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National Coal Board : Opencast Executive

HYDROLOGICAL SURVEY
GARNANT SITE

January 1985

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CHAPTER 1

INTRODUCTION

1.1 APPOINTMENT AND TERMS OF REFERENCE

In a letter reference OE/7/CON.31/7 dated 1st October 1984, the National Coal Board, No. 7, South West Region (NCB), invited Sir Alexander Gibb & Partners, to carry out an Hydrological Survey of Garnant Site in accordance with a brief attached to that letter. In addition, the NCB indicated that they required Gibb to act as an expert witness at a Public Inquiry in connection with Garnant Site. A copy of the NCB's letter dated 1st October 1984, together with the attached brief is enclosed as Appendix 'A'.

Gibb indicated their willingness to undertake the work and included in their team, a representative from the Institute of Hydrology, Wallingford, to deal with the hydrological aspects of the survey. On the 24th October 1984, the NCB confirmed the appointment of Gibb to carry out the hydrological survey and, if necessary, to act as an expert witness at a Public Inquiry.

At a meeting with the NCB on 29th October 1984, certain information was handed to Gibb and further details delivered to Gibb's Cardiff Office on 30th October, 1984. A schedule of the information provided by the NCB is included in Appendix 'B'.

1.2 EXTENT OF REPORT

This report considers the hydrological aspects of the proposed opencast coal site at Garnant. In particular, consideration is given to the hydrology and hydrogeology of the site under the following conditions:

(i) in its present state
(ii) during opencast activities
(iii) in its restored state

Of particular relevance are the capacities of three existing culverts to accommodate the water generated by the site. These culverts are referred to in the report as Nant-y-Gath, Nant Maen and Minor Catchment, and their locations are shown in Figure 1.1.

In addition to evaluating whether there is likely to be an increased risk of flooding as a result of the NCB's activities, a description of the present condition of the culverts is given, with recommendations for any necessary repair, refurbishment or replacement works together with budget cost estimates. Recommendations are also presented to attenuate the effect of any possible increased flooding which may occur as a result of any inadequacies in the culverts as they now exist.

For convenience, the report has been divided into the following:

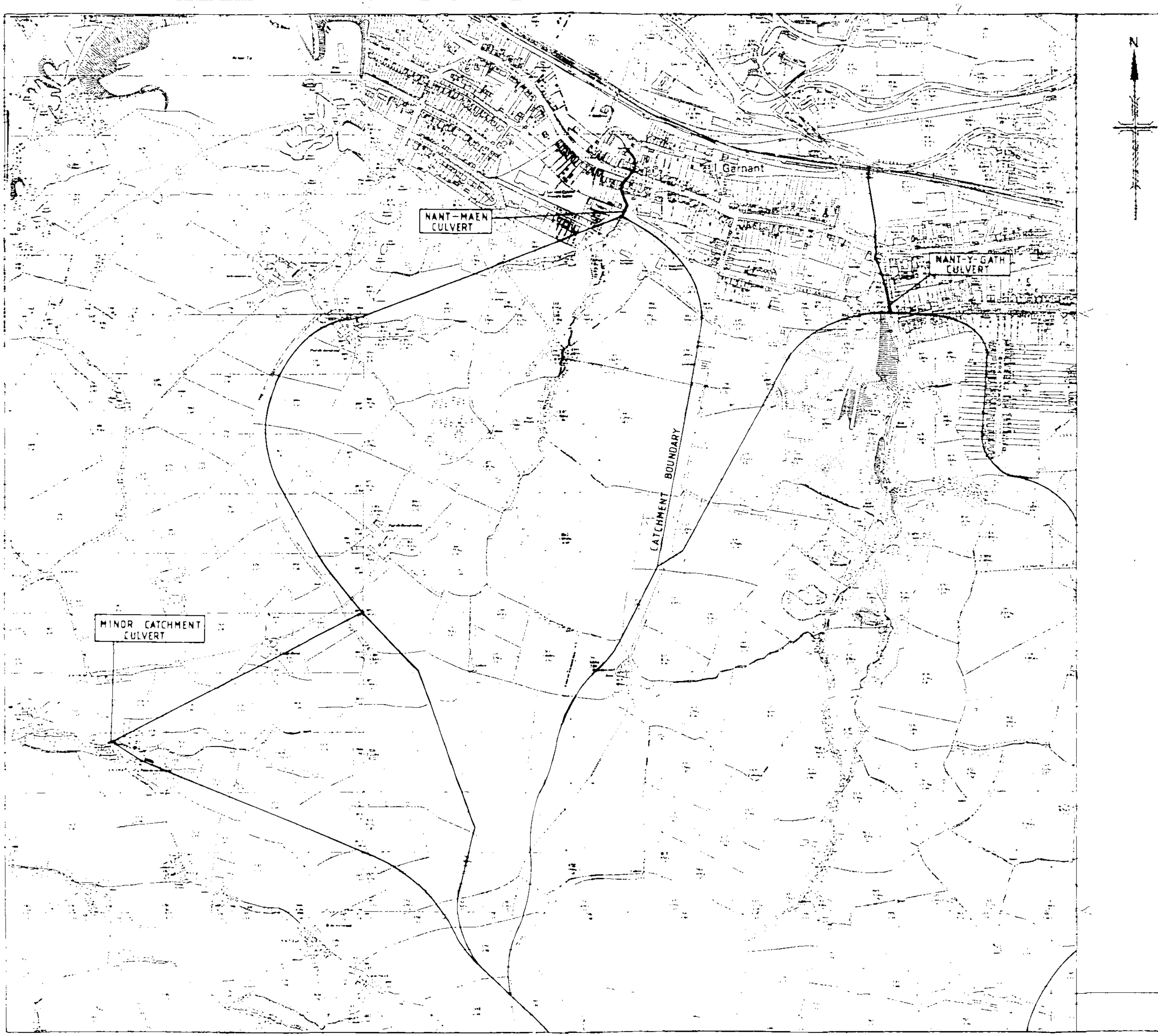
CHAPTER 2 - Hydrology of the Site

CHAPTER 3 - Hydrogeology of the Site

CHAPTER 4 - Existing Culverts

CHAPTER 5 - Summary

A Supplementary Volume accompanies this report and contains calculations and other data in support of statements made, and opinions given.



SCALE
100 50 0 100 200 METRES

NATIONAL COAL BOARD OPENCAST EXECUTIVE
GARNANT SITE
AMMANFORD, DYFED
HYDROLOGICAL SURVEY

TITLE: LOCATION OF CULVERTS

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London Road
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DATE December 1984

FIG. No. 1·1

CHAPTER 2

HYDROLOGY OF SITE

2.1 SCOPE OF CHAPTER

This chapter describes a flood investigation of three catchments affected by the proposed opencast coal site at Garnant, Dyfed. The Nant-y-Gath (1.18 km^2) and Nant Maen (0.44 km^2) catchments drain to major culverts in Garnant. A third catchment (0.16 km^2) drains through a minor culvert towards the Nant Grenig; this will be referred to as the Minor Catchment. (See Figure 2.1).

The principal aim of the investigation was to provide flood estimates to enable the adequacy of the culverts to be checked. A subsidiary aim was to comment on the likely effect of the proposed opencast mining on flood frequency in these streams.

The culvert locations and their respective catchments are shown in Figures 1.1 and 2.1. Comparison with NCB plan G5 ("Likely sequence of operations, Garnant") indicates that most of the Nant Maen catchment, and approximately 30% of the Nant-y-Gath catchment, will be affected either by working or dumping. About two-thirds of the Minor Catchment will be affected by overburden dumping. Figure 2.2 provides an approximate guide to the spatial extent to which the three catchments will be affected.

The flood frequency regime is considered for three conditions: the present (Section 2.2), during working (Section 2.3) and on restoration (Section 2.4). Section 2.5 comments on past flooding in Garnant.

2.2 PRESENT CONDITION

2.2.1 Flood Estimates

Figure 2.3, shows flood frequency relationships derived for the

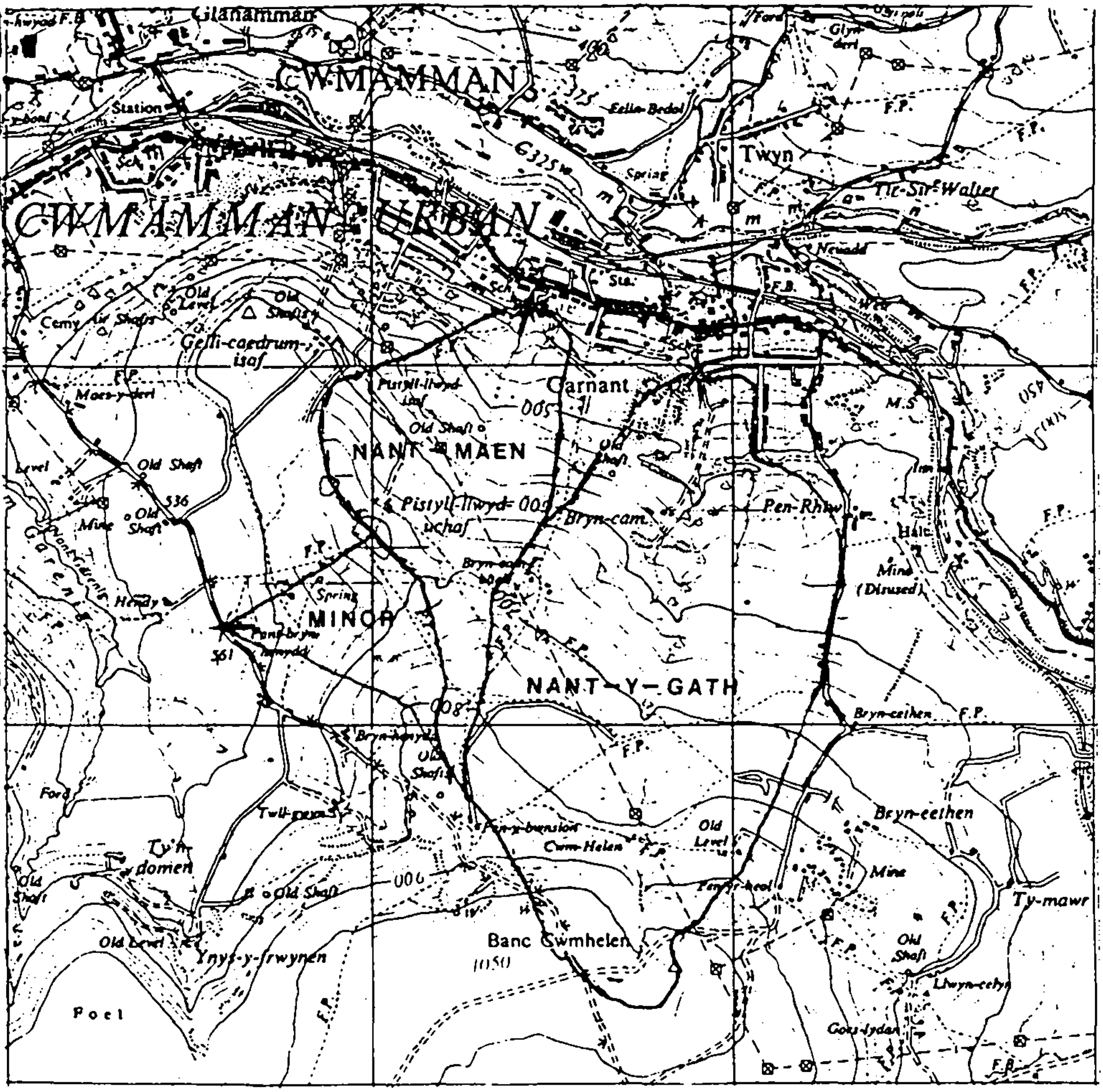


Figure 2.1

Catchments affected by proposed Garnant opencast coal site.

