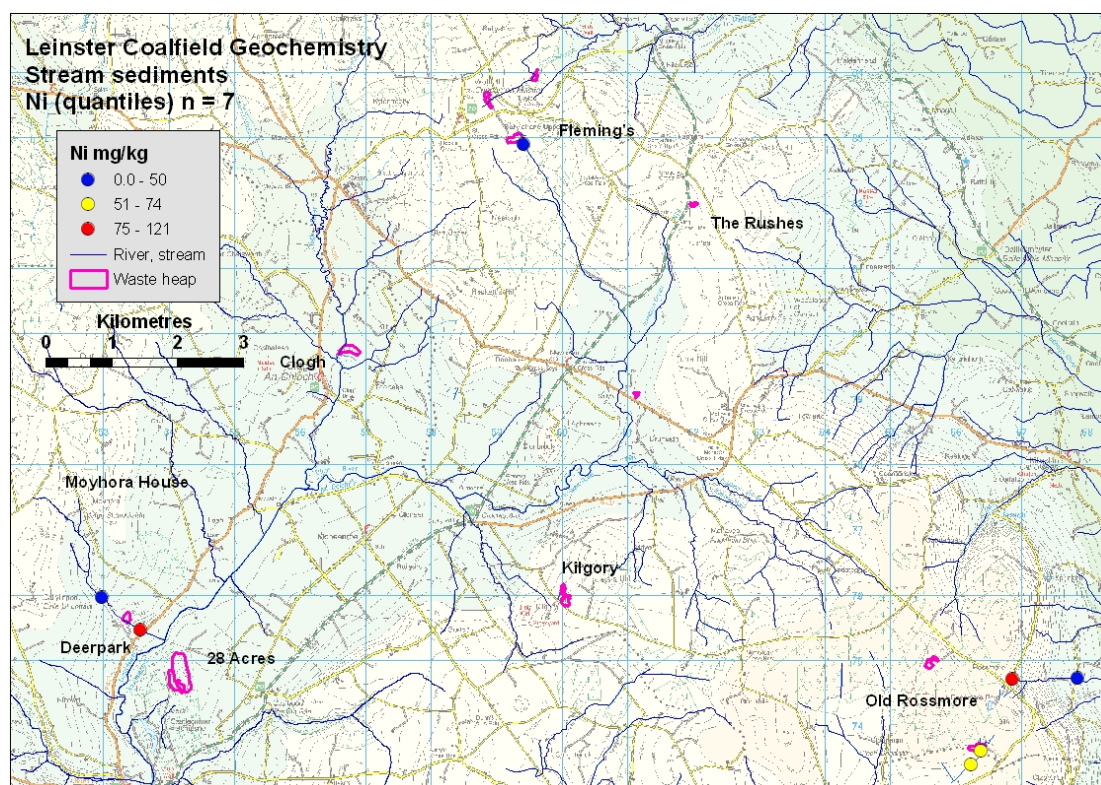
## 2. Stream Sediments

Stream sediments were collected in the vicinity of just three collieries, Deerpark, Old Rossmore and Fleming's (Fig. 15). Two samples were collected at Deerpark, one upstream and one downstream of the site. At Old Rossmore, four samples were collected from two streams, the one draining southwest from the southern section of the site and the other stream that drains to the east from the northern part of the site. This latter stream receives water from the adit discharge and the local spring and the sample taken closest to the mine is essentially sediment from the adit drainage channel. One sample was taken downstream of the Fleming's site, a dry sample from the bed of the drainage stream normally fed by the waste seepage. Table 4 summarizes the results.

