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DRAINAGE, WATER SUPPLY, SOUGHS AND OTHER TUNNELS IN THE COALBROOKDALE COALFIELD, PAST, PRESENT AND FUTURE

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SYNOPSIS

The combination of topography and mining tradition has brought about an unusual range of problems in the Coalfield, now the site of Telford New Town in Shropshire. The availability of men skilled in mining techniques and of engineers capable of putting ideas into practice through their furnaces, foundries and engines made possible the development of many ingenious drainage and transporation schemes. Some of these schemes were single purpose, such as the drainage of mines or as means of getting from A to B avoiding some obstacle or *other. Others however were dual purpose like the Wrockwardine Wood 'Navigation Levels' which were used both for drainage and for transportation.*

The related subjects of drainage and water supply are complex and only those aspects directly affected by geology, mineral working and land reclamation are referred to in this paper. The presence of hitherto unrecorded tunnels, whose original purpose is no longer remembered, makes it necessary to include all tunnels since many of these are now acting as drainage channels, and all of them could result in some degree of instability at the surface.

1. HISTORICAL BACKGROUND

(a) Extent of problem

The Coalfield is fairly hilly with several steep scarps and at least one major gorge. This has resulted in the watershed drainage system shown in Fig.1, surface water draining from the north to the Tern and from the south to the Severn. To the east drainage is to the Worfe but this in turn is a tributary of the Severn, joining it just outside the area.

Below the surface the strata are generally nearly horizontal, giving rise to numerous outcrops of the economic seams of mineral and the working of these has seriously affected the original water table in the high ground. Interconnection between the various seams via shafts and over the whole area via old workings permits almost free flow of underground water. Had it not been for the influence of subsidence and spoilheaps damming up the surface drainage channels, this underground flow would have resulted in very dry conditions over a large part of the area. Even so numerous wells and reservoirs were necessary in order to supply the area's industrial and domestic needs.

As mining went deeper so the problems of underground drainage became more acute and long subterranean drainage channels, called locally 'water levels' or 'soughs' became necessary. These in turn formed useful sources of water for the industrial activities, both manufactory and transportation, and in some cases a means of transport in themselves. At a later date, but with considerable overlapping in time, central steam pumping engines had to be employed to drain from greater depths, but even these nearly always pumped only up to 'sough-level' thus reducing the pumping head and, in consequence, costs.

The area's drainage 'balance', water removal, utilisation and ensuing problems is shown in the following table. The main features of this are now discussed while the problems of land reclamation and development of the area are dealt with later in this paper.

Natural drainage of surface water	— streams, rivers.
Artificial drainage of surface water	— ditches.
Utilisation of surface water	— reservoirs and ponds.
	— power and transportation
Problems	— subsidence 'flashes'.
	— spoilheaps interrupting drainage paths,
	— disused reservoirs, ponds, canals, quarries.
Natural drainage of underground water	— springs.
Artificial drainage of underground Water	— soughs,
	— interconnecting 'levels',
	— central pumping stations.
Utilisation of underground water	— wells,
	— transportation,
	— power and industry.
Problems	— ground stabilisation wells, subsidence, landslip.
	— dangers of access (gases, drowning).

(b) Surface water drainage

As mentioned previously the higher parts of the area form watersheds draining into the rivers Worfe, Tern and Severn. The streams so formed, and in their higher reaches the rivers themselves, have been much used in the past to power waterwheels and, when possible, not only to act as feeders for the local system of canals but also to provide navigable channels. For these purposes several streams have been diverted from their natural course, as this was too steep, thus leaving 'dry' valleys, subject however to flooding following heavy. rainfall. The permanent shortage of water in the higher areas has led to the construction of numerous reservoirs, artificial ponds and wells, most of which are now disused.

The requirements of industry and agriculture has also led to the development of an artificial surface drainage system involving numerous ditches and field drains. The low-lying Weald Moors to the north have been drained almost wholly artificially by these means under a system administered by the Strine Internal. Drainage Board.[1]

Subsidence caused by mining has seriously affected many of the streams and ditches and some flooding has occurred with the formation of flashes as at Priorslee and Old Park. Silting up caused by the reduction in gradient, and also by the tipping of spoil, has also occurred. A further problem has been caused by the formation of spoilheaps which have not only interrupted the drainage paths but necessitated the construction of culverts to take the original streams. In later years these culverts have collapsed causing large scale flooding behind the heaps. A good example of this caused an extended law-suit in the 1930s when the Wenlock Borough Council sued the owners of the Blists Hill Mines for failing to maintain culverts under their spoilheaps and this resulted in the bankruptcy of the mining company.

(c) Underground water drainage.
The natural movement of underground water has produced numerous spring lines along the valley sides especially at the base of the permeable sandstones. The effect of these springs can be excentuated especially when the flow is increased due to mining, and this may have some bearing on local landslips. One of the main problems however with regard to "springs" is to decide whether they are in fact the result of a collapsed. or buried mine adit.

All the methods of mine drainage described in standard text books have been extensively used in the area but the methods used which have left the widest range of problems were -

(i) water levels or soughs,
(ii) interconnection of underground workings by 'levels'
And (iii) central pumping stations.