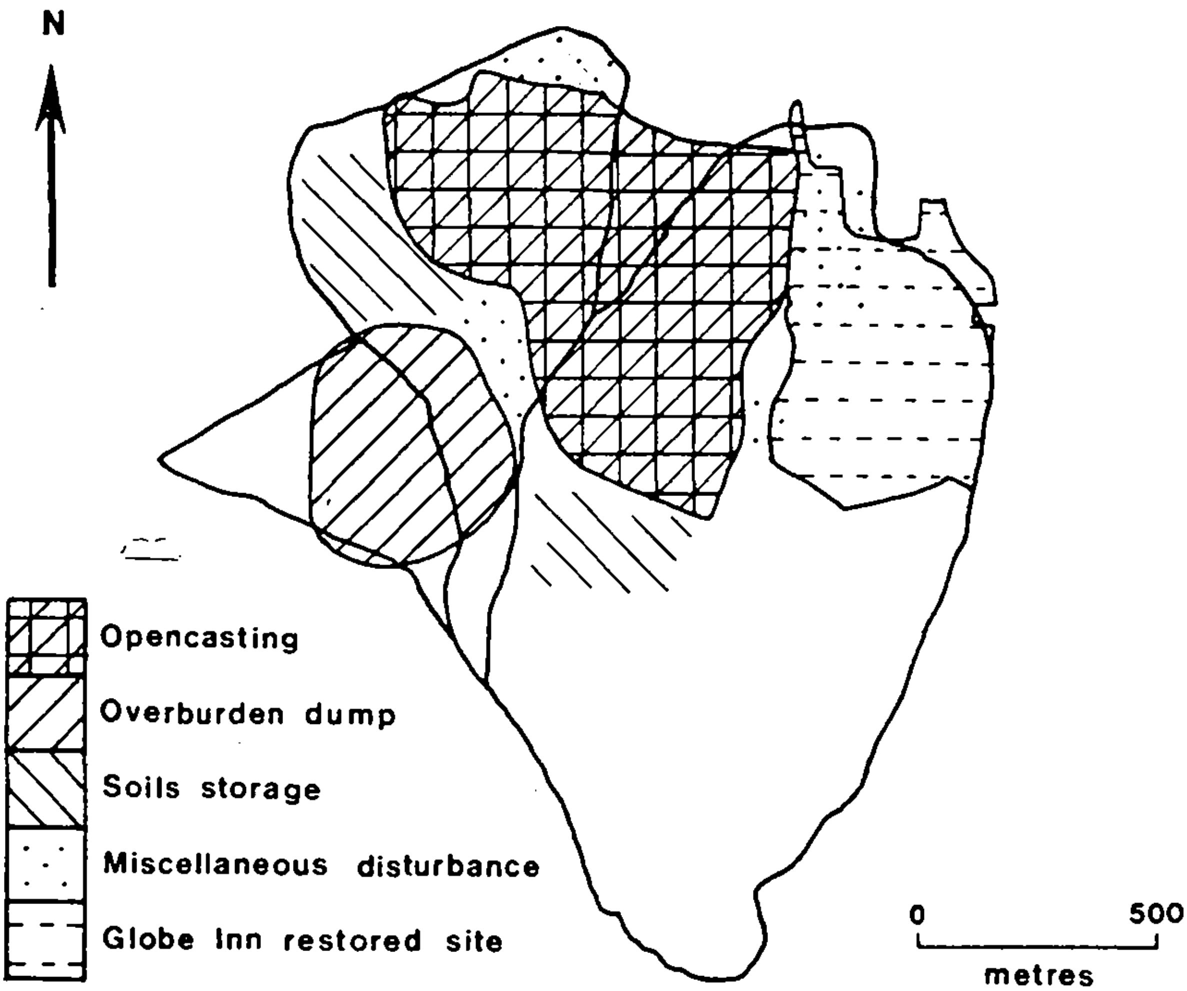


Figure 2.2

Guide to spatial extent to which catchments will be affected by opencast operations.

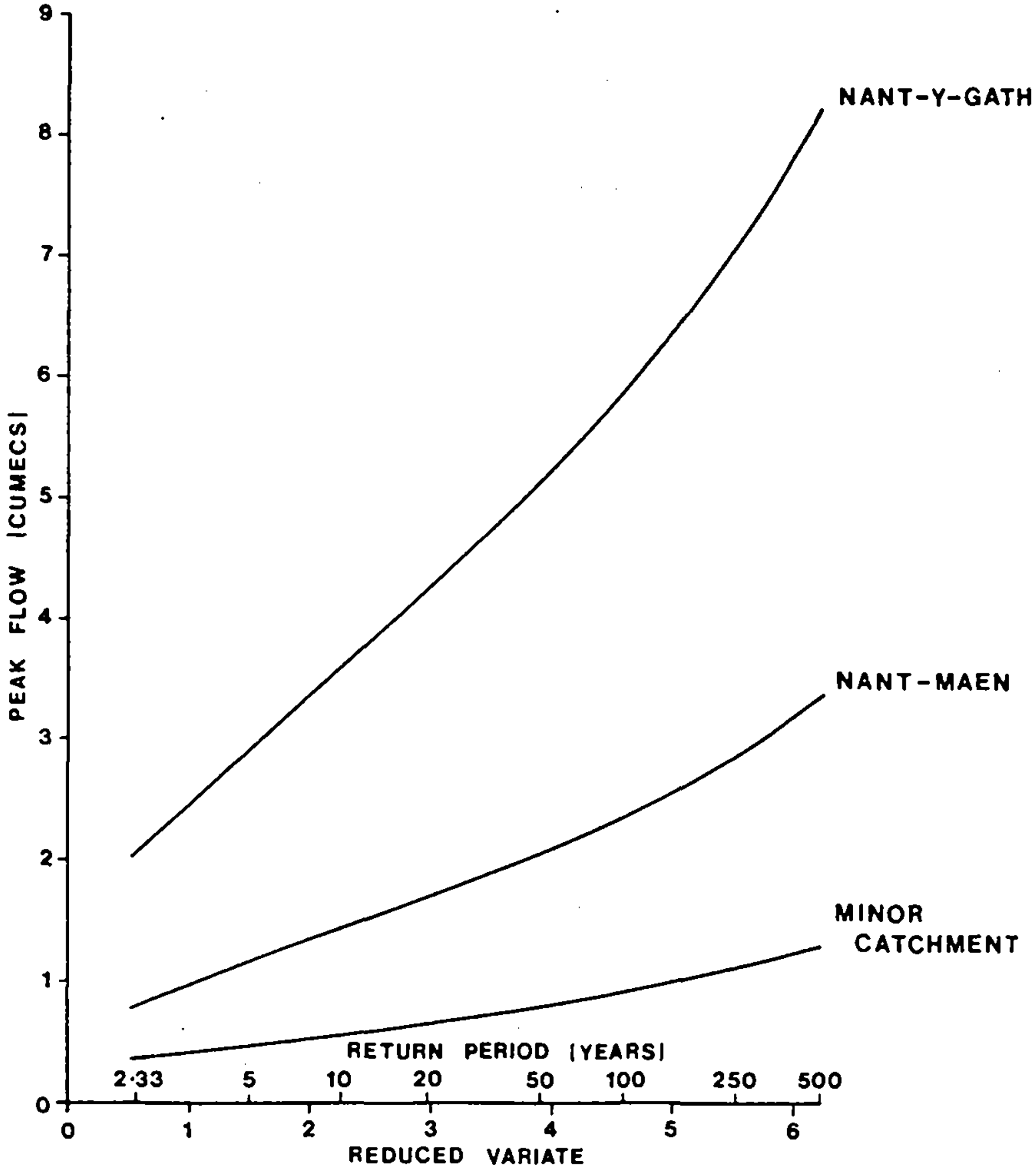


Figure 2.3

Flood frequency curves - present condition present condition. For example, the 100-year return period flood on the Nant-y-Gath is estimated to be 5.7 cumecs. The calculations follow the Flood Studies Report rainfall/runoff method[1] and incorporate the latest revisions thereto[2]. The calculations are included in a Supplementary Volume of Technical Papers.

There are no gauged flow data available for the particular streams under study (or for nearby similar catchments) and therefore, the flood estimation has been made in terms of the physical characteristics of the catchment based on Flood Studies Report. Some characteristics (such as catchment area and mainstream length) are well-defined by maps; others (such as soil properties) require a degree of subjective appraisal. Flood estimates made from catchment characteristics alone are inevitably approximate. To obtain precision it is necessary to gauge flood flows in the particular stream for many years.

Two aspects of the calculations merit further comment; the assessment of standard percentage runoff (SPR) and the omission of an explicit allowance for field drainage and mining activities.

2.2.2 Assessment of Standard Percentage Runoff

Standard percentage runoff (SPR) represents the proportion of rainfall that forms quick response runoff in a typical event. This is defined as a storm depth of up to 40mm. occurring when the catchment is initially saturated (i.e. with no soil moisture deficit). Actual percentage runoff is expected to be lower than SPR if there is an appreciable initial soil moisture deficit but somewhat higher for storm depths greater than 40mm. Thus, whereas percentage runoffs vary from event to event, SPR is taken to be a fixed characteristic of the catchment.

In the absence of gauged flow and rainfall data, SPR is normally determined by the "winter rain acceptance potential" classification, loosely referred to as the "soil index". This is a simple division into five classes; soil type 1 represents highly permeable soils and underlying geology (such as chalk outcrops), soil type 5 represents highly impermeable soils. For a non-urbanised catchment on soil type 5, the expected standard percentage runoff is

53%[3]. However, within the national flood event database maintained at the Institute of Hydrology, there are several catchments on which consistently higher percentage runoffs are observed. An SPR value of 53% is merely the average for catchments on soil type 5 and does not represent an upper limit.

Independent research carried out by the Ministry of Agriculture, Fisheries and Food's Field Drainage Experimental Unit (FDEU) at Garth Graban (near Llantrisant) in South Wales has noted percentage runoffs of 70 to 80% for winter events[4]. The site has somewhat similar soils and underlying geology to Garnant. Whilst the Garth Graban values refer to experiments at plots scale (e.g. 0.1 ha), and it is not proven that such high percentage runoffs persist at small catchment scale (e.g. 100 ha), the results point to the adoption of a higher SPR value than 53%.

Walking over the Garnant catchments on 7th November 1984, it was evident that, despite its steep slope (approx 10%), much of the area is poorly drained. This is less a reflection of land management practice than of the inherent imperviousness of the catchments. The depth of soil to an impermeable (or only slowly permeable) layer appears to be very shallow and there is only limited storage capacity to retain water, mainly in the form of surface ponding in local depressions. That the catchments receive a high average annual rainfall (approx. 1775 mm.) ensures that parts are waterlogged for much of the year.

Based on the above observations and impressions, a standard percentage runoff value of 60% was assessed for all three catchments.

2.2.3 Effect of Previous Mining

Old mine workings under the catchment are likely to have some influence on the groundwater behaviour of the catchment. However, in the context of the very rapid response to heavy rainfall which gives rise to flooding on such streams, the contribution of groundwater is thought to be inconsequential.

Previous opencast mining has been carried out in the Nant Maen and Nant-y-Gath catchments, the most notable being the Globe Inn opencast coal site in the north-east sector of the Nant-y-Gath catchment. Some of the long-term effects of opencasting (referred to in Section 2.4) may thus apply in the present condition, although they are diluted by the relatively small proportions of the catchments affected. An allowance has been made in the Nant-y-Gath flood estimates for a slightly higher standard percentage runoff on account of the Globe Inn site.

2.2.4 Effect of Field Drainage

It was noted on site inspection that fairly extensive field drainage works have been carried out in the upper middle part of the Nant-y-Gath catchment. This land is not in NCB ownership and it is understood that the drainage - which consists of a herringbone network of open ditches - has been carried out to intercept spring water and permit a modest "improvement" in land use. Coupled with drainage ditches installed in the north-east sector of the catchment (as part of restoration of the Globe Inn site) these field drainage works will no doubt, have some influence on the streamflow response to heavy rainfall.

While there has been extensive research by FDEU and others, into the effects of drainage at field and plot scale, there remain uncertainty and controversy about effects at catchment scale [5,6]. Disregarding economic factors, key influences on the effect of field drainage are the soil type (and general ground condition), the climate and the type of drainage employed.

For example, in fenland areas the improved groundwater/soil water control brought about by underdrainage can lead to improved flood control. Even on clayey upland catchments in mid-Wales, research has shown that field drainage can provide a storage buffer which reduces the volume of quick response to rainfall[7]. However, the increase in drainage density and hydraulic efficiency, that open ditching (moorland gripping) provides, generally leads to a quicker response to rainfall. This in turn means that the catchment becomes sensitive to shorter duration storms, with a correspondingly higher design intensity. Unless secondary treatment (subsoiling, moling) is really effective in achieving better soil water control, the net effect of ditching may be to increase flood frequency downstream.

Such an effect has been demonstrated in a detailed investigation of the response of a small peaty upland catchment[8].

With regard to Garnant, the key aspect is whether the field drainage has achieved significant improvements in soil water control (signalling an upgrade in agricultural use) as opposed to marginal improvements which have merely extended the season over which the land is productive. It appears that many of the drainage schemes that have been carried out in the locality (viz. Betws parish) have been directed to intercept and drain spring waters, which characteristically emanate where relatively permeable bands outcrop above impermeable strata (as for example in the upper middle sector of the Nant-y-Gath catchment).

On balance, given the steep gradient and poor natural soil conditions of the Garnant catchments, it is considered that the field drainage will have increased the flood frequency downstream, the increased channelling outweighing any moderation by improved soil water control. However, given the present limited understanding, it is impracticable to simulate the effect of field drainage with a catchment model of the kind presently available for flood estimation.

The role of field drainage in land restoration after opencasting is considered in Section 2.4.1.

2.3 DURING WORKING

It is possible to comment on the interim effect of working of the proposed Garnant opencast coal site only in very broad terms. The effect on floods will depend on the detailed method of working adopted (for example, on the nature and sizing of diversion channels) and on the chance that an extreme storm event occurs during the period of working.