In general, concentrations of metals in stream sediments collected around mine sites in the Leinster Coalfield are relatively low, generally much lower than the metal sediment limit concentrations for livestock exposure adopted for the HMS-IRC project (Table 4). The small number of samples taken allows only very tentative conclusions. This applies to the upstream sample as much as it does the downstream samples. However, when concentrations in downstream samples are compared with those from the only upstream sample, taken at Deerpark, it appears that the mines have some impact on stream sediment composition, with elevated downstream concentrations of As, Pb, Ni, Fe and Mn. In the case of As and Pb, only the sample downstream of Fleming's showed significantly elevated concentrations (the maximum values in Table 4); other samples had measured As and Pb concentrations below 40 mg/kg. Downstream concentrations of Zn and Cu are low and not very different to those of the upstream sample. Only Ni and Fe, and to a much lesser extent Mn, show systematically higher concentrations in downstream samples compared to the upstream sample. Fe concentrations consistently breach the 10,000 mg/kg limit for livestock exposure. The presence of elevated Ni in stream sediments is consistent with the water chemistry data and with concentrations measured in stream sediments in the Leinster Coalfield. Fig. 15 shows the distribution of Ni in the samples collected.

**Table 4 Summary statistics for stream sediment analyses, Leinster Coalfield**

mg/kg	As	Pb	Zn	Cu	Ni	Fe	Mn
n	7	7	7	7	7	7	7
Minimum	12	23	0.0	26	0.0	34897	118
Maximum	185	115	109	38	121	64097	25120
Median	18	28	81	31	58	53203	2061
Mean	45	41	67	31	54	48795	5613
Upstream (Deerpark) (n = 1)	16	28	90	28	0.0	36654	2734
Limit concentrations	300	1,000	5,000	100	1,000	10,000	5,000



**Fig. 15 Stream sediment sampling sites, Leinster Coalfield**

The presence of Ni in stream sediments and the failure to detect it in solid waste analyses (below) is of interest. The fine fraction ( $< 150 \mu\text{m}$ ) collected tends to concentrate metals and this may be sufficient to account for the observed data. Certainly, Ni seems to be present in coal mine waste but at levels too low to be detected and measured using the techniques employed in this study.

### 3. Solid Waste

There are many extant waste heaps in the Leinster Coalfield. Most consist of shale with a small amount of coal waste and their potential to contain significant concentrations of contaminants such as metals are low. Nevertheless, water analyses, notably at Fleming's, demonstrated that some heaps might contain significant concentrations of contaminants. Accordingly, Fleming's was selected for analysis. The main waste heap at Old Rossmore was also analysed because it is a large heap on a site mined in relatively recent times and has not undergone any significant rehabilitation or revegetation.. Of the two, the heap at Fleming's contains more coal as well as more obvious pyrite. However, a significant amount of pyrite at Rossmore is microscopic (McArdle 1992).