The three methods normally formed a single system covering a considerable area, the system being extended and expanded as time progressed. In general, such a system would start as a water level to a single mine in the 17th or 18th century but, with increased mining activity during the 18th century, more workings would be connected to it by levels. From the early 18th century steam pumps would be added to raise water from workings to the 'sough'. These engines, and soughs, would in many cases have to be maintained long after the mines they originally served closed in order to prevent the formation of underground water ponds which would endanger surviving mines. In this way many such systems remained in use until well into the present century and with the widespread closure of mines in recent years the full implication of destroying such systems is only now being realised. One effect is the pressurisation of gas accumulations underground such as that that caused the outburst at Halesfield Shaft, but the rising water may also be partly responsible for a number of landslips. There is also some evidence that rising water may cause surface settlement due to the saturation of fireclays and mudstones, which in consequence become more fluid and tend to flow into old workings.[2]

(d) Reasons for constructing tunnels
As will be seen 'tunnels' have been used for many purposes and the reason why a tunnel was constructed in preference to what appears today to be a much simpler task of either forming a cutting, constructing a bridge or even providing

n alternative form of transport is not fully understood. Labour was undoubtedly often cheaper than materials and the local population certainly had the skills necessary for tunnel construction but there are several tunnels where these reasons are not in themselves sufficient. An example of this is the long '1800 tunnel' which runs parallel to the Wharfage at Ironbridge.[3] Perhaps the cost of purchasing or maintaining a surface route was too great or perhaps such avid tunnel builders as William Reynolds were in fact 'tunnel mad'.

However the principal reasons for constructing tunnels appear to have been:-

- (i) for getting mineral, adits, ventilation tunnels and second means of egress.
- (ii) for drainage purposes as soughs and sewers.
- (iii) for transport systems including 'navigable levels', horse tramway levels, shaft and canal systems, canal and railway tunnels.
- (iv) for miscellaneous purposes such as the Decker Hill tunnels (a rich man's folly?), Wrockwardine Wood Glasshouse Tunnel (to avoid paying tolls over a canal) and the numerous tunnels associated with limekilns and pottery kilns.

Without doubt William Reynolds (1758-1803) was the greatest tunnel builder the area has known and the following tunnels can with certainty be attributed to him.[4]

The Tar Tunnel constructed in 1787 and said to be 1.6km long.
Ketley Canal Tunnels (two) completed in 1788.
The Derbyshire Level referred to by Prestwich and said to be 2.4km long.
The Wombridge Canal Tunnel, about 55m long, constructed mid 1780s.
Wrockwardine Wood Glasshouse Tunnel.

Reynolds also constructed countless other tunnels as part of his mining activities and at least three other documented tunnels are probably the result of his enthusiasm:

The 1800 Tunnel at Ironbridge.
A Tunnel on Willey Estate referred to in a deed of 1822 held in Shropshire County Record Office.
A Tunnel possibly associated with prospecting for lead at Shipton.
As in all areas of the country rumours exist of tunnels between the great houses and the local monastic buildings but as yet not one has been found.

2. TECHNICAL ASPECTS

The hazards and problems associated with shallow workings, tunnels and adits are well known. Briefly they include subsidence due to roof collapse, effects of water and gas seepage, the dangers of human access into old workings and interference with surface conditions such as landslip and natural drainage. Other problems connected with sealing off such shallow workings have also been mentioned including the build-up of gas pressure and general settlement due to the formation of underground water ponds. On the other hand if water is drained from flooded underground workings this may also cause surface settlement by removing hydrostatic support. It is essential therefore that careful thought is given to the implications of altering any drainage pattern either by surface development or by the sealing off of shafts and tunnels. To appreciate this fully it is necessary to understand both the reasons for making the tunnels and the methods employed.

(a) Tunnels for drainage.
A large number of short drainage levels or soughs are known and their outlets or 'mouths' can be seen in all the valleys in the exposed coalfield area. Typical examples are present at Arleston (662 104), in Loamhole Dingle and Ladywood. Most can be recognised as either a hollow containing an ochrous resurgence, as a cutting into a hillside, sometimes with the top of a brick or stone arch showing, or occasionally they come to surface in a stream bed. In the latter case they can be recognised by the discolouration and eddying in the stream water. Longer soughs connecting many mines are also known and these are often characterised by a line of shafts at regular intervals along their routes. Brief details of the most important of these are as follows:

(i) Old Park to Ketley, also known as the Derbyshire Level. Constructed in the 1780s and described by Prestwich(5) who said that its route could be followed on the surface by means of "the mounds of trap (basalt) collected at the different shafts". Prestwich stated that this tunnel was in basalt for most of its 2.4 km length this was a hard-rock and miners had to be brought in from Derbyshire, hence the name. The writer however has doubts as to the geological basis for statement but basalt has certainly been found beneath the Productive Measures in the area.

Another level, known as the Ketley Level and which may be the same or connected to the above, comes to the surface in a pool near the A5 London to Holyhead Road. It is said to be at 73 m depth at The Rock and was in use until very recently both to drain the Rock Fireclay Mine and to remove sewage from a number of properties.[6]

(ii) St. Georges and Donnington Wood to Donnington (also known as the Day Level). The outfall is in the heavily guarded Central Ordnance Depot at and the Stafford Pits. Local information seems to be borne out by a witness at a place formerly known at Lamey Lakes. It had (or has) a small building alongside its mouth known as the 'Sough Mouth Cabin'. This is shown on the Donnington Wood Sale Catalogue Plan dated 1914. Regular inspections of this level, known as "level creeping" were carried out until the early 1930s. Although reports vary it would appear that the level connected and helped in draining mines at the Cockshutt, The Nabb, Mumpton Hill, Pudley Hill, Dark Lane and the Stafford Pits. Local information asserts to be borne out by a witness at the 1858 Inquiry[7] who stated that the "Lilleshall Co. brought their level 3 or 4 years ago ..... it terminates at the Randles". The water from the mines east of the Lightmoor Fault had to be raised to the level by means of a central pump at Pudley Hill.