The risk, r, of one or more events greater than the T-year event occurring during an N year period is given by:

$$r = 1 - [1 - \frac{1}{T}]^N$$

Thus, for example, the risk of a 100-year event occurring during a six-year period is:

$$r = 1 - [1 - \frac{1}{100}]^6 = 1 - [0.99]^6 = 0.059$$

This represents a chance of 1 in 17. Table 2.1, provides some other examples.

TABLE 2.1

RISK OF ONE OR MORE DESIGN EXCEEDANCES OCCURRING IN A GIVEN PERIOD

Design Return Period T years	Period of Concern N years			
	4	6	8	10
10	.34	.47	.57	.65
20	.19	.26	.34	.40
50	.08	.11	.15	.18
100	.04	.06	.08	.10
250	.016	.024	.032	.039
500	.008	.012	.016	.020

Because the strata to be worked dip into the hillside fairly steeply, the working is likely to attenuate flooding to some extent. Rain falling directly on the hole will not, of course, runoff in the short-term. In an extreme event, runoff may exceed the capacity of the diversion channel and enter the hole. The return period of flood at which this might occur would depend upon the detailed design adopted for the diversion channels, but would advisably be at least 20 years. Clearly, any flood runoff entering the hole would reduce the flood effect passed down to the culvert.

However, there are other factors of the working that may have an adverse affect on flooding. Firstly, stripping of soils to expose the rockhead and the concomitant compaction is likely to accelerate and increase runoff (an analogy with a paved area may not be far-fetched). Secondly, the movement and heaping of soils and overburden, the extraction and transportation of coal etc, will lead to an increased sediment loading. Although not a hydrological factor as such, the transport of sediment and incidental debris - in the event of an extreme storm say, one of return period of 25 years or greater, occurring during the period of working - is clearly liable to aggravate any flooding that may occur at the culverts. (See Section 2.5.3). Finally, the opencast operation may modify catchment boundaries. For example, if the site is worked from East to West (as envisaged in Plan G5) there may come a stage when the area draining to the Nant Maen culvert is temporarily increased.

In summary, the flood frequency downstream will be affected by the detailed methods of working adopted. At times the risk may be decreased by the storage provided in the hole. However, once reinstatement commences the risk is likely to increase.

2.4 ON RESTORATION

2.4.1 Long-term Effects of Opencasting

Land restoration is a gradual process and it may be several years before the catchments establish a new pattern of response.

Reasearch on opencast sites at Hirwaun Common North[9], Radar[10], Cinderford[11] and elsewhere indicates that, on restoration, the response of catchments to rainfall is both quicker and increased in volume. These experiments have been carried out mainly at field scale (e.g. 1 ha.) rather than small catchment scale (e.g. 1 km^2). However, the various physical explanations put forward for the effects appear to be valid at any scale.

The passage of earth scrapers and other machinery over the area presents a very significant (and measurable) compaction. This leads to a reduction in soil pore space and hence in the capacity to absorb infiltration. Thus a greater proportion of rainfall becomes quick response runoff, travelling over or just beneath the land surface. A second effect, in addition to compaction, is that the removal and replacement of topsoils disrupt their structure. Pronounced pores and cracks in the soil - whether they be induced by plants, animals or climate - are likely to be severed or destroyed. This further reduces the capacity for infiltration of storm rainfall. Thirdly the inevitable practice of replacing overburden and soils in layers leads to pronounced lamination, which encourages lateral transmission of water as opposed to vertical penetration. Fourthly, the restored landform is likely to be rather more uniform than before; fewer local depressions mean that the attenuating effect of surface ponding on flood runoff will be reduced.

There is, of course, the question of the extent to which field drainage can counteract the agricultural degradation of the land that the above effects otherwise bring about. As noted in Section 2.2.4, open ditching generally accelerates runoff. Work by FDEU has shown the importance of secondary treatment (e.g. moling or subsoiling) if land is to be restored to its full agricultural potential. However, if effective secondary treatment proves impractical or, in the long term, economically unsupportable, then the open ditching in itself will undoubtedly increase flood frequency downstream. Even if secondary treatment proves possible, the overall effect of the field drainage may be to increase flood frequency because of the dominance of the acceleration of response (brought about by ditching) over the increased soil water retention (brought about by secondary treatment).

With regard to Garnant, the proposed contract stipulates specific rooting and surface treatments to the top 1.2 metres of restored ground. These are designed to expose and remove large stones, to break down large clods and - through tillage - to counteract the compaction and lamination effects referred to above.

It is perhaps relevant to add that the extent to which open ditching accelerates the response will be influenced by the detailed design adopted. Clearly if drainage were carried out using long runs across the groundslope, the effect would be proportionately less than for a design which set out to minimize construction costs. The provision of local storage ponds, drain by drain, would also assist in attenuating the flows experienced downstream.

2.4.2 Impact on Culvert Design

Taking the above considerations into account, it is reasonable to assess that the effect of opencast mining at Garnant is to increase the standard percentage runoff (SPR) from 60% to 70% for all areas affected by the working (see Figure 2.2 and Table 2.2). This adjustment reflects the known reduction in infiltration brought about by compaction, disruption and lamination of soils and subsoils. However, the numerical value of this increase is a subjective estimate and is only indirectly supported by data.

For reasons stated earlier, it has not been possible to make an explicit allowance for the effect of existing and proposed field drainage. (While such drainage may possibly reduce percentage runoffs it is believed that this effect will be outweighed by a quicker response.) Thus the only adjustments made in calculating the "on restoration" flood estimates are the SPR increases detailed in Table 2.2.

The "on restoration" flood estimates are illustrated in Figure 2.4. Comparison with Figure 2.3, shows that the Nant Maen catchment will experience the largest percentage increase. This is because virtually the whole of the catchment will be disturbed in some shape or form.

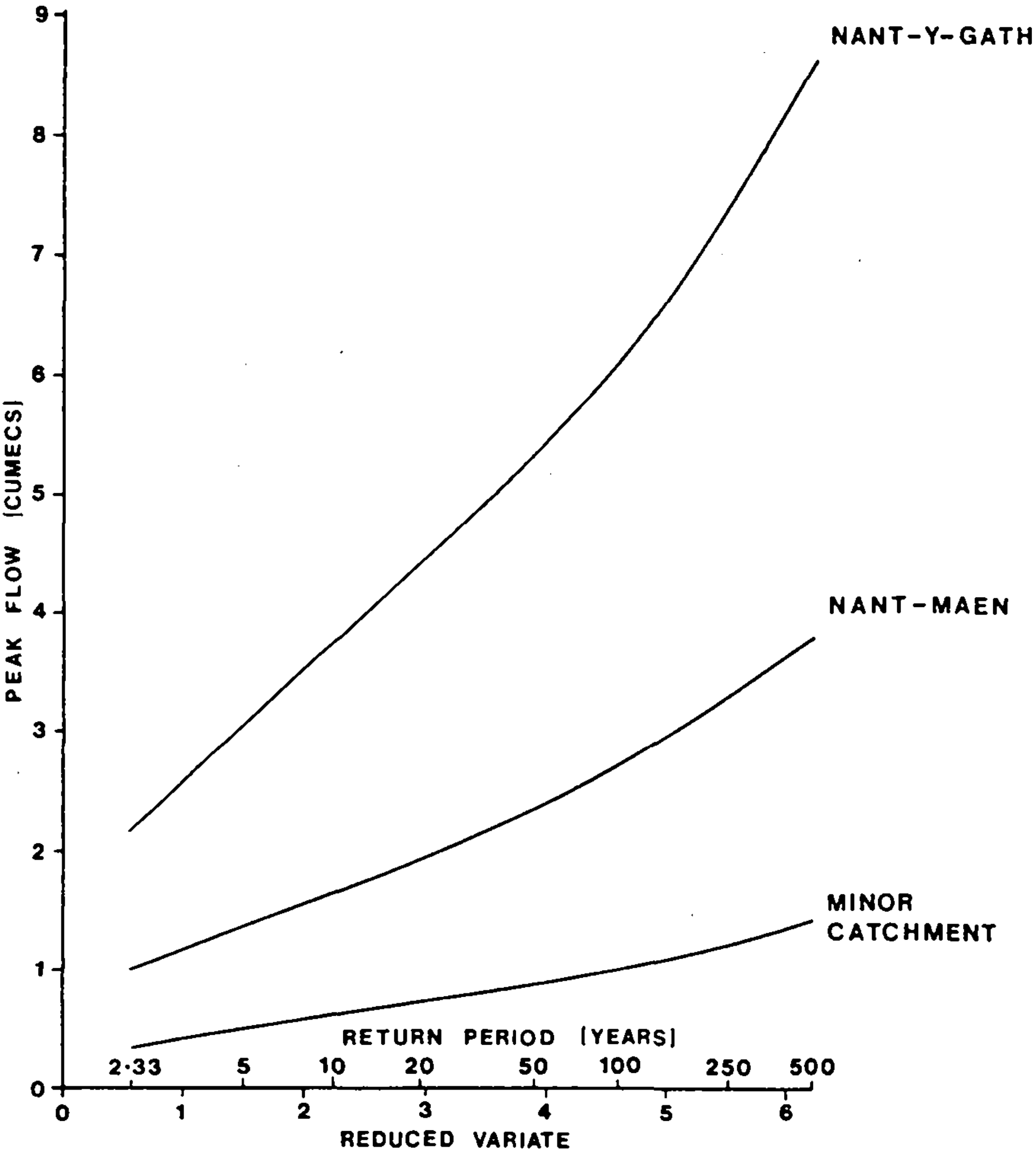


Figure 2.4

Flood frequency curves - on restoration.

TABLE 2.2

ALLOWANCE IN FLOOD ESTIMATES
FOR EFFECT OF OPENCASTING

Catchment	Proportion Affected by Opencasting		Assessed SPR		Typical % Change in Peak Flow Estimates
	Now	Future	Now	Future	
Nant-y-Gath	0.2	0.5	62%	65%	+ 4½%
Nant Maen	0.0	1.0	60%	70%	+ 16%
Minor	0.0	0.67	60%	66.7%	+ 10%

Figure 2.4 provides flood frequency relationships against which the adequacy of the culverts can be checked. The implication of the increased flood estimates is, of course, that on restoration the risk of flooding will be increased and this aspect is considered in detail in Chapter 4.

2.4.3 Remedial Measures

Several reactions are possible to the increased flood risk perceived above. The options include:

- accepting the increased risk
- increasing the capacities of the culverts
- improving maintenance of the culverts and watercourses
- redistributing catchment areas (e.g. divert a proportion of the Nant Maen catchment to the Nant-y-Gath.)
- providing storage within the catchments to attenuate flood peaks

2.5 HISTORICAL FLOODING

2.5.1 Sources of Information

Newspaper searches, and discussions with local authorities and local residents, were undertaken to ascertain the history of flooding from the Nant Maen and Nant-y-Gath. The newspaper searches were guided by a computerised scan of heavy rainfall events for the period 1961 to 1980.

From the above, it appears that there have been few incidents of note since the Nant-y-Gath culvert was extended and improved in 1971. However, the above sources of information did point to a noteworthy incident on the Nant-y-Gath in October 1966. It appears that serious flooding occurred on 19th October 1966, due to surcharge and/or blockage of the Nant-y-Gath culvert (which, prior to the improvement works, commenced approximately 100 m. further downstream).

2.5.2 Rainfall Information for 19th October 1966 Event

Daily and monthly weather reports issued by the Meteorological Office were studied, together with daily rainfall data for 60 gauges in central South Wales. In addition, data from five recording raingauges (each within 30 km. of Garnant) were examined to establish the likely temporal profile of rainfall on 19th October 1966.

X There was evidence in the above information that a storm cell passed over Garnant from East to West, depositing about 20 mm. of rainfall in one or two hours. This was in addition to a background rainfall of about 30 mm. on that day, falling in several isolated bursts. The flood calculations indicate that the Nant-y-Gath is sensitive to heavy rainfalls lasting several hours. (The duration of design storm was calculated to be 3.75 hr). From the available information concerning rainfall on 19th October 1966, it appears that perhaps 35 mm. fell in a 4 hour period. Comparison with the calculated design rainfalls, indicates a return period for the storm of no more than about 8 years. While the possibility cannot be ruled out that something exceptional happened as the storm cell passed over Garnant, no evidence has been found to support this proposition.