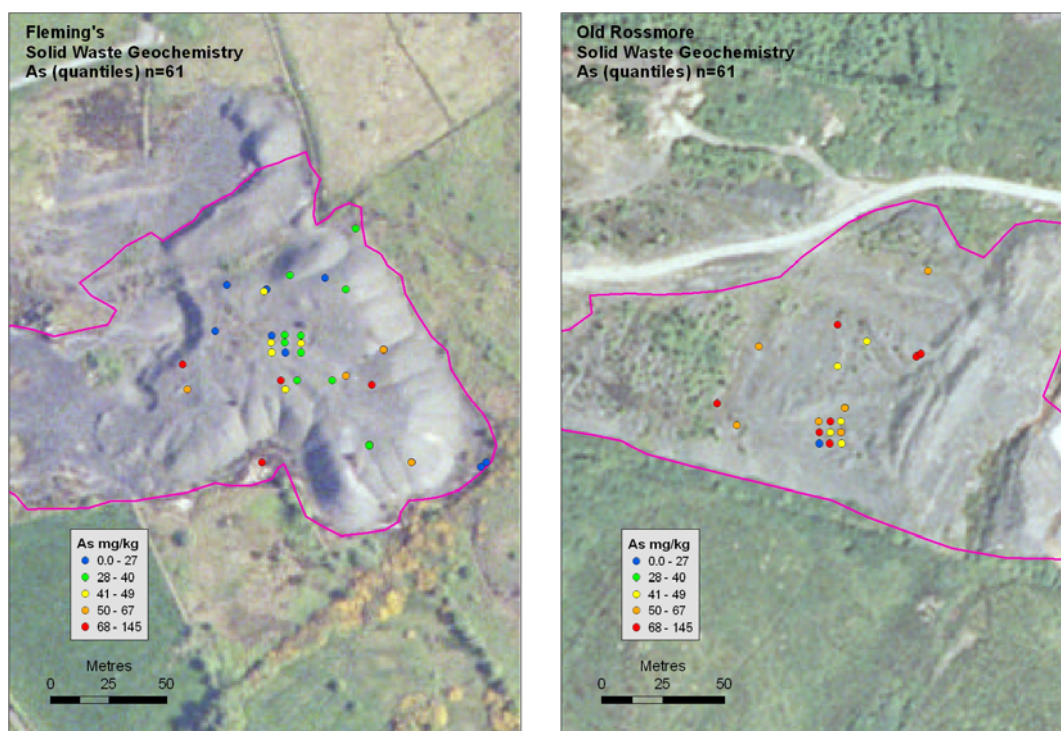
Analysis of the waste at both sites revealed elevated levels in some samples of As, Zn and Pb. Table 5 summarizes the data. Compared to waste analysed on metallic mine sites, the waste in the Leinster Coalfield has relatively very modest absolute concentrations of metals. However, compared to regional median data from the National Soils Database ([www.epa.ie/nsdb](http://www.epa.ie/nsdb)), computed using soils overlying the Upper Carboniferous bedrock in the Slieve Ardagh – Leinster Coalfield area, the waste at both Fleming's and Old Rossmore is clearly enriched, if moderately so, in As, while the waste at Fleming's is also somewhat enriched in Pb.

There is no clear correlation with water analyses. Ni, which is present in high concentrations in run-off water samples at Fleming's and in adit discharge at Old Rossmore, was below the detection limit in all analyses. As, detected in most solid waste samples, was detected in very few water analyses despite the reduced-pH conditions that would be expected to increase its solubility. In the case of Ni, this may reflect high detection limits in the XRF.

**Table 5 Summary statistics for solid waste analyses, Leinster Coalfield**

mg/kg	As	Zn	Cu	Ni	Pb
<b>All analyses</b>					
n	61	61	61	61	61
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	145	487	37	0.0	278
Median	44	0.0	0.0	0.0	33
Mean	49	8	4	0.0	39
<b>Fleming's</b>					
n	39	39	39	39	39
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	145	487	32	0.0	278
Median	38	0.0	0.0	0.0	46
Mean	43	12	0.8	0.0	56
<b>Old Rossmore</b>					
n	22	22	22	22	22
Minimum	21	0.0	0.0	0.0	0.0
Maximum	124	0.0	37	0.0	36
Median	58	0.0	0.0	0.0	7
Mean	61	0.0	9	0.0	10
<b>NSDB (median)</b>					
Namurian-Westphalian (n=20)	7	71	13	18	23

Fig. 16 shows the As distribution at Fleming's and Old Rossmore. The classification is based on all samples analysed to allow direct comparison of the two sites. As concentrations are generally higher at Old Rossmore than Fleming's, with particularly high values clustered around the northern flank of the heap, despite the fact that Fleming's yielded higher metal concentrations in water than were measured at Old Rossmore (Table 5).



**Fig. 16 Solid waste geochemistry, Leinster Coalfield: As in solid waste, Fleming's and Old Rossmore**

The median concentrations for elements analysed in solid waste at Fleming's and Old Rossmore have been applied to remaining waste heaps in the district in order to score them for the HMS-IRC Site Scoring system. There are numerous such waste heaps in the coalfield, consisting mainly of slate and shale with subordinate amounts of coal waste. Many are grassed over or otherwise overgrown by vegetation but they have been included where volume estimates are available. Table 6 below lists the solid waste heaps for which volumetric data is available.