On 28 February 1931 a blockage occurred, "at the Donnington end of the Day Level, causing water to make an appearance through the top of some of the pits causing slight damage to the farmlands belonging to T. Ward".[8] This damage was put to rights when a shallow surface drain was put in by the Lilleshall Company.

(iii) The Donnington Wood Navigable Levels have been described elsewhere.[9] The Double Coal Level runs from SJ 709 122 to 707 129, about 730 metres including branches, while the Clod Coal Level runs from 698 116 to 704 124, a distance of 1440m including branches. Neither navigable level is shown as coming to surface on the old plans of the Donnington Wood Colliery dated 1788, but there is a tunnel to bring the water from "the Engine" to the "Sough". Part of this system at least was constructed by John Gilbert who was also connected with the Duke of Bridgewater's underground canals at Worsley.[10]

(iv) Other levels and soughs are known including one at Greenfields near Oakengates called the "New Sough" in the Charlton Estate Papers (Shrops. Record Office) dating between 1730 and 1738. Another at Langley is known to connect at least five pits between OS 688 072 and 694 071 but is not thought to come to. surface. A further sough connects about eleven pits in the Lightmoor area[11] and its route is indicated on Fig.1. The use of a level to drain a quarry is described in Aris's Birmingham Gazette January 21 1767 when "On Tuesday last at the Lilleshall Lime Works ... a pool 9 yd (8.23m) deep ... was let off by means of a level brought up to drain the works". Adams[12] has stated that this may be the stone lined culvert which issues into the Headford Brook near Greenfields Farm. This is believed to be connected with airshafts at 733 166 (6.l0m deep), Smith's Yard, 201m away (10.06m deep); and at a point 45.72m beyond this (11.28m deep).

As has already been mentioned water from deeper mines was often pumped up into the sough by central pumping engines. The development of steam pumping engines in the area has been described by Trinder.[13] He shows that the earliest engine was in use only seven years after Newcomen's first successful steam engine was put to work in Worcestershire. By 1800 over 200 steam engines were in use for all purposes in the study area, about one-sixth of the total number of engines built to that date. Some of the most interesting engines were at Wombridge and Pudley Hill (Cornish-type), Donnington Wood (Boulton and Watt?) and the Lloyds (Newcomen?). In 1928 the Lilleshall Company was still operating central pumping engines at the Stevens Barracks, Muxton Bridge, Stafford and Lawn Pits although most of the mines they originally served had closed. There were also steam pumping engines at most of the larger mines at this time. One central pump remained in use until the mid 1970s, this was electrically operated and pumped to surface at the Woodhouse Shaft.

(b) Tunnels for transportation purposes.

The known 'navigable levels' have already been referred to but tunnels used for other forms of transportation, including horse tramway levels, shafts and canal systems, surface canal and railway tunnels, exist within the area and their approximate position is shown on Fig.1. Brief details of these tunnels are as follows:-

(i) Horse-tramway tunnels, the ‘1800’ Tunnel at Ironbridge with capstone showing that date and running from 669 036 to at least 671 036.

(ii) Shaft and canal system tunnels at Hughs Bridge,[14] Brierley Hill, Coalbrookdale[15] and the Tar Tunnel. In this system a canal at a higher level was connected with a canal at a lower level by means of shafts giving entry to a subterranean extension of the lower canal.

(iii) Surface canal tunnels; Ketley Canal - two tunnels at Shepherds Lane (18.29m) and at Reynold’s Ketley Works (the former tunnel collapsed in 1897 killing a horse);[16] Wombridge Canal, one tunnel at Wombridge Church (about 54.86m); Shropshire Canal, three tunnels, at Snedshill (255.12m), at Stirchley (256.95m) and a short one at Oakengates (Greyhound).

(iv) Railway tunnels on standard gauge track were constructed at Oakengates (427m) Greyhound Tunnel) and at Horsehay (55) and Blists Hill (60m).

(c) Construction of tunnels.
All the tunnels mentioned above seem to have been constructed using similar techniques. Contemporary evidence, including the description referred to below, and visual examination, indicates that in most cases shafts were put down first at about 150 yards (137m) intervals and then headings were driven towards these, sometimes from several shafts simultaneously. The close spacing of the shafts would permit some natural ventilation and of course make access possible to several faces at the same time. It would also be useful in controlling flooding and also in the removal of material along the tunnels especially where they were of small diameter. No standard diameter was used, the finished diameter depending on the strata passed through and the purpose for which the tunnel was to be used. All the work would be carried out by hand and there was very little blasting done.

After excavation nearly all the tunnels were ‘arched’ in sections using semi-circular brick arching with vaulting at junctions. In very hard ground however the tunnel was left in the solid while, occasionally, completely circular brick arching was used as in parts of the Tar Tunnel.