2.5.3 Discussion

Given that the storm event on 19th October 1966, does not appear to have been very exceptional, it is somewhat surprising that it led to serious flooding on the Nant-y-Gath. However, newspaper reports suggest that the flooding was aggravated by sediment/debris from the Globe Inn opencast coal site which was then approaching restoration. One report speaks of 12 incidents in a five-week period prior to the 19th October 1966 event.[12]

An examination of the NCB's files of correspondence at the time indicates that the flooding was caused by blockages in the culverts. It is not entirely clear from the correspondence what caused the blockages since this dealt with the apportionment of responsibility and liability for their consequences. It has not been possible to determine whether or not the blockages were due to lack of maintenance of the culvert through the build up of debris or to the inadequate capacity of the culvert. The fact that shortly after the flooding in October 1966, steps were taken to improve the culvert and provide silt and debris traps suggests a combination of the above. Such works have altered the circumstances which caused the flooding prior to 19th October 1966 and since the improvement works,there have been no reported incidences of flooding on the Nant-y-Gath.

The provision of settling lagoons is an important feature of the NCB proposals. These are designed to ensure that the discharge consent conditions specified by the Welsh Water Authority will be met. However, the extent to which the lagoons will succeed in trapping silt and sediment from the distrubed areas - in the event of an extreme storm occurring during the period of working - will depend on the detailed design adopted for the lagoons and diversion channels.

2.6 PRINCIPAL CONCLUSIONS

(i) Flood estimates for the Nant-y-Gath, Nant Maen and the Minor Catchments are illustrated in Figure 2.3. The detailed calculations are given in a Supplementary Volume of Technical Papers. These estimates apply to the present land condition.

(ii) During working of the proposed Garnant opencast coal site it is possible that the flood risk on the Nant Maen or Nant-y-Gath may be reduced by storage in the hole. However, factors such as increased runoff due to ground compaction and increased sediment loading may aggravate flooding downstream of the site if a severe storm occurs during the operation.

(iii) There are several physical factors that point to an increased flood potential following working and restoration of the site. Figure 2.4, summarizes flood estimates made for the three streams for the restored condition. Comparison of Figures 2.3 and 2.4, shows that the opencast operation is expected to increase the frequency of flooding in the long-term.

(iv) There are no gauged flow data available for the particular streams under study (or for nearly similar catchments), and therefore the flood estimation has been made in terms of the physical characteristics of the catchment based on the Flood Studies Report. Some characteristics (such as catchment area and mainstream length) are well-defined by maps; others, (such as soil properties) require a degree of subjective appraisal. Flood estimates made from catchment characteristics alone are inevitably approximate. To obtain precision it is necessary to gauge flood flows in the particular stream for many years.

CHAPTER 3

HYDROGEOLOGY OF SITE

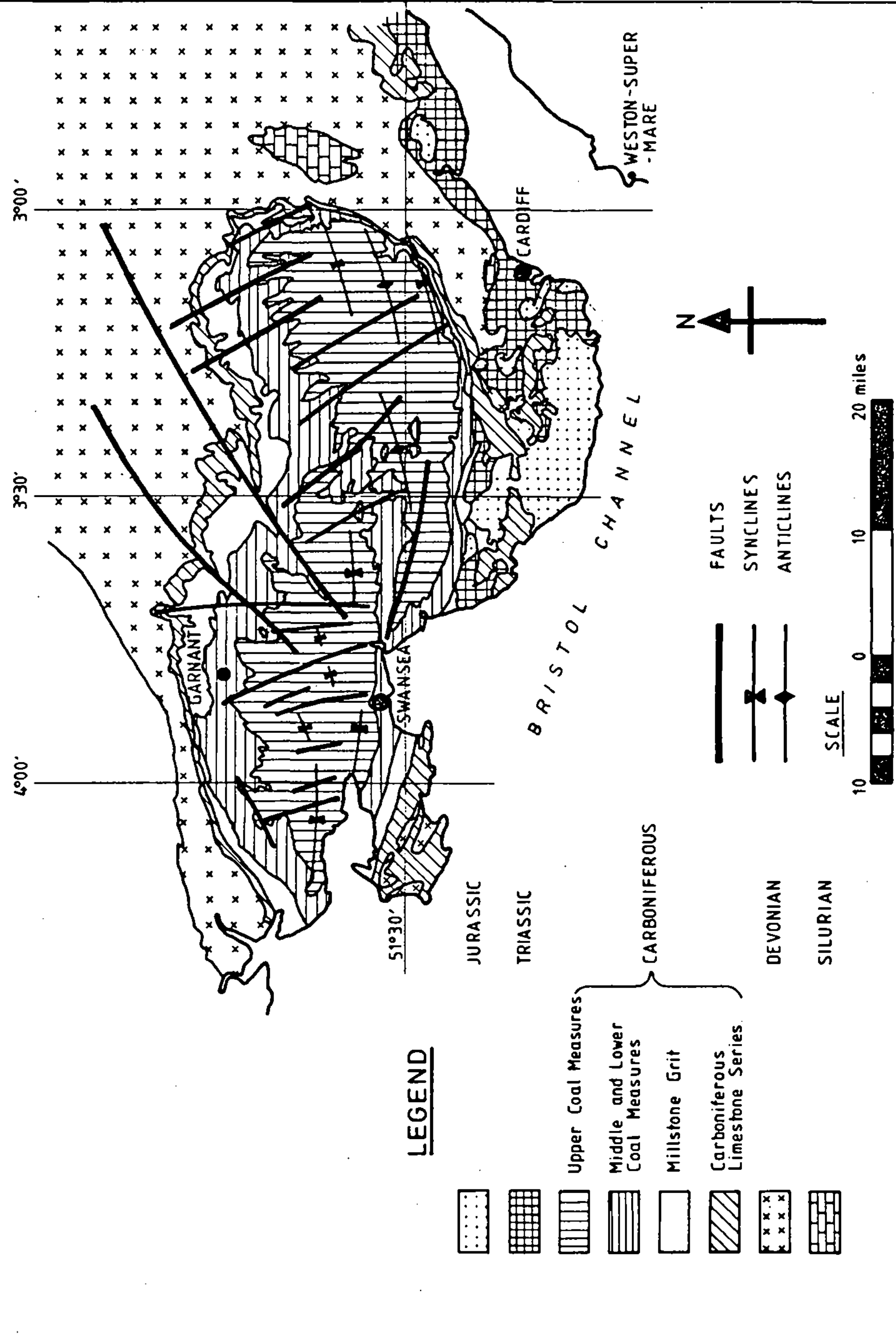
3.1 SCOPE OF CHAPTER

This Chapter describes the geological and hydrogeological conditions at the proposed Garnant opencast site and provides an estimate of the amount of water which will require to be pumped from the excavations during the period of working.

3.2 REGIONAL GEOLOGY

The proposed Garnant opencast site is located in the North-Western part of the South Wales Coalfield. The coalfield comprises a sequence of Coal Measure rocks of Carboniferous age which have been folded into a broad open East-West trending basin; see Figure 3.1. The area has also been affected by major North-West to South-East trending high angle faulting. The geological succession is summarized as follows:

RECENT	
Glacial	Boulder clays
CARBONIFEROUS	
Upper Coal Measures	Predominantly sandstones and grits with coal
Middle Coal Measures	Mudstones, siltstones, seatearths and coal with occasional sandstones
Lower Coal Measures	Mudstones, siltstones, seatearths and coal with occasional sandstones
Millstone Grit Series	Coarse sandstones
Carboniferous Limestone Series	
DEVONIAN	
Old Red Sandstone	Sandstones and siltstones



GEOLOGICAL MAP OF SOUTH WALES

Figure 3.1

3.3 GEOLOGY OF PROJECT AREA

3.3.1 General

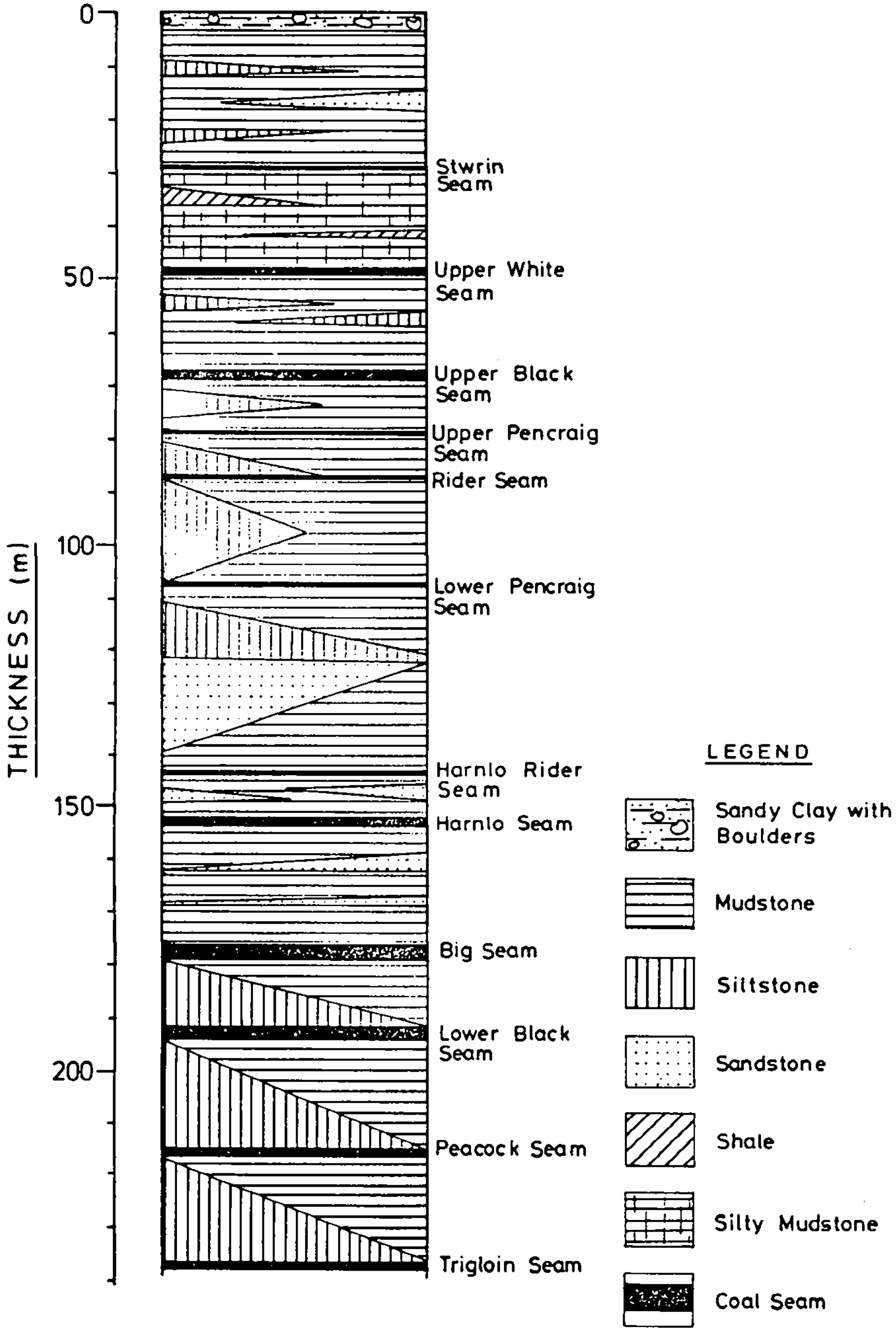
The Garnant site area is underlain by rocks of the Middle Coal Measures and the upper parts of the Lower Coal Measures. The site is situated on the northern limb of an East-West trending syncline, the rocks underlying the site dipping gently at between 11° and 15° towards the South to South-South-West. The major structural feature of the site is the North-North-West to South-South-East trending Ty Llwyd Fault, which is a normal fault crossing the centre of the site and downthrowing approximately 100 m. to the West.

3.3.2 Geological Succession

The geological succession underlying the site has been investigated by means of a comprehensive programme of drilling which has included cored strata boreholes and open holes for which gamma logs are available. Boreholes have been drilled over the whole of the site on an approximately 50-60 m. grid. It has therefore been possible to provide a fairly accurate picture of the subsurface conditions, particularly the variation in the geological succession across the site and the presence of faulting and washouts in the coal bands.

The site is effectively cut in half by the Ty Llwyd Fault. To the East of the fault the full succession illustrated in Figure 3.2 occurs in the boreholes, however to the West of the fault only the upper part of the succession occurs. A total of twelve coal seams have been located at the site. These vary considerably in thickness from 0.20 m. to 2.75 m. Of these only eight seams have been assessed as having any commercial value.

Within many of the seams and in particular the Big Seam, Peacock Seam and Trigloin Seam, numerous areas of old workings have been encountered.



GEOLOGICAL SUCCESSION AT PROPOSED GARNANT OPENCAST SITE

Figure 3.2

In general, the rocks between the coal seams are dominantly argillaceous comprising mudstones and silty mudstones with poor coals and seatearths associated with the thicker coal bands. Sandstones and sandy siltstones with sandstone bands occur, but generally form less than 5% - 10% of the total sequence. The sandstones are very variable in thickness and often impersistent. The main areas in which sandstones occur are described below.