**Table 6 Solid waste heaps, Leinster Coalfield**

Waste ID	Site	Area (m <sup>2</sup> )	Volume (m <sup>3</sup> )
SLA-SP01	Fleming's	24656	142236
SLA-SP02	Old Rossmore	22292	66577
SLA-SP03	New Rossmore	13654	76462
SLA-SP04	Clogh	28757	313803
SLA-SP05	Deerpark	12059	36177
SLA-SP06	Wolfhill	11525	56821
SLA-SP07	Sally's Bridge	2972	2607
SLA-SP08a	Kilgory	28648	81318
SLA-SP8b	Kilgory	4709	22132
SLA-SP9	The Rushes	4873	14619
SLA-SP10	Modubeagh	15269	59098
SLA-SP11a	28 Acres	107663	734978
SLA-SP11b	28 Acres	28847	155808

#### 4. HMS-IRC Site Score

**Table 7 Site Scores for mine waste, Leinster Coalfield**

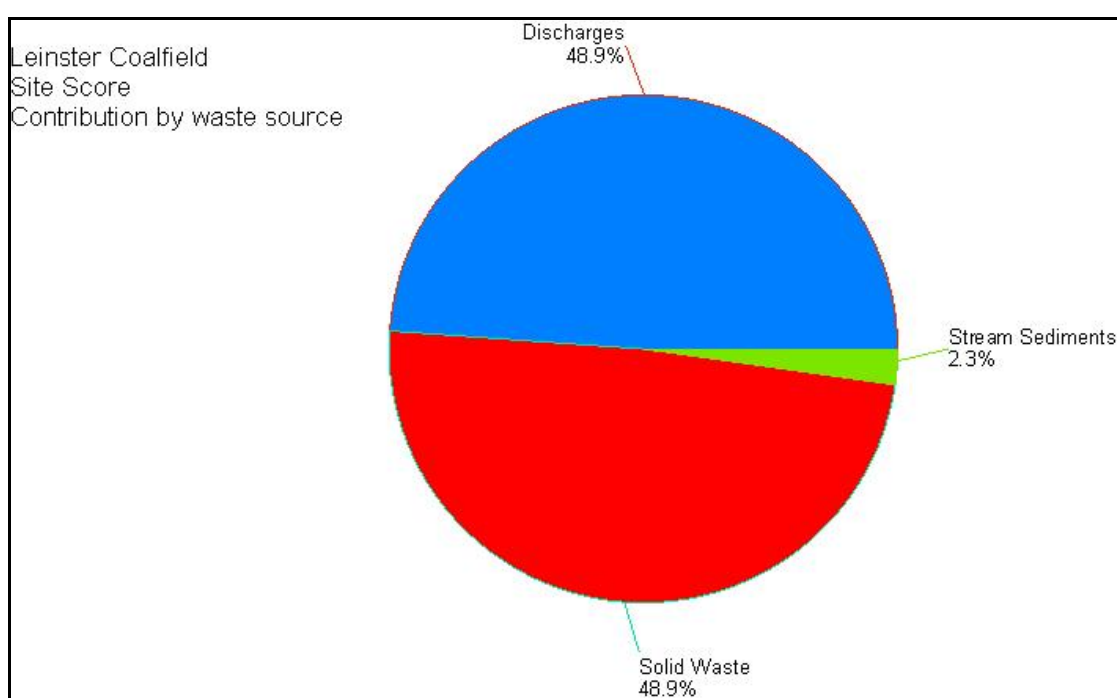
<b>Waste</b>	<b>SP01</b>	<b>SP02</b>	<b>SP03</b>	<b>SP04</b>	<b>SP05</b>	<b>SP06</b>
<b>1. Hazard Score</b>	15	12	12	19	11	12
<b>2. Pathway Score</b>						
<i>Groundwater</i>	3.97	4.27	4.65	3.00	1.63	2.54
<i>Surface Water</i>	4.88	3.81	0.83	3.14	3.64	0.79
<i>Air</i>	0.06	0.05	0.03	0.01	0.01	0.00
<i>Direct Contact</i>	0.15	0.09	0.14	0.14	0.14	0.14
<i>Direct Contact (livestock)</i>						
<b>3. Site Score</b>	<b>9</b>	<b>8</b>	<b>6</b>	<b>6</b>	<b>5</b>	<b>3</b>