A contemporary account survives[17] which gives full details of the construction of “a Day Level across the measures to drain the water from near the Old Lodge Mansion”. This commences in 1818 and while there is no proof it appears to be the sough referred to earlier as the Day Level. Commencing in May 1826 156 yd of existing level was repaired and arched (this had two access shafts), then heading proper began;

distance to first shaft (new shaft)	252 yd, shaft 43 yd deep
heading to second shaft	140 yd, shaft 40 yd deep
heading to third shaft	143 yd, shaft 40 yd deep
heading to fourth shaft	129 yd, shaft 42 yd deep

and so on to the seventh shaft. From the seventh shaft a further 94 yd was headed out until a fault was reached and work stopped. The sough so far had

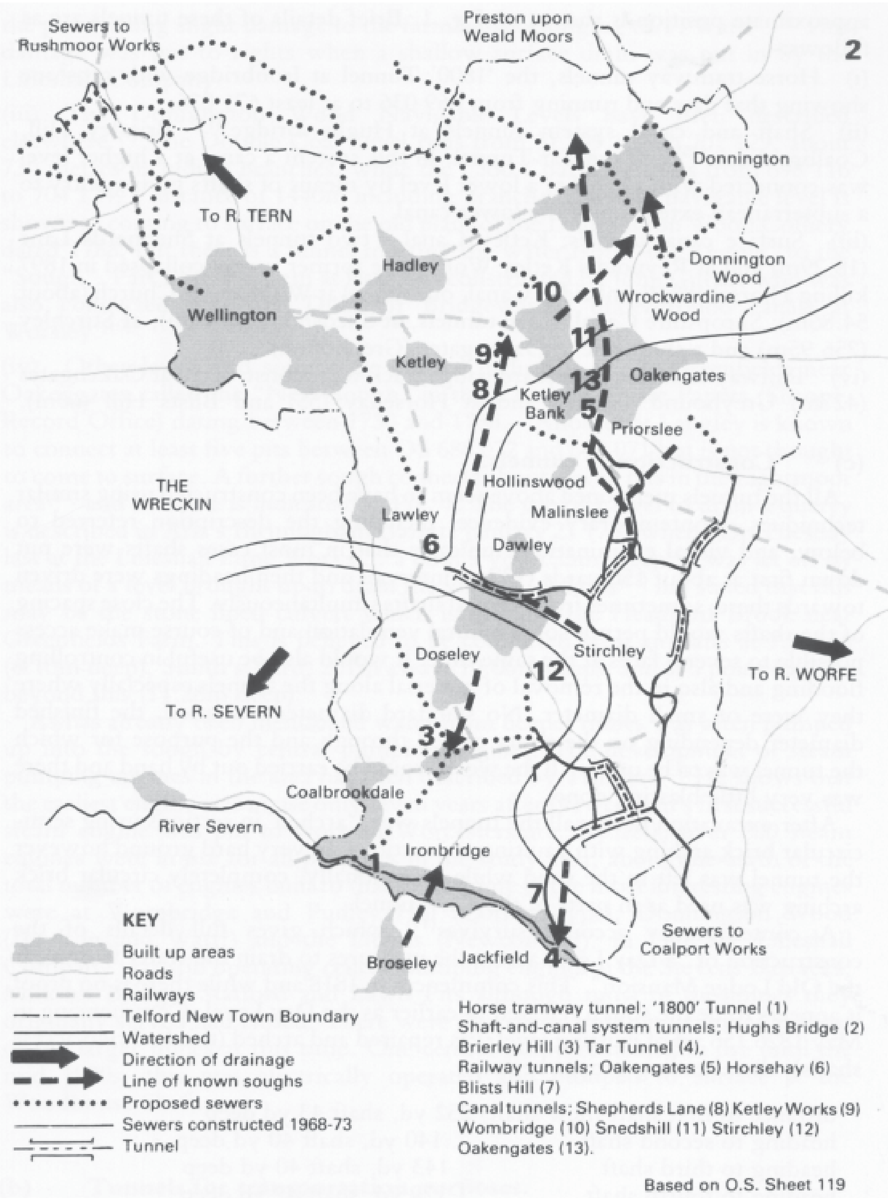

Fig.1. Sketch showing drainage paths and principal tunnels in the Coalbrookdale Coalfield.

taken almost 2½ years during which time 304½ yds (278.44m) of shaft sinking was done (cost £423) and 1269 yd (1130m) of heading (cost £1935). During the next three months No.8 pit was sunk on the deep side of the fault to 58 yd and then, to Aug. 1829, "heading and arching" was carried out from No.8 shaft both "north and south" in order to complete the sough.

Problems encountered included one months delay due to flooding at No.6 pit and 691 yd (83.21m) had to be repaired by "ripping and raising and arching" due to subsidence when the Top Coal was worked beneath the level. In addition 476 yd (435.23m) had to be repaired a second time for the same reasons (total cost of repairs £463).

A "cross level" was then driven with three shafts, during 1831 and 1832, from No.4 pit to the Engine Pit near the Lodge. This was obviously a central pumping station.

The same problems and methods described above are evident in all the tunnels explored by the writer in the area, and especially in the 1800 Tunnel, the Tar Tunnel and the Oakengates Railway Tunnel. It is obvious too that care must be taken when developing adjacent to these tunnels not only because of the possible effects of accumulation of water and gas but also the possibility of unstable linings, hidden shafts and their liability to collapse.