A thick band of sandstone and siltstone up to 18 m. thick has been encountered overlying the Harnlo Rider Seam, but this band appears to be impersistent and is very variable in thickness. Two discontinuous (2 to 3 m. thick) sandstone bands occur between the Harnlo Seam and Big Seam. These appear to be impersistent and cannot be traced over the whole site. In the western part of the site up to 25 m. of sandstones and siltstones are encountered between the Big and Trigloin Seams, but again these beds are impersistent and do not occur to the East of the site.

3.3.3 Superficial Deposits

The thickness of the superficial deposits in the Garnant area is very variable. Much of the site with the exception of the stream beds is mantled by thin (2 to 4m.) glacial deposits which comprise boulder clays and sandy clays with boulders and gravel. In the central northern part of the site an area of made ground is associated with old open cast excavations in the Lower Black and Big Seams. Reworked spoil in this area is up to 15 m. thick. To the North-East of the site is a small area of colliery spoil associated with the mining operations at the Old Raven and Dynevor Colliery. Site inspection indicated that reworked spoil covers 20% to 30% of the site area. Peat occurs locally.

3.4 GEOLOGICAL STRUCTURE

3.4.1 Bedding

The site is situated on the Northern limb of a major East-

West trending syncline. Dips of the strata are generally gentle dipping at between 11° and 15° towards the South-South-West; the steeper dips generally being recorded in the Southern part of the site. As a result of local small scale folding and faulting, the dip of the strata is locally variable, especially in the vicinity of the Ty Llwyd Fault.

3.4.2 Faults

A major fault, the Ty Llwyd Fault, crosses the middle of the site in a North-North-West to South-South-East direction. To the East of the fault the succession illustrated in Figure 3.2 has been encountered, however to the West, the Upper Black seam is downthrown to the level of the Big Seam; a throw of approximately 100 m.

As the fault has not been intersected by any inclined boreholes, it is not possible to fully describe its character, however, it is most probably a near vertical normal fault comprising several fault planes, the adjacent strata being highly fractured and distorted. Other minor faults may occur through the succession but these have not been encountered in the drilling.

Interpretation of the borehole records suggest that numerous small scale overthrusts occur in many of the coal seams. These may be the result of the regional folding as the upper beds slide in a Northerly direction relative to the underlying beds. Such overthrusts are generally very localised and displacements are in the order of 4 - 5 m.

A zone of faulting was encountered in borehole 671 at 41.40 m. depth which is described as comprising dense and indurated fault breccia.

3.4.3 Jointing

Joints occur as distinct breaks produced by the brittle fracture of the rock mass. The spacing of the joints in surface outcrop has been recorded during the course of site visits as described below.

The joints are steeply dipping at between 75° and 90°. Within the mudstones, two joint directions defining diamond shape wedges 10 to 100 mm. across are apparent. Within the sandstones and coarse siltstones, the joints occur as well developed persistent features, the spacing of the joints is variable being closely to moderately widely spaced from 100 mm. to 300 mm. The joint surfaces are generally rough planar and tight. Bedding places are more closely spaced from 50 to 100 mm. but again appear to be tight.

Rock discontinuity information is occasionally recorded on borehole logs as a measurement of joint dip and a description of joint surfaces. Measurements of RQD are available on all the logs but systematic recording of Core Recovery, RQD and fracture index is only given for boreholes 1050 (R), 1045 (g) and 1040.

Inspection of all the borehole logs indicates that all the rocks are well joined, RQD values are generally low, the majority of the values being between 0% and 30% with occasional values of up to 90%. A similar range of values is recorded for all rock types. Measurements of fracture spacing from the boreholes give a range of values from 10 mm. to 150 mm., however, the majority of measurements lie in the range of 10 mm. to 50 mm. Measurements of the angle of dip of joints as encountered in the boreholes indicate that these are variable from 45° to the near vertical. Many joints display weathering and slickensides. Measurement of the dip direction or openness of joints was not possible during the investigations.

The widespread presence of quartz and mineralised infillings to the joints has not been noted although the occasional presence of sericite is reported.

Additional logging of the cores to obtain further information on the degree of jointing has not been carried out as considerable deterioration has occurred since drilling, the result of weathering and repeated handling of the cores.

3.5 GENERAL HYDROGEOLOGY

The majority of the strata which comprise the Lower and Middle Coal Measures are argillaceous mudstones with bands of coal and seatearth. Occasional discontinuous bands of sandstone and siltstones with sandstones occur across the site forming approximately 5% of the sequence.

The primary porosity and permeability of the strata is likely to be very low due to the high argillaceous content of the mudstones and siltstones, and the indurated nature of the sandstones which often have a clay matrix. Permeability measurements carried out on samples of Pennant Sandstone (which are often coarse grits) from the Upper Coal Measures[13] gave values of 1 to 2×10^{-8} cm/sec. The primary porosity and permeability of the mudstones, siltstones and probably the sandstones of the Garnant site, will be somewhat lower than this.

The permeability of the rock mass is controlled by the presence of discontinuities which give the rock a secondary porosity and permeability. Joints form when the rock mass deforms in a brittle manner, the sandstones may therefore contain distinct open discontinuities. Unlike the sandstones, the mudstones will not readily deform in the same brittle manner and joints will be indistinct and impersistent. Where joints and discontinuities do occur these will frequently be infilled with clay derived from degradation of the mudstones. The presence of sericite derived from the alteration of the clay has been noted on a number of joint surfaces.

Within the South Wales area, argillaceous rocks are therefore essentially impermeable forming aquicludes while groundwater movement may be possible within the sandstones.

Direct measurements of bulk permeability directly related to the rocks of Garnant area, have not been located and therefore the assessment of rock mass permeability on geological and geotechnical evaluation has been quantified on the basis of published formulae relating permeability to joint spacing and opening. Where the rock is cut by parallel fissures uniformly spaced at a distance of 'd' apart with a fissure face separation of 'b' the bulk permeability is given by the following formula.[14]

$$K = \frac{b^3}{12d} \times \frac{\gamma_w}{\mu} \times F$$

where K = mass permeability

b = joint spacing

d = spacing of joint

γ_w = unit weight of water

μ = dynamic visocity of water

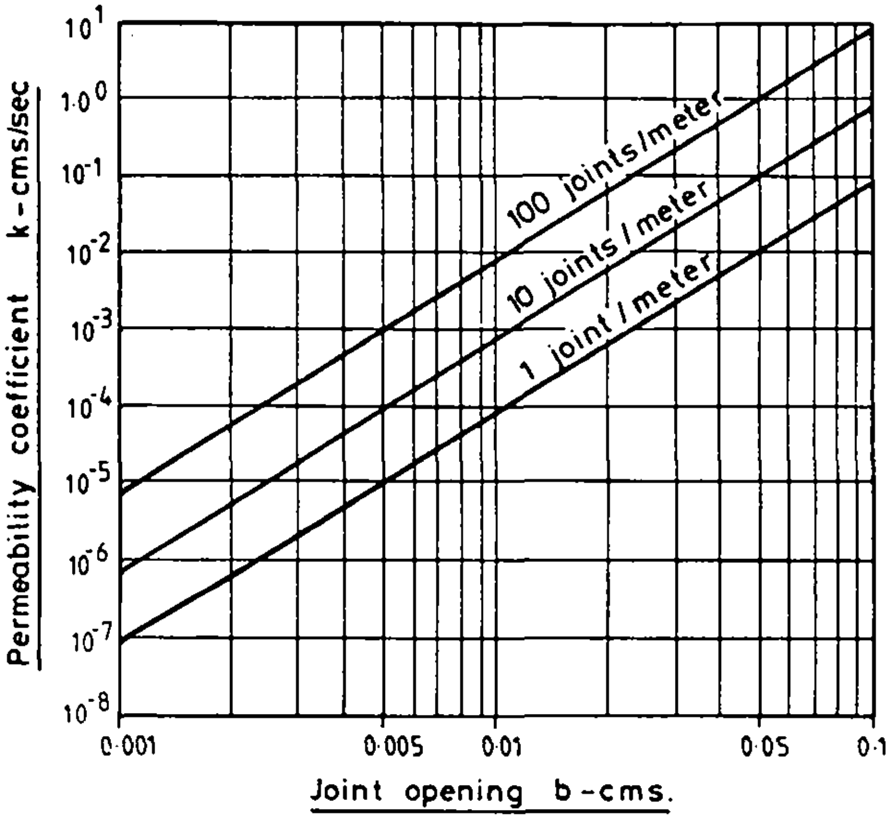
F = joint infilling and roughness modification factor (Has value $\leqslant 1$)

The above equation assumes that the joint surfaces are smooth and planar and that flow is laminar. If the joint surfaces are rough or infilled, modifications have to be made to the formula, the effect of these modifications is to reduce the value of 'k' obtained. These modifications were not introduced in order to ensure that groundwater flows at Garnant are not underestimated. The permeability coefficient on the intact rock is ignored as being insignificant in comparison to the permeability of the open joints. Use of the above equation in argillaceous rocks probably overestimates the value of the in situ permeability obtained. The equivalent permeability 'k' of a parallel array of cracks with different openings is plotted in Figure 3.3 [15]. This plot shows that the permeability of the rock mass is very sensitive to the degree of opening of the discontinuities. Since this opening will change with stress, the permeability of the rock mass is therefore influenced by changes in stress. Such changes may be based on faulting, glaciation or mining activity.

3.6 STRESS INDUCING INFLUENCES ON COAL MEASURES HYDROGEOLOGY

3.6.1 Faulting and Tectonic Activity

Within the geological past the rocks of the Lower and Middle Coal Measures have been subjected to folding and faulting. The effect of folding has been to produce sets of orthogonal joints throughout the rock mass, the intensity of which is greatest at or close to, the main flexures.



The chart above is based on the following equation :-

$$K = \frac{b^3}{12d} \frac{\gamma w}{\mu} F$$

where :- K = Mass permeability

b = Joint opening

d = Spacing of joints

γw = Unit weight of water

μ = Dynamic viscosity of water

F = Joint infilling and roughness modification factor (Has value ≤ 1)

(After Hoek and Bray 1973)

INFLUENCE OF JOINT SPACING AND OPENING ON PERMEABILITY

Figure 3.3

The effects of faulting are more localised and may be much more intense resulting in considerable fragmentation of the rocks, with the formation of a clay gouge and possible secondary mineralisation. The permeability of a fault zone is strongly dependent on whether secondary infilling and mineralisation has occurred and on the lithology of the surrounding rocks. Faults in argillaceous rocks are frequently marked by zones of reduced permeability filled with remoulded clay while coarse grained brittle rocks may produce open and highly permeable fractures in response to fault movement.

3.6.2 Glaciation

During Quaternary times the whole of South Wales was affected by glaciation. Movement of the ice as glaciers resulted in the over deepening of the valley profiles and formation of typically 'U' shaped valleys. The subsequent melting of the ice resulted in stress relief and in rapid exposure of the previously supported oversteep valley sides to normal erosion processes. Where geological conditions are appropriate this stress relief may result in valley side cambering and fissuring of the hillsides and in particular the hilltops dividing the valleys. The geometry of such cambering fissures is likely to be controlled by the trends of high angle discontinuities within the rock mass and effects are most marked where such discontinuities are close to parallel to valley sides.[16] In many cases, stress relief will probably be taken up as a slight opening of many joints rather than all the movement occurring in one place. The overall effect being to increase the rock mass permeability especially in a direction parallel to the valley.

3.6.3 Mining

Extensive mining activity has occurred over a long period of time throughout the South Wales Coalfield. As a result of considerable research, the effects of extracting an underground coal seam by modern longwall methods is well understood. Surface subsidence resulting from the total extraction of a seam is in the form of a wave moving parallel to and at the same rate as the line of the face. This subsidence is accompanied by horizontal strains in the ground surface, which are tensile at the crest of the wave which occurs above the face, and within the angle of draw, and compressive in the trough behind the face. During the mining of several seams in a particular area, the surface strata may therefore be subjected to several transient phases of extension and compression resulting in a general opening up of the whole rock mass. In general the largest compressive strains are experienced at the centre of the area of highest extraction, whilst tensile strains develop at the boundaries with areas of little or no extraction. With modern longwall mining techniques the amount of subsidence and the corresponding strains induced can be calculated with a high degree of accuracy.

The same reliability of prediction is not possible however where the coal seams have been worked by pillar and stall methods. In this method, pillars of coal are left as permanent support to the openings and little surface movement is experienced. However, it was common practice to backfill the workings with dirt and rob the pillars as an area was abandoned. Robbing of the pillars results in the compressible backfill taking over the support and consequently surface subsidence results.[17] Where pillars have been left deterioration and spalling can lead to a progressive weakening of the support leading to a sudden collapse. Also where soft seatearths underly the coal, they are capable of flowing under the high concentrated stresses resulting in a slow and steady collapse of the roof and settlement of the ground surface.

Attempting to evaluate the amount of settlement and the consequent strains imposed by partial and irregular collapse of several seams is therefore extremely difficult unless accurate topographic survey measurements have been made of the ground surface over a period of years before, during and after mining.