<b>Waste</b>	<b>SP07</b>	<b>SP08a</b>	<b>SP08b</b>	<b>SP09</b>	<b>SP10</b>	<b>SP11a</b>
<b>1. Hazard Score</b>	10	13	11	11	10	31
<b>2. Pathway Score</b>						
<i>Groundwater</i>	2.14	2.66	2.36	2.20	2.39	7.21
<i>Surface Water</i>	0.06	0.08	0.07	0.06	3.32	0.10
<i>Air</i>	0.00	0.02	0.00	0.00	0.00	0.08
<i>Direct Contact</i>	0.01	0.08	0.01	0.01	0.01	1.04
<i>Direct Contact (livestock)</i>						
<b>3. Site Score</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>2</b>	<b>6</b>	<b>8</b>

<b>Waste</b>	<b>SP11b</b>	<b>W007</b>	<b>W015</b>	<b>W018</b>	<b>W029</b>	<b>W036</b>
<b>1. Hazard Score</b>	15	11	13	15	130	23
<b>2. Pathway Score</b>						
<i>Groundwater</i>	3.24	0.12	0.14	0.40	13.83	1.54
<i>Surface Water</i>	0.04	1.24	4.14	1.70	39.70	1.01
<i>Air</i>	0.01					
<i>Direct Contact</i>	0.10					
<i>Direct Contact (livestock)</i>						
<b>3. Site Score</b>	<b>3</b>	<b>1</b>	<b>4</b>	<b>2</b>	<b>54</b>	<b>3</b>

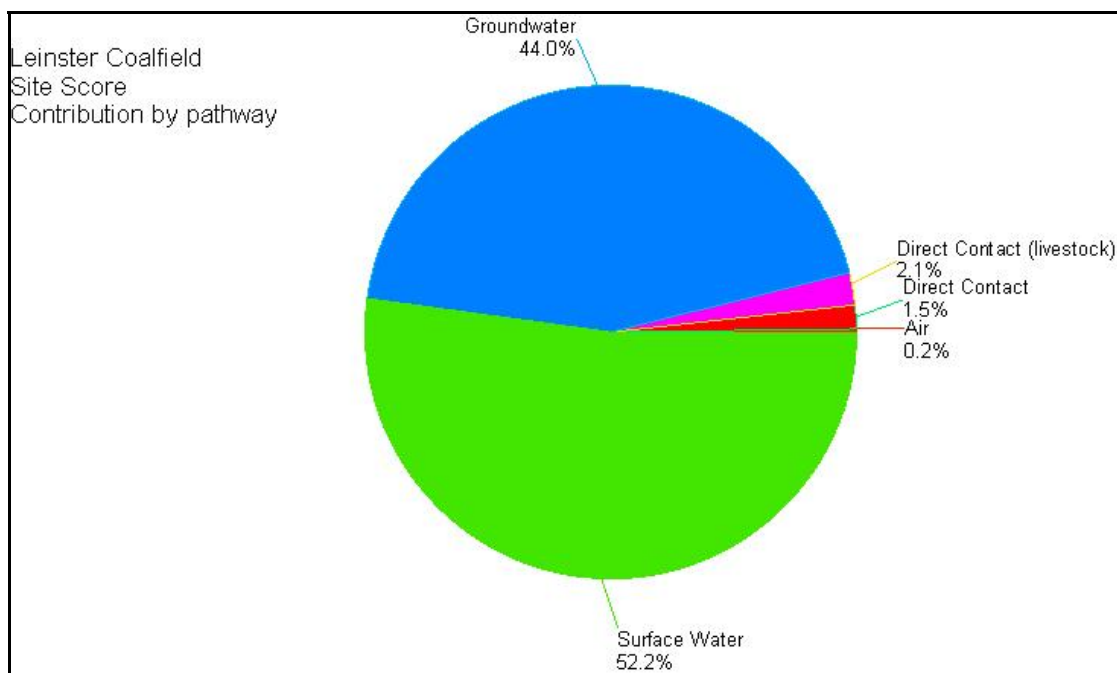
<b>Waste</b>	<b>W046</b>	<b>Deerpark sediments</b>	<b>Fleming's sediments</b>	<b>Rossmore sediments</b>	<b>Total</b>
<b>1. Hazard Score</b>	8	7	0	0	389
<b>2. Pathway Score</b>					
<i>Groundwater</i>	0.19				58.49
<i>Surface Water</i>	0.81				69.42
<i>Air</i>					0.27
<i>Direct Contact</i>					2.06
<i>Direct Contact (livestock)</i>		2.80	0.02	0.00	2.82
<b>3. Site Score</b>	<b>1</b>	<b>3</b>	<b>0</b>	<b>0</b>	<b>133</b>