As will be seen later the new town development has necessitated the construction of a system of trunk sewers and of this about 4km has so far been in tunnels (Fig.1). The principal of construction has been much the same as described above, shafts firstly at fairly regular intervals with headings between. The first tunnel system was constructed south east of Madeley, the main tunnel being up to 3.5m dia. and the deepest shaft 21m. All loading was done by hand after blasting and an advance of about 1.8m per 12 hour shift was maintained. Compressed air pressure was used to keep back the ground water and small battery locos were used for haulage.[18]

The second tunnel system was constructed east of Stirchley, and this included the construction of a syphon draw-off from the balancing reservoir. The tunnel had three branches, the largest was 3.66m diameter and, as in the first system, concrete segment panels were used for support. In plan all branches were curved in part, the tightest curve being 15m radius. Compressed air at 15lb/sq.in. was used to maintain dry conditions and in order to obtain the correct syphon characteristics a scale model was made and tested at Salford University. Once perfected the model was scaled up for use in the final work.[19]

The third tunnel system, north of Dawley, was much more complicated geologically. It involved the crossing of a major fault line, passing through an area of shallow mine workings and numerous shafts and also passing beneath occupied properties at very shallow depth.

3. INVESTIGATION OF SITE DRAINAGE, TUNNEL AND RESERVOIRS.

In addition to the normal site investigation carried out before undertaking the developments mentioned, some of which must of course be very stringent, there are a number of special considerations to be taken into account in areas such as the one under study. It is with these special considerations that the writer has been concerned and it is these that are discussed here.

(a) Site drainage.
The site investigation carried out before any development includes an assessment of the drainage situation. For this both the documentary research and field reconnaissance are religiously carried out. Old documents and plans frequently show drainage paths no longer visible on the surface and this is particularly true of the O.S.1:2500 scale early editions. 'Issues' and 'Sinks' are also indicated and these can be a clue to the presence of adits, culverts or other tunnels. Comparison of the size and shape of a pond or marshy area as shown on the early plans with that observed in the field can also give a good indication of the history of a site.

Experience has shown that whereas in earlier times landowners and tenants cared for their ditches and streams the tendency has been for these to be ignored in recent years with consequent silting up and the formation of waterlogged areas.

Where a land reclamation scheme involving earth works is to be carried out the actual areas of waterlogged ground have to be determined and the amount of unsuitable material "calculated". This is done by probing.

In addition all sources of water make, all drainage paths and all points at which water leaves the site have to be carefully examined and the consequences of any adjustments considered. This applies not only to natural surface and underground water courses but also to foul and storm water sewers and town water supply. In the Halesfield and Kemberton Mine spoilheap areas for example, all the above problems exist and will have to be carefully considered and allowance made for the continued flow by diversion where necessary. The drainage of these particular sites can be considered in three phases:

(i) Natural – consisting of the Mad Brook Valley with some springs near the Bridgnorth Road.

(ii) During industrial occupation – the springs were tapped by the canal and this was supplemented by the ochrous waters pumped from the mines (Halesfield group and Kemberton). At Kemberton the 'clean' Mad Brook was culverted and the spoilmounds tipped over this while the ochrous mine water was directed down the roadside, passed over the clean brook by an aqueduct then through a separate culvert under the mounds. It crossed the fields and went around the south of the Halesfield spoilheap to terminate in the drain leading from Halesfield Mine. The drain from the Halesfield Mine passed down between the two parts of the southern spoilheap, was joined by the Kemberton Mine drain and then crossed a long aqueduct over the fields to the canal at The Basin. Subsidence and spoiltipping also affected the drainage pattern and considerable ponding occurred.

(iii) During the new town development period 1968 to 1972. A trunk sewer had been laid through the area between the Kemberton and Halesfield spoilmounds and a balancing reservoir formed to the north of the railway embankment. The area contained by this embankment, the two old spoilmounds and some high ground to the south now formed part of a

Plate I. Entrance to canal tunnel, Donnington 1974

Plate II. Lloyds Pumping engine c1910.

"catastrophic storm reserve flood area" where water could be retained and then let off as the storm subsided.

The above is only the basic outline of the situation as found and does not include domestic drainage, town water supply, cattle feeding arrangements and even a 'sheep dip'. It does show however the problems that can exist on a single site.

A further major source of information is local knowledge and interviewing old inhabitants, former tenant farmers, owners and even fisherman can provide much useful material – as well as the local authorities and public utility service boards.

(b) Culverts and tunnels.
It is now generally accepted that it is not satisfactory to retain old culverts in modern drainage systems, the cost of maintenance being high and their future useful life unreliable. However since they often form part of an existing system, and may introduce other hazards associated with tunnels, each culvert has to be investigated. The direction of water flow can be tested with chemicals such as fluorescence and the quantity of water passing measured by weirs and vee notches. Some of these culverts are quite long, for example, the one carrying the Wash Brook beneath the Shawfield and Blists Hill spoil areas is about 0.8km in length. The writer believes that the subsidence of about 0.3m in the eastern abutment of the historic high level Lee Dingle tramway bridge, and its consequent abandonment, was mainly due to the collapse of this culvert beneath it.