In the South Wales Coalfield, the area in which the seams are worked is generally delineated by the colliery boundaries and the presence of major cross-faults. Where a fault forms the boundary to the workings in several seams much of the tensile strain will be taken on the fault, where the strains are able to exert their maximum dilation effect due to the presence of closely spaced joints. In extreme cases reactivation of the fault may occur with surface movement resulting in a surface step on the fault.

As well as causing subsidence, shallow workings can also drastically modify the flow of groundwater, the workings effectively acting as preferential flow paths and under-drains. This effect will be most pronounced where workings underly the zones of extension.

3.6.4 Summary

The effects of both mining subsidence and glaciation on the hydrogeological properties of the strata are similar and summarised below:

1. Dilation may increase the secondary permeability of the rock.

2. Dilation may lead to disruption of argillaceous strata which previously acted as barriers to groundwater flow.

3. The effect of zones of extension and compression will be to produce an extremely complex pattern of groundwater flow. The zones of extension effectively produce a preferential pathway for water whilst zones of compression act as barriers. As a result of subsidence over old pillar and stall mining the distribution may also be more complex even within one stratum.

4. The dilation of previously low permeability clay filled joints may lead to a loss of infilling by internal erosion leading in a marked increase of the mass permeability.

5. Infiltration of rainfall into the ground may be enhanced by the opening of surface joints.

6. Old mine workings may act as drains locally drawing down the groundwater levels.

3.7 HYDROGEOLOGY OF THE PROPOSED GARNANT OPENCAST SITE

3.7.1 Introduction

The proposed Garnant Opencast Site is situated on a North facing hillside immediately to the South of the village of Garnant. The ground surface generally falls at approximately 5° to 10° towards the North although in the West of the site the fall swings to the North-East. Much of the area is mantled by 2 to 4 metres of boulder clays with gravels. However, in the North of the site there are areas of fill derived from earlier opencast mining operations. A number of man made hollows, old shafts and adits occur across the site. However, there is no apparent surface indication of widespread subsidence over old workings.

3.7.2 Mining Activities

Within the eastern half of the site extensive mining has been carried out in the Big, Peacock and Trigloin seams from both the Old Raven and Dynevor Collieries. The Westerly extent of these workings is limited by the presence of the Ty Llwyd Fault. In the Western part of the site extensive mining has been carried out in the Big, Peacock and Trigloin Seam from both the Gellicaedrum No. 1 and No. 2, collieries and the Gadre Waun No. 2. Colliery. The approximate extent of these workings based upon available survey information is shown on Figure 3.4. It is probable that these were predominantly pillar and stall type workings.

During the course of the exploratory drilling numerous areas of old workings have been encountered within the Trigloin, Peacock, Big and Lower Black Seams. The approximate extent of these workings is also shown in Figure 3.4.

3.7.3 Groundwater Levels

Information on the levels of the groundwater table has been obtained from the results of exploratory drilling on the site particularly from the drillers logs and the gamma logging of the open holes.

N

EXTENT OF OLD MINE WORKINGS

As excavated in boreholes -

- Big vein
- Lower Block
- Peacock
- Trigloin

As taken from abandoned mine records

- Big vein
- Lower Black
- Peacock
- Trigloin
- Brynllor

SCALE
100 50 0 100 200 METRES

NATIONAL COAL BOARD OPENCAST EXECUTIVE
GARNANT SITE
AMMANFORD, DYFED
HYDROLOGICAL SURVEY

TITLE EXTENT OF OLD MINE WORKINGS

Sir Alexander Gibb & Partners
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124, Cathedral Road
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Earley House
London Road
Reading England

DATE December 1984

FIG. No. 3.4

Records of water levels from the drillers logs are not totally reliable, the records noting the presence of water in the flush return and whether the drillers rods were wet. As a majority of the holes were drilled in a day the boreholes were not left standing for a long enough period for the water levels to fully stabilise. The level readings are therefore probably a function of the insitu permeability and not necessarily a reflection of the groundwater level.

The gamma logs provide a better indication of the general groundwater level as the gamma logging is carried out after the hole has been standing open for a longer period of time. The values obtained from both the drillers logs and the gamma logs are plotted on Figure 3.5, which has also been contoured on the basis of the gamma log results.

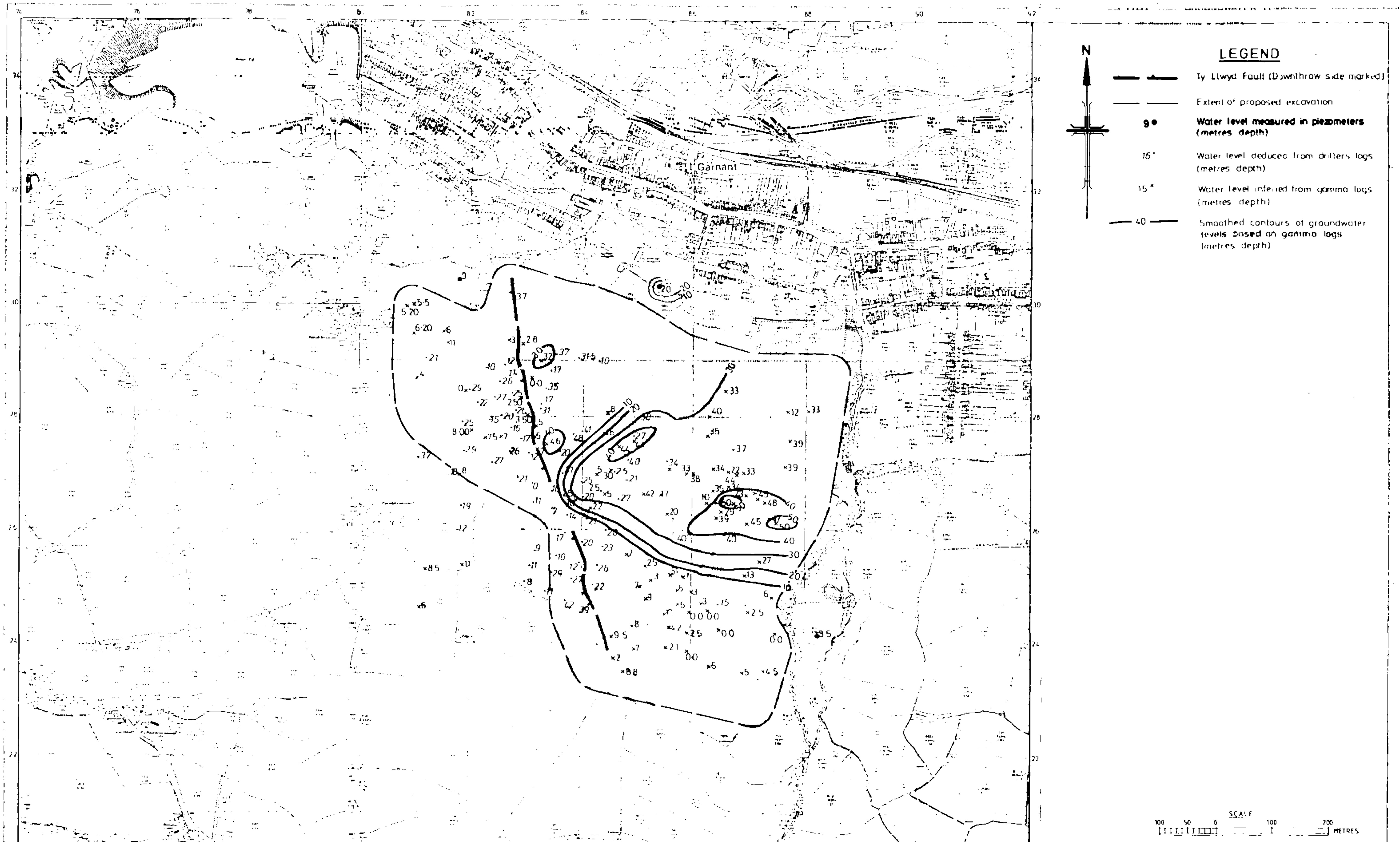
The following conclusions can be drawn from a study of this plot:

1. The level of the water table is influenced by the presence of abandoned underground works. These workings and their related shafts effectively acting as drains and drawing down the water table. This is particularly marked in the central Eastern part of the site, which is probably related to abandoned shafts draining into the Trigloin and Big Seam workings.

2. The presence of the Ty Llwyd fault is not associated with a local reduction in water levels which would indicate it was acting as a drain. It can therefore be concluded that the permeability of the fault zone is likely to be the same or lower than that of the insitu rock. If the fault was a zone of increased permeability it would act as a drain into the underlying workings with the resultant development of a zone of depressed water levels.

3. Zones of extension which would be indicated by zones of higher permeability and consequently lower ground water levels have not been observed.

4. It is considered unlikely that the effects of glaciation will have been significant due to the location of the site, on the lower slopes of a relatively flat sided valley.



NATIONAL COAL BOARD : OPENCAST EXECUTIVE
GARNANT SITE
AMMANFORD, DYFED
HYDROLOGICAL SURVEY

TITLE GROUNDWATER LEVELS

Sir Alexander Gibb & Partners
Consulting Engineers
124, Cathedral Road
CARDIFF

Earley House
London Road
Reading England

DATE December 1984

FIG. No 35

The information from the boreholes indicates that the groundwater levels in the bedrock are generally within 5 to 10 metres of the ground surface except in the Eastern half of the site. Site inspections in December 1984, indicated the presence of considerable amounts of surface water; much of the surface was very wet and boggy. Although the site was visited after a period of heavy rainfall the presence of marshland tussocky grasses indicates that the ground is fully saturated throughout much of the year. This is probably due to the blanket of boulder clay and low permeability spoil which covers much of the site and appears to be acting as a barrier to infiltration.

In the area of the old backfilled opencast mine in the centre of the site and the old spoil heaps surface water was also observed.

3.7.4 Insitu Permeability

As no direct information on the insitu permeability is available from the boreholes, it has been necessary to estimate this by means of general formulae and back analysis of the available records.

The formula discussed in Section 3.5 has been used as the basis to estimate the permeability. Based upon the borehole logs a joint spacing of 10-50 mm. has been assumed throughout. Inspection of the surface outcrops indicate that the joint spacing is somewhat greater than this. However, although variable, joint spacings closer than 10-50 mm. are considered unlikely. The joint opening is more difficult to assess from the cores, but the absence of any infilling or mineralization of the joint, apart from occasional references to sericite, and inspection of the cores indicates that the joints are generally tight in the argillaceous rocks and a joint opening of 0.001 cm. has therefore been assigned. Within the sandstone and siltstone bands, the joints are probably more open, the presence of quartz being noted in the borehole logs, a joint opening of 0.05 - 0.1 mm. has therefore been assigned in these rock types.

Inspection of surface outcrops suggests that in general, the degree of joint opening may be slightly less than indicated above.

Based upon the above values and the chart in Figure 3.3, the following values of the insitu permeability have been derived:

Mudstones, Siltstones, Coal	=	1×10^{-5} to 1×10^{-6} cm/sec
Sandstones and Siltstones with Sandstone bands	=	1×10^{-3} cm/sec

The permeability of the fault is regarded as being similar to that of the surrounding rocks.

A back analysis of the amount of water pumped from the Gadrewaun No. 2. Colliery, has also been carried out. Based upon the minimum roof area of the works (approximately 12,150 m^2) and the amount of water being pumped from the works (24,000 galls/day) a permeability of 1×10^{-5} cm/sec has been calculated. This assumes that all the backfilled workings are effectively free draining. This figure supports the estimates made for the Garnant area.

3.7.5 Hydraulic Gradient

During opencast mining operations, hydraulic gradients will be established by drainage of groundwater to the opencast workings. These gradients will be a function of both the insitu permeability of the rock mass and the volume of available recharge and will control the volume of water entering the pit. Steep groundwater gradients have been locally established on the site around abandoned shafts which permit drainage to deep abandoned workings. (See Figure 3.5). These gradients (approximately 1:2.5) therefore represent a natural situation very similar to that which will be established during opencast workings. To the East of the site a more gentle gradient (1:3) representing drainage from the Nant-y-Gath to the bottom of the pit is the steepest which is likely to be established. Groundwater gradients of 1:2.5 on the highwall and West side of the workings and 1:3 on the East side of the workings have therefore been used in calculations.

The calculations for the amount of water which will flow into the excavations during the different stages are summarized in Table 3.1 and shown in more detail in Table 3.2.

The flow of water has been calculated using Darcy's law which is based upon flows through a fully saturated medium:

$$q = Aki$$

where

q	=	volume of water flowing per unit time
A	=	cross sectional area of medium corresponding to flow q
k	=	coefficient of permeability
i	=	hydraulic gradient

This relationship is considered to be the most appropriate in the circumstances and with the quality of the available base information. Detailed flow net considerations based upon rigorous application of Darcy's law are not considered justified because of the heterogenity of the rock mass and the general nature of the available data.