Table 7 gives the HMS-IRC site scores for each individual waste source in the Leinster Coalfield that has been scored. The total score for the district is 133 (Class IV), of which solid waste and discharges each accounts for almost 50% (65) and stream sediments make up the rest, just 2.3% (3) (Fig. 17). Solid waste was analysed only at two sites, Fleming's and Old Rossmore, but the median concentrations of the analyses for these two sites were applied to all other waste heaps in order to generate site scores. The high proportion of the total site score contributed by the discharges is almost entirely made up by the seepage at Fleming's site. This seepage has metal concentrations that are unusually high for the district and hence its high score. Without this seepage, the score for the district would be dominated by the solid waste, a reflection of the large amount of material present rather than a high concentration of metals or other potential contaminants. The low score for stream sediments reflects the very low concentrations of metals within them.



**Fig. 17 Leinster Coalfield, site scores, contribution by waste source**

Fig. 18 shows the contribution to the total site score by individual pathways. The proximity of streams to most sites boosts the surface pathway score but this is balanced by the groundwater vulnerability ("extreme" aquifer vulnerability in most cases, according to GSI's classification). The relatively small contribution by the direct contact (livestock) pathway (i.e. stream sediments) reflects the very low concentrations of elements of interest in the sediments analysed. A similar explanation accounts for the low direct contact (humans) pathway and low air pathway scores.



**Fig. 18 Leinster Coalfield, site scores, contribution by pathway**

## 5. Geochemical Overview and conclusions

The Leinster Coalfield district is a very extensive area with numerous abandoned mine operations. It occupies the upland Castlecomer Plateau which is drained by a network of streams exposed to potential impacts from coal mining. Many of the mine sites have been partly or even fully rehabilitated since closure. Nevertheless, large waste heaps, open pit lakes and active drainage adits remain and are the main potential sources of environmental impacts in the district.

Water that is in direct contact with solid mine waste (seepage or surface run-off) has relatively high concentrations of elements such as Al, Cd, Cu, Ni, Zn and SO<sub>4</sub> as well as low pH and high EC. Stream water downstream of such discharges may display elevated concentrations of some of these elements, notably Ni. Adit discharges in general do not display the high element concentrations or low pH that characterize surface run-off. The exception is sulphate which is present in significantly higher concentrations in adit discharges than in upstream samples or groundwater. Stream water immediately downstream of mine water discharges may also have elevated sulphate concentrations. However, these concentrations are well below standard limits. In general, stream water has low concentrations of most parameters measured and shows only very limited and localized chemical impact from mining.

Solid waste analyses at two sites have demonstrated that at least some coal waste in the Leinster Coalfield has elevated metal concentrations: As, Zn, Cu and Pb were all measured in concentrations exceeding regional median background levels for soil. However, the absolute concentrations measured were low and unlikely to have any negative implications for human or animal health. Analyses of stream sediments indicated some impact from mining but concentrations were below standard limits for the protection of livestock. The total HMS-IRC Site Score for the Leinster Coalfield is 133, placing it in Class IV.

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