When old tunnels are found on a site they have to be investigated since, as has been shown, they can affect surface conditions. Such tunnels are commonplace around the surface buildings of mines and factories where they have been used for access roads, pipelines, ropeways and ventilation ducts. These are normally of little consequence and can easily be removed. Other tunnels are not so easily dealt with and these include the longer tunnels for transportation and shallow mine workings. When a tunnel is located the routine given below is usually followed:-

(i) documentary search,

(ii) inspect, taking all the necessary precautions, in order to determine possible past uses and reasons for construction,

(iii) examine the tunnel for general safety and stability,

(iv) survey the tunnel,

(v) consider effect on development and decide on future usefulness or means of treating the tunnel.

The writer has undertaken several such investigations including those of the Oakengates Railway Tunnel and the Tar Tunnel

The location of old tunnels, known to exist from documentary sources, is probably best done using probe-drilling methods although certain firms and individuals claim that geo-physical and even dousing "methods" are quicker, however these "methods" by themselves lead to probe-drilling eventually to obtain confirmation!

The routes for proposed new tunnels, for such purposes as trunk sewers, have to be carefully investigated, and great emphasis has to be given to the subsurface conditions existing in terms of geology, past mining and stability. The routes are all fully investigated by probe-drilling and an appraisal must be made of problems likely to be encountered both during construction and in later years.

The first two tunnel systems constructed for the new town were in deep mining areas and it was only necessary to carry out the normal soil investigations and to avoid known shaft and quarry positions etc. The third tunnel system, the Dawley-Malinslee Outfall Sewer Tunnel situated north of Dawley was partly in shallow-mined area and, as has been stated, provided a wide range of problems. The investigations carried out for this tunnel and the problems encountered during its construction are dealt with as a case history at the end of this paper. The sewer tunnel beneath the River Severn was a special case.

The problems encountered here included potential instability of the river banks on both sides, possible shallow workings at river level and what appeared to the writer to be solution voids in the Silurian calcareous mudstone beneath the river bed.

(c) Reservoirs and associated dams.
Over a certain size these are designed under conditions laid down by statute but there are many reasons for forming small reservoirs and ponds unaffected by these requirements. Such works may include the rehabilitation of small industrial reservoirs, the landscaping of flooded quarries, formation of irrigation lakes in golf courses and millponds as museum exhibits. In the latter class were three small interconnected reservoirs on the Blists Hill Open Air Museum Site where during site investigation under the direction of the writer an open mine shaft was located beneath one of the earth dams. In all cases of reservoir and dam construction, especially on high ground, extensive investigations using all the standard techniques are necessary to ensure public safety.

Similar investigation work, but not on such an extensive scale, is necessary along the routes of major sewer pipe-lines and main drains and in areas where “reserve flood meadows” are to be provided.

4. TREATMENT OF THE DRAINAGE PROBLEM AND OLD TUNNELS.
Basically the drainage system for the area in the future will consist of local drains, for surface water and for foul water, leading to district drains which, finally, will lead to the trunk sewers. The new town area itself divides into two drainage catchment areas, separated by the high ridge of land from Ketley Bank to Lawley Bank. The area to the south drains to the River Severn and that to the north drains to the River Tern. The network of trunk sewers proposed (Fig.1.) follows this general pattern. To the south the eastern area surface water drains through a system of culverts and tunnels to an outfall at Coalport, balancing reservoirs being provided as necessary. Provision is however made for the normal water flow to continue through the agricultural area on the

eastern flank. Foul water follows a similar path either parallel to the surface water sewer or in an enclosed tube within it to the large new Water Pollution Control Works at Coalport. From the western area drainage takes place down the Coalbrookdale Valley, the foul water sewers continuing to the Coalport Works.

The northern area is provided for by trunk sewers leading to a surface water interceptor which discharge into the Tern below Longdon. The foul water will, in the long term, go to the Pollution Control Works at Rushmoor.[20]

(a) Drainage of development sites and reclamation areas.
The work of draining such areas, after the site investigation and design work has been completed, can be subdivided into four stages:

(i) The diversion or maintenance of existing springs and water courses as required.

(ii) The maintenance of dry conditions on site during development and the protection of adjacent properties.

(iii) The dewatering of ponds, waterlogged areas and ditches etc. their infilling and other earthworks.

(iv) The provision of permanent drainage.

While the actual design and constructional details of land drainage schemes are outside the scope of this study the following aspects have been found of special relevance to work in the study area.

Several British Standards Institute Codes of Practice deal with this topic and these should be studied especially with regard to alteration of water tables and of infilling over impervious strata.

A considerable saving in cost can be made if the temporary drains constructed to keep the site clear of water can in fact be incorporated in the permanent drainage pattern. To change from temporary status to permanent status may require only the filling of open ditches with rubble or piping.

If a compacted area is to be left undeveloped for any length of time considerable erosion, both by wind and water can occur. In addition compaction leads to a very high water run-off ratio with risk of flooding both on site and on neighbouring property. To protect neighbouring property, bunds or open boundary ditches are frequently necessary.

Poor drainage, standing water, the formation of erosion gulleys and the deposition of silt can seriously impede the efficient working of a site and also cause annoyance to neighbouring property owners.