Backfill to the exhausted workings will be end tipped in approximately 10 m. layers. Because of the uncertainty associated with the backfilling it has been assumed that this material will be essentially free draining; a situation which has been observed in most colliery spoil tips[18], and compacted shales.[19]

TABLE 3.1

SUMMARY OF GROUNDWATER INFLOWS

Area	Inflow (litre/sec)	Remarks
Phase 1	0.8	Phase 1, (Effectively separated from other workings.)
Phase 2	7.5	
Phase 3	16.5	Draining Phase 2 and 3
Phase 4	17.0	Draining Phase 2, 3 and 4

TABLE 3.2 Water Inflows into the Proposed Garnant Opencast Pit

Phase	Wall	Area Of Wall (m^2)	Hydraulic Gradient	% Sandstone/ Siltstone	Inflow l/sec	
					Mudstone	Sandstone/ Siltstone
1	Highwall	14,000	1:2.5	0%	0.56	0
	Eastern Wall	2,700	1:3	0%	0.09	0
	Western Wall	2,700	1:2.5	0%	0.11	0
	TOTAL				0.76	0
2	Highwall	10,000	1:2.5	5%	0.38	2.0
	Eastern Wall	10,800	1:2.5	5%	0.41	2.16
	Western Wall	10,800	1:2.5	5%	0.41	2.16
	TOTAL				1.20	6.32
3	Highwall	18,975	1:2.5	5%	0.72	3.79
	Eastern Wall	Phase 2 Workings			1.20	6.32
	Western Wall	18,000	1:2.5	5%	0.68	3.60
	TOTAL				2.60	13.71
4	Highwall	11,250	1:2.5	0%	0.45	0
	Eastern Wall	Phase 3 Workings			2.61	13.71
	Western Wall	3,325	1:2.5	0%	0.13	0
	TOTAL				3.19	13.71

All calculations based on an in situ permeability of 1×10^{-5} cm/sec for Mudstone
1×10^{-3} cm/sec for Sandstones/Siltstones

A maximum flow of approximately 17 litres/second will therefore require to be pumped from the excavations as a result of groundwater inflows. All the calculations assume that the underground workings are effectively drained to levels below the excavation.

Small inflows of water from the old workings may occur but these are likely to be of short duration and will only result in small increases in the quantity of pumped water.

Additional water resulting from rainfall in the area of the pit will also require to be pumped. The increase in the pumped quantities resulting from the rainfall will however be largely a function of the installed pumping capacity and the pit will effectively attenuate the rate of run off. The effect of a 1000 year storm occurring at the site when excavation is at its maximum extent has been studied as a worst case. It has been assumed that 10% of the area is open and 90% has been backfilled but not restored, a run off coefficient of 50% has been assumed for the backfilled area.

what size? in mm?

NB

In such circumstances a total of 18,128 m^3 of water will fall into the pit and require to be pumped out. If this was to be carried out within two days, pumps with a capacity of approximately 122 litres/second would be required. This should however be regarded as effectively an attenuation and control of surface run off.

3.8 WATER QUALITY

3.8.1 Introduction

The quality of the water which will be derived from the surface run off in the area of the works and pumped from the excavations will be a function of:

- the amount of suspended material
- the pH of the water

3.8.2 Suspended Material

Although much of the sequence of rocks at the site comprises mainly argillaceous mudstones and siltstones observations indicate that these rocks do not readily degrade to clay or silt size materials. Considerable work has been carried out on the geotechnical properties of Carboniferous Shales and Coal Measure rocks by a number of authors,[20] who studied the disintegration and decomposition of shales on exposure to the air. Their studies showed that samples of shale subjected to several cycles of wetting and drying rapidly disintegrate as a result of tensile failure; the rate of disintegration being related to the presence of siltstone laminae. They concluded from laboratory testing and field observation that fresh cemented shales cannot create particles smaller than a coarse sand or fine gravel. Further disintegration requires significant mechanical effort or chemical decay.

Considerable mechanical disintegration will be associated with blasting and excavation and with plant repeatedly passing over the fragmented shale. However, the degree of disintegration will be a function of the operating method of the contractor who works the pit.

Chemical decay of the shales occurs as a result of weathering; the shales reducing to clayey silts arising from the loss of cementation. Such decay occurs very slowly but appears to be accelerated by the presence of pyrites. However within the time scale of the operations at Garnant it is unlikely to be a problem, particularly as pyrite is not of frequent occurrence.

It is not possible within the scope of this report to quantify the amount of silt and clay size material which will be derived from the spoil heaps and the pit itself as much depends on the operating methods of the contractor and the susceptibility of the main rock types to disintegrate. However, if the amount of handling and therefore the mechanical disintegration is kept to a minimum, the amount of fine material is likely to be small and could be controlled by a suitable system of settling lagoons.

WEAK

3.8.3 Acidity of Water

The mudstones, siltstones and coals of the coal measures were formed under swampy anaerobic conditions and relatively high amounts of pyrite (FeS_2) were deposited with them. Whilst underground the pyrite and other metaliferrous materials are inactive but upon exposure to the elements these can suddenly become active.

The main reaction affecting pyrite is when it weathers producing sulphuric acid by the action of water and oxygen, which is aided by the action of micro-organisms. Many reactions occur but the essential end products are sulphuric acid ($H_2 SO_4$) and ferric hydroxide ($Fe (OH_3)$).

The rate of pyritic breakdown and the volume of acid water produced depends not only on the amount of pyrite but also on the grain size. The amount of pyrite available is very variable from one pit to the next but in general the Coal Measures of South Wales have relatively low quantities of pyrite compared to the Yorkshire and other areas. The effects of the pyrite can also be drastically reduced by the presence of ankerite and siderite, both are carbonate minerals which are able to neutralise the acidity producing secondary minerals like gypsum and jarasite. However, if acidity is produced in excess, free hydrogen ions accumulate and the spoil may be very acid ($pH < 3$).

The grain size of the pyrite is also a controlling factor on the rate of acidity produced, the smaller the grain size the more reactive the pyrite. Samples with a relatively high pyrite content can therefore produce acid at the same rate as samples with a much lower content. It is at the surface of the spoil heaps and the backfilled areas where acidity will develop most strongly and be leached out by rain water. A general assessment of the nature and pyrite content of the rocks at Garnant does not indicate any significant concentration of iron pyrites and the pH of the water produced is not likely to be unusual. The drainage water is likely to be less acid than that water already draining from nearby abandoned workings as it will have less time in contact with the surrounding rock. Monitoring of pH throughout the operation will ensure that discharge remains within the constraints of the Working Consents.

CHAPTER 4

EXISTING CULVERTS

4.1 SCOPE OF CHAPTER

This chapter considers the three existing culverts which serve the site and are shown on Figure 1.1.

Section 4.2, outlines the researches which were undertaken to obtain record drawings of the three culverts viz: Nant-y-Gath, Nant Maen and Minor Catchment. Section 4.3, summarizes the survey of the culverts which was carried out during November 1984. Section 4.4, gives an assessment of the hydraulics of the culvert and identifies if there is any possible flooding risk. Recommendations are given in Section 4.5, to carry out remedial works to attenuate peak flows and thus minimize the possibility of flooding. Section 4.6, identifies repair works that need to be carried out to the culverts.

4.2 RECORD DRAWINGS OF CULVERTS

Enquiries were made to determine what persons, authority or organisation were responsible for the maintenance of the culverts to enable record drawings of their construction to be obtained. These enquiries revealed the following:

1. Minor Catchment
   - Dyfed County Council

2. Nant Maen Culvert
   - Dyfed County Council under Cwmamman Road
   - Dynefwr Borough Council elsewhere

3. <u>Nant-y-Gath Culvert</u>

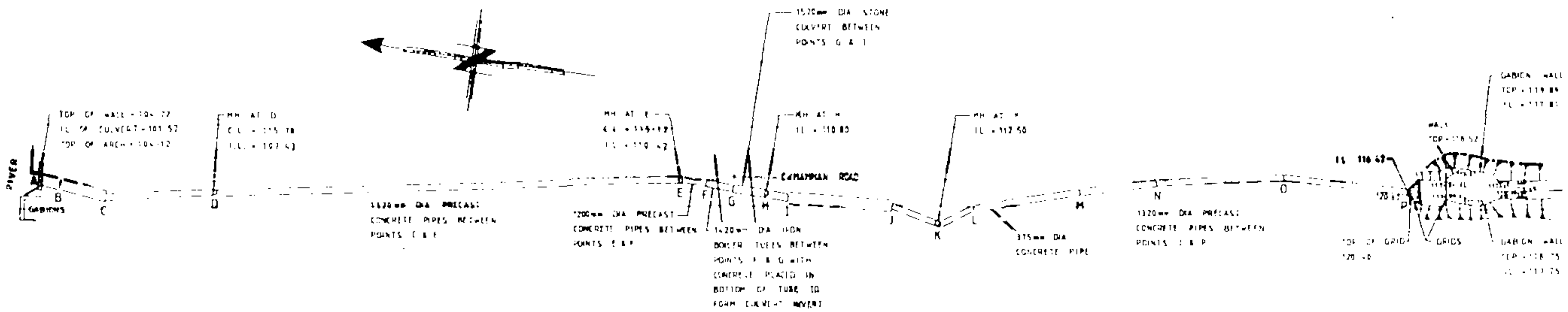
- Dyfed County Council under Cwmamman Road
- British Rail under the railway line
- Dynefwr Borough Council elsewhere

Figures Nos: 4.1 and 4.2, indicate the lengths of culverts maintained by the above bodies.

British Rail confirmed that where the Nant Maen and Nant-y-Gath streams were culverted under their railway, record drawings indicating the construction of the culverts do not exist. Similarly, Dyfed County Council confirmed that they do not possess any details of the culverts for which they are responsible.

The Technical Services Department of Dynefwr Borough Council advised that prior to local government re-organisation in 1974, the responsibility for maintenance of the culverts was with the former Cwmamman Urban Council. However, shortly before re-organisation, there was a serious fire at the offices of Cwmamman Urban Council, during which a great many of their records were lost. These included details of the Nant Maen and Nant-y-Gath culverts. Consequently only a few contemporary records exist of the culverts. Some drawings of the Nant-y-Gath culvert have survived and are held by the Planning Department of Dynefwr Borough Council. One drawing in particular gives details of the culvert before improvement works were carried out in the early 1970's. An abstract of this drawing is included in Figure 4.3.

From a newspaper report in the South Wales Guardian published on 7th November 1968, there is mention of Cwmamman Urban Council's intention to improve Nant-y-Gath culvert and that Messrs. J. Laing & Sons would be appointed consulting engineers to prepare the scheme. The company of Messrs. J. Laing & Sons exists today as Laing Design and Development Centre, Nelson House, Rupert Street, Bristol. That firm provided copies of drawings which they had prepared for reclamation of the former Raven Colliery and improvements to Nant-y-Gath culvert viz: drawing Nos: E/3989 1 - 12



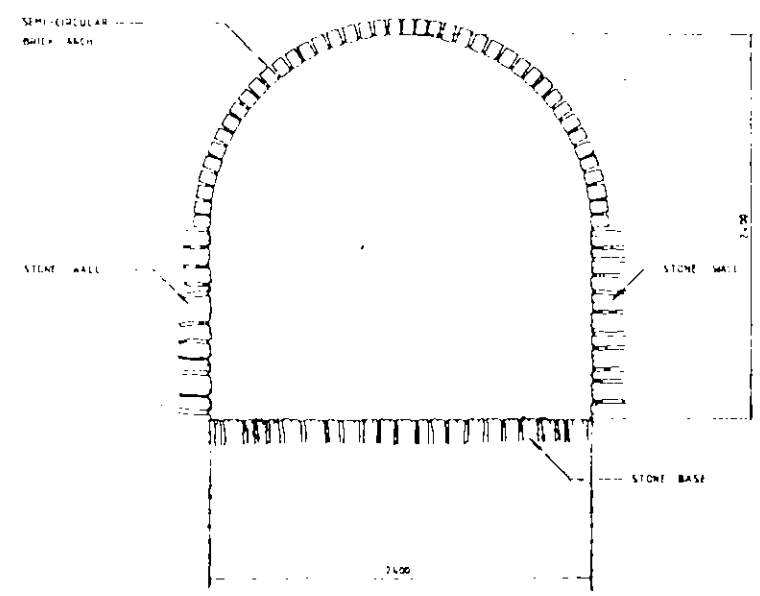
PLAN ON NANT-Y-GATH CULVERT

NOTES

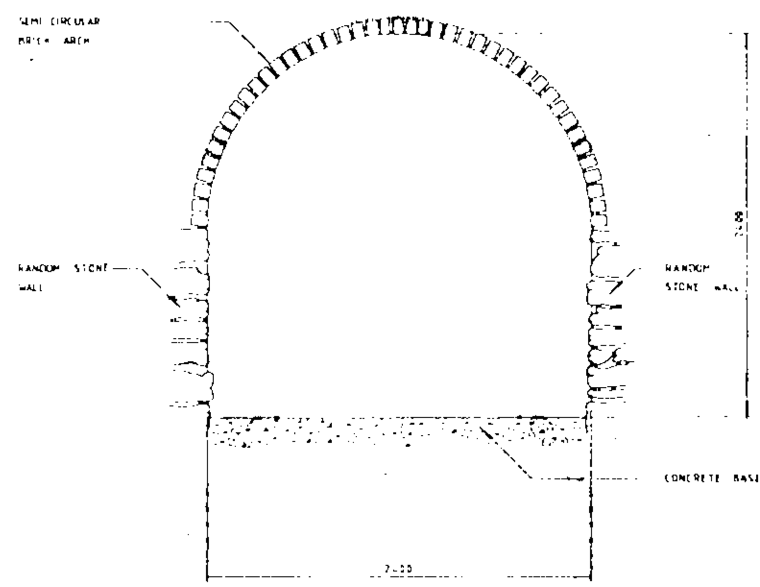
1 LENGTH A TO C IS MAINTAINED BY BRITISH RAIL