Steeply graded slopes introduce inherent problems in the forms of surface erosion and the formation of gulleys, soil creep, slides of detritus and rock and rotational shear slips. Flash flooding may aggravate the situation and several such incidents have occurred in the study area. In one case the main Chester-Didcot railway line had to be closed for several, hours when the increased drainage from a site is said to have caused a landslide in the railway cutting near Hollinswood.

The pattern and type of permanent under-drainage depends on the angle of slope and elevation of a site in relation to the surrounding ground as well as on the after-use for which the site is intended.

The permanent drainage of steep slopes must incorporate such features as 45° angled hill grips, reinforcement of the drainage channels and silt traps. Great care must be taken to prevent the silting up of drains during the construction period and in particular that all such drains are cleaned out before connecting to existing sewers.

The construction of the channels for culverts and the infilling of the void around the pre-formed culvert tube, especially in areas of compaction, needs special attention. In addition newly positioned culverts may need protection if heavy plant has to pass over them. Care is also needed during the construction of deep channels to ensure safety when passing through unstable materials to avoid side-wall collapse and also when passing through old household refuse heaps and coal-seam outcrops, where inflammable or other gases may be met. Similarly un-recorded mine shafts may be located or collapse occur into shallow old mine workings.

Frequently old mineshafts may serve as drains and, if located and treated during fine weather, this fact may not be fully appreciated. In one instance at the Fairview Housing Estate[21] one such shaft was backfilled and treated and then, after a heavy storm, water running from the site deposited large quantities of silt on an adjacent road and flooded nearby houses.

The pollution of water both on the site and draining from it, by leaching of contaminated materials or by the discharge of oil etc., must be avoided.

The above aspects, together with many other features referred to in standard works and in statutory instruments, should be enforced by inclusion in the respective contract documents. Experience has shown that the adequate drainage of the site is a primary requirement of any land reclamation scheme and its importance should be appreciated at all stages.[22]

(b) The drainage of housing and industrial areas.

While all the factors previously mentioned still apply a number of additional problems have arisen with regard to the drainage of areas already developed or where infilling is taking place.

When an area is ‘developed’ there is a tremendous increase in run off, indeed percolation is often found to account for less than 25% of rainfall, and during heavy rainfall much less. This additional water has to be accommodated in balancing reservoirs and ‘flood meadows’. In the new town existing features have been utilised wherever possible to form these areas. At Randlay part of the old flooded clay pit, in all about 2.5 hectares, has been adapted as a balancing reservoir, while at Holner, the embankment of a mineral line has been incorporated into the dam system. In another area it is proposed to re-excavate a 0.8km length of disused canal to serve as yet another balancing reservoir. Reserve flood areas have been formed using existing low-lying areas surrounded by spoilheaps although the spoilheaps have been landscaped and the ‘meadow’ made into an open space area.

The design of the trunk sewers also has to take into account the existence of obstacles such as unexpected mineshafts, and a diversion has also been made around a factory chimney. In the Malinslee area the storm water outfall has been so constructed that the water will cascade down the face of a sandstone quarry to form a feature in the Town Park.

A further factor to be considered is the continuance of water supplies to consumers in the low-lying areas. As has already been mentioned the development of an area reduces percolation and several such areas are in fact catchment areas for water supplies elsewhere. In the case of the south eastern area the interception of surface water has had to be adjusted so that sufficient water will remain in the streams to irrigate the farmlands on the new town perimeter. In an area to the north fears are being expressed that, if the surface water is tapped off around Old Park, the artesian head will be removed from the Hadley shafts which now provide several large factories with up to 4,546,000 litres water per day.

(c) Reducing the hazards due to old tunnels and culverts.
The safest way of treating an old tunnel is to remove it by total excavation and wherever this can be done economically, and when it is not necessary to preserve the tunnel, this is infact carried out. Most of the old tunnels are of simple brick lining construction and collapse easily but the demolition of more recent underground structures using concrete frequently requires blasting or the use of a drop-ball. Such structures include disused underground reservoirs as at Old Park, the fan drifts at Halesfield Mine and air raid shelters as at Ketley Bank.

Obsolete tunnels and culverts which cannot be removed are dealt with by methods used for shallow workings and adits.

Where development is to take place in the vicinity of tunnels which must be preserved special treatment methods are required depending on the type and use of the tunnel. Two such tunnels have so far been considered, the Oakengates Railway Tunnel and the Tar Tunnel. With the former tunnel the problem was really one of careful site investigation to determine construction methods and general stability, in view of the proposal to increase the loading on the tunnel. In the case of the Tar Tunnel the proposal was to develop part of it as a public show-mine. This involves regular inspections to determine continued stability in view of other developments in the vicinity and public access. The methods used include the study of re-plastered old cracks, glass tell-tales and the testing for ‘hollows’ using traditional ‘tapping’ techniques. Several such hollows have been located behind the existing brickwork and these areas are to be removed and’ re-arched or roof-bolted” as appropriate.

5. SPECIAL PROBLEMS

(a) Ochrous water.
A feature of all old coal and ironstone mining areas is the number of streams

seriously affected by the presence of ochre. This yellowish-brown discolouration appears to be due to the suspended particles of iron in various chemical combinations. These particles appear in practice to settle out readily both as a 'cake' on the sides of the water channel and onto anything else that comes into contact with them. Underground explorations in mines containing ochrous waters are most unpleasant as the ochre tends to form dams over slight ridges permitting further silting up behind. When the water level is low a crust forms on the ochrous cake but this is not strong enough to support any weight and the explorer breaks through into a considerable thickness of foul smelling yellow paste. Ochre staining can only be removed with the greatest of difficulty from clothing and flesh.

Similar conditions also occur in surface streams carrying ochre and, although very little appears to have been done to prevent this as yet, the writer considers that this situation will not be permitted to continue much longer.

The ochre appears to come from two sources, underground mineworkings and the leaching of spoilheaps as is the case with the Wash Brook. The water from the recently closed Madeley Wood Mine was heavily charged with ochre and attempts were made to remove it by oxidation using cascades and by settling in large ponds. This was fairly successful provided that certain maintenance standards were kept up. (A similar arrangement has been used commercially to recover ochre at the Dyffryn Adda Copper Works on Parys Mountain, Anglesey).

In the case of the water coming up. the shafts at Hadley this too contains ochre but before it gets to the industrial consumers it visibly clears. This occurs first by settlement in the Middle Pool and then, apparently, by filtration as the water passes through the railway embankment which separates Middle Pool from Valley Pool. It would appear that the only way to reduce the leaching effects on the spoilmounds of surface streams would be to line the streams where they pass through spoilheap areas. This would be difficult however as many not only pick up water from the mounds but also pass under them in culverts.

(b) Water supply.

The obtaining of water from wells, old shafts and adits within the area has already been mentioned and in some instances this situation is likely to continue for many years. The River Severn has also been used as a major source but in more recent years much of the domestic supply has been obtained from boreholes put down to the Bunter Sandstone mainly in the north east and east of the study area.

A 'town-supply' has been available in the more developed parts of the area since the turn of the century, although several major private schemes, such as the Lilleshall Company Scheme, existed for many years before this. The local Water Board has done considerable investigation into the future demand and sources of water for the area and, based on a consumption of about 340 litres per head per day, has estimated that about 83 million litres per day will be required in the late 1980s.[23] At the time of writing seven boreholes (Woodfield, Lilleshall, Sheriffhales, Hilton Bank, Shifnal, Beckbury and Grindleforge) give a reliable yield of 45.5 thousand cu.m per day although limitations in pumping capacity restrict supply to 30.1 thousands cu.m per day. Other locations are also being tested and, together with the Board's entitlement from the Severn, it is anticipated that sufficient water will be available to meet the predicted demand.[24]

It is of interest to note that the yield from Woodfield Borehole, the nearest borehole to the Adamston brine spring area has to be limited due to its saline content at depth.

An announcement[25] by the Water Resources Board highlighted Shropshire's potential as a future water supplier in its long-term strategy plan, the water being tapped from the sandstones to the north of the present supply area. Some of the exploratory boreholes supervised by the writer have located considerable quantities of water even within the superficial deposits on the higher ground in the area.

Boreholes in the deeper drift channels especially around Hollinswood and Wombridge have been particularly wet. On one occasion the ground was so charged with water that, when drilling with air-flush commenced, the water rose in a well some distance away and flooded low-lying property. In several other cases, such as was found at Trench Lock, small fountains occurred in open fields and continued for up to 30 minutes after drilling had ceased. In another instance at Wombridge water rose from a borehole under artesian pressure for nearly two days after drilling was completed.

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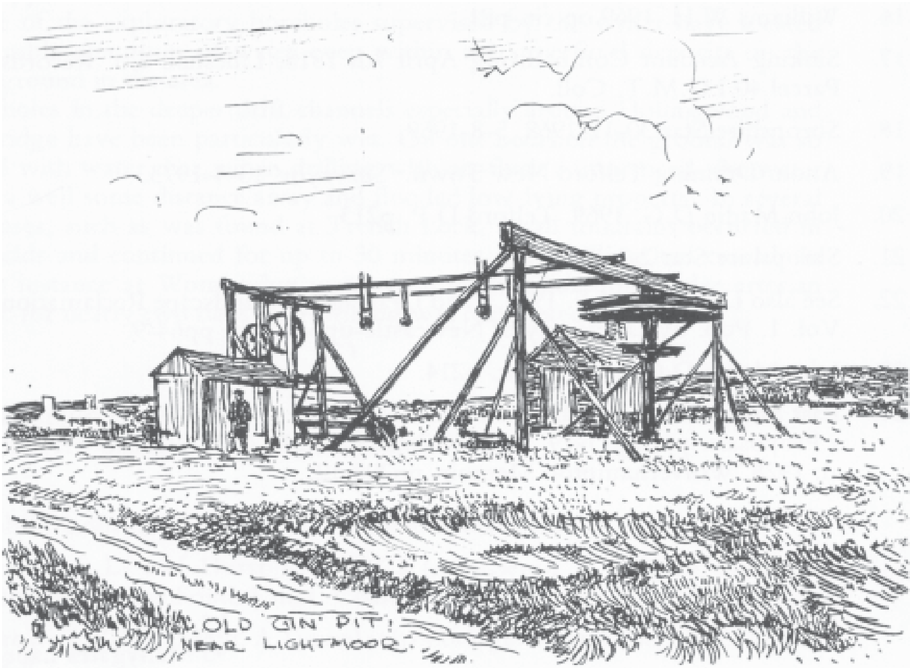

OLD GIN PIT NEAR LIGHTMOOR