2 LENGTH F TO I IS MAINTAINED BY DYFED COUNTY COUNCIL

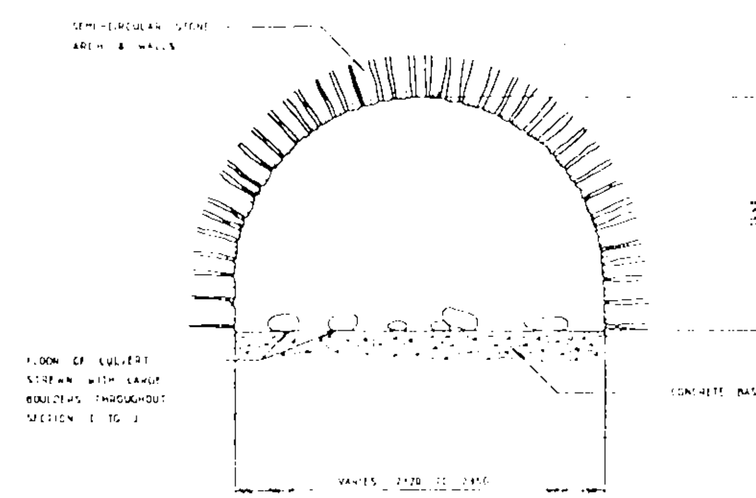
3 ALL OTHER LENGTHS ARE MAINTAINED BY DYNEFWR BOROUGH COUNCIL



SECTION A TO B



SECTION B TO C



SECTION I TO J

SCALE

20 10 0 20 40 METRES

NATIONAL COAL BOARD : OPENCAST EXECUTIVE
GARNANT SITE
AMMANFORD, DYFED
HYDROLOGICAL SURVEY

TITLE : NANT-Y-GATH CULVERT & DETAILS

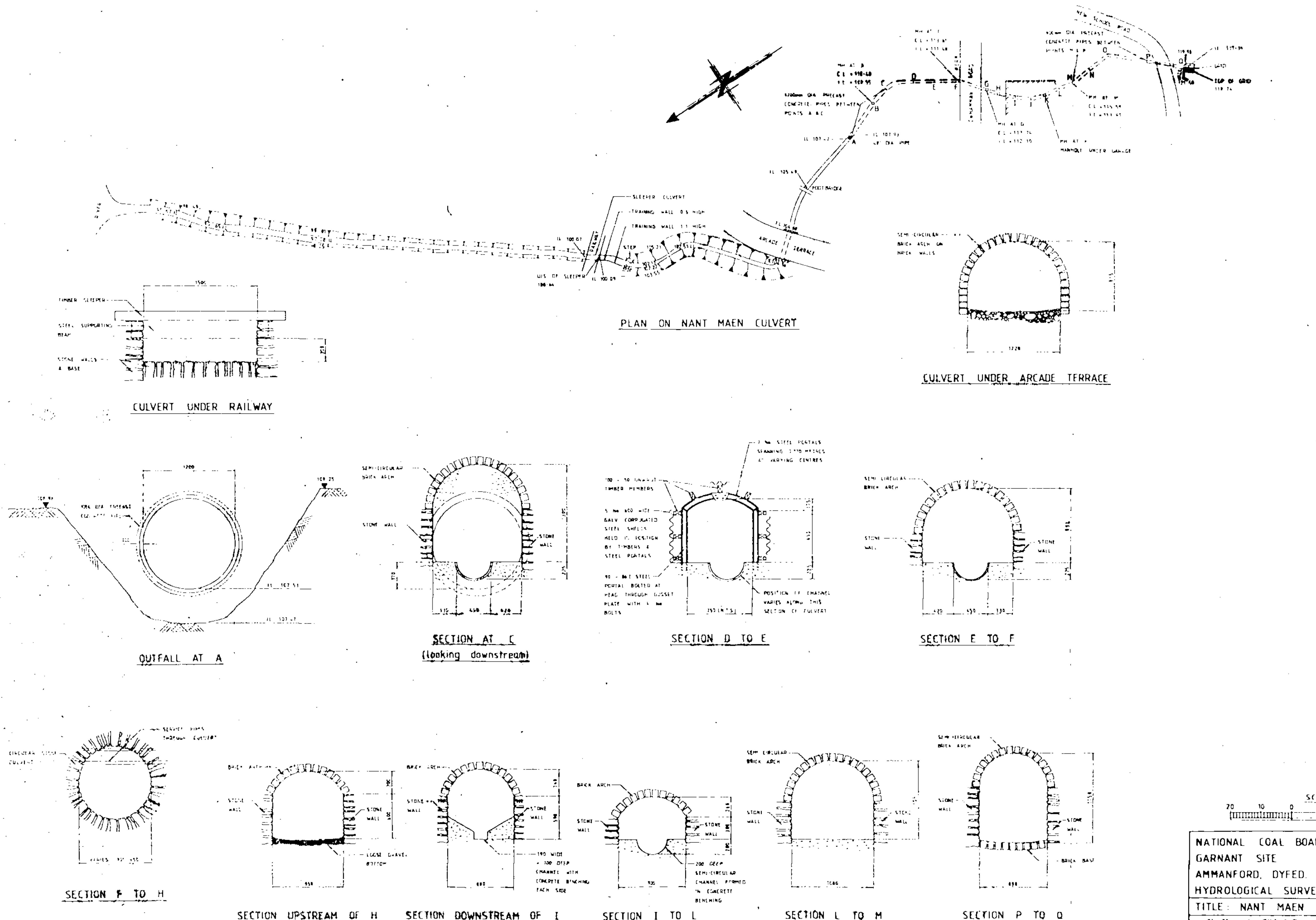
Sir Alexander Gibb & Partners
Consulting Engineers
124, Cathedral Road
CARDIFF

Earley House
London Road
Reading England

DATE December 1984

FIG No. 4·1

AMENDMENTS | A | B | C | D | E | F | G | H



NOTES

1. EXCEPT FOR THE LENGTH F TO H THE CULVERT BETWEEN POINTS A TO Q IS MAINTAINED BY DYNEFWR BOROUGH COUNTY COUNCIL
2. THE LENGTH F TO H IS MAINTAINED BY DYFED COUNTY COUNCIL.
3. DYNEFWR BOROUGH COUNCIL MAINTAIN THE CULVERT UNDER ARCADE TERRACE ROAD
4. BRITISH RAIL MAINTAIN THE CULVERT UNDER THE RAILWAY LINE

NATIONAL COAL BOARD OPENCAST EXECUTIVE
GARNANT SITE
AMMANFORD, DYFED.
HYDROLOGICAL SURVEY

TITLE: NANT MAEN CULVERT & DETAILS

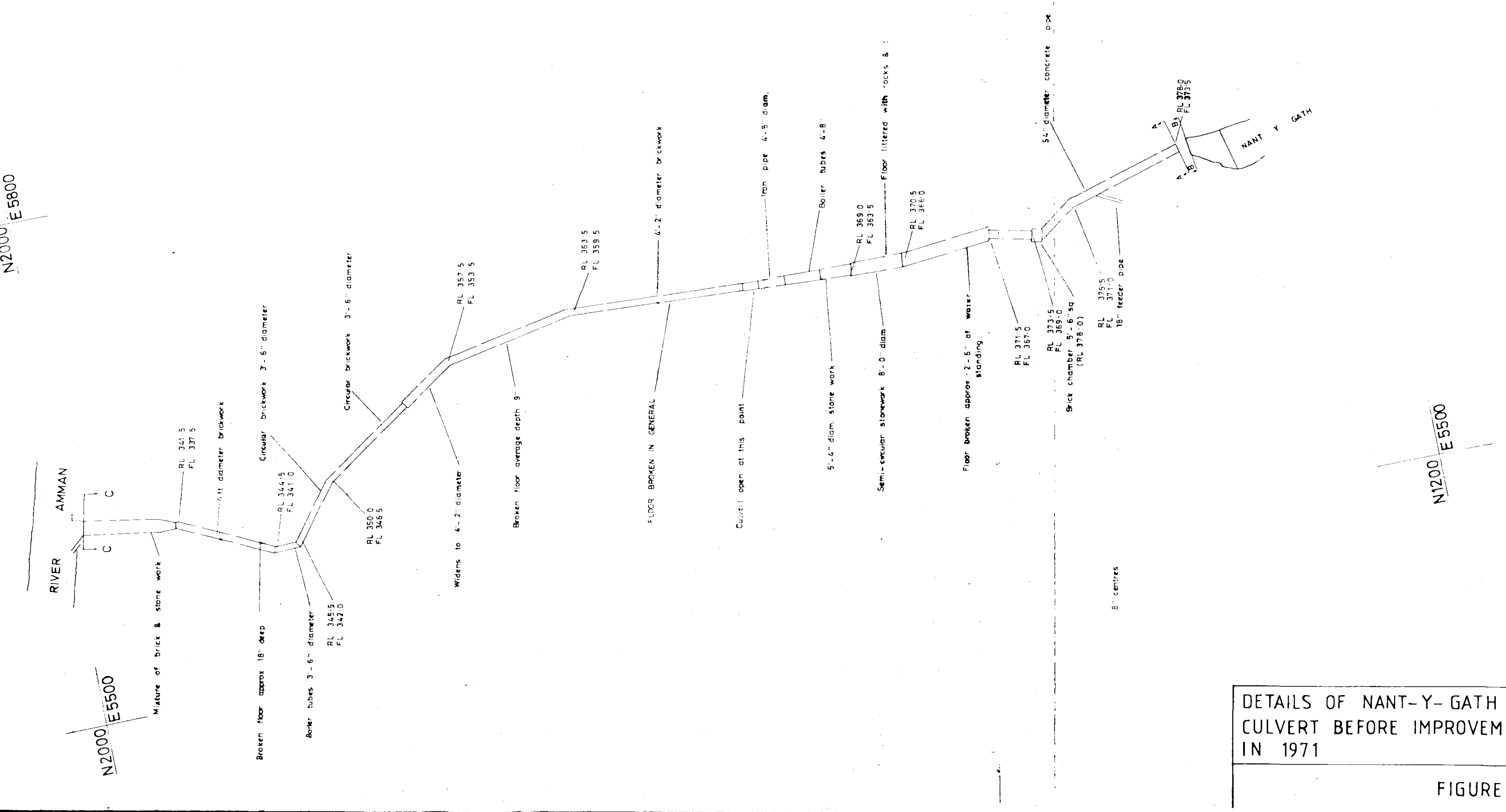
Sir Alexander Gibb & Partners
Consulting Engineers
124, Cathedral Road
CARDIFF

Earley House
London Road
Reading England

DATE December 1984

FIG. No. 4·2

AMENDMENTS



DETAILS OF NANT-Y-GATH CULVERT BEFORE IMPROVEMENTS IN 1971

FIGURE 4·3

inclusive. Drawing Nos: E/ 5, 6,11 and 12 are relevant in showing details of the Nant-y-Gath culvert and are included in the Supplementary Volume of Technical Papers. Messrs. Laing also provided a letter dated 28th May 1971 from the South West River Authority which states, "The form of culvert which you indicate on the drawings is acceptable as far as this Authority's requirements are concerned."

Tenders for the work were received in July 1971, and the contract awarded to a Leicestershire firm. As far as work on Nant-y-Gath culvert is concerned, the culvert was replaced and realigned between points C and E shown on Figure 4.2, and also it was extended upstream between points M and P. In addition there were major intake works comprising a large safety grille at the entrance to the culvert, a trash screen just upstream of this together with a silt trap and two stilling basins.

With regard to the Nant Maen culvert, there is evidence of refurbishment work having been carried out to part of this culvert in February 1972. In particular a new 220 mm. deep precast concrete channel was installed between points C and F (shown on Figure 4.1) and between points D and E, steel portal sections with corrugated steel sheets spanning between, were inserted; presumably to strengthen the roof of the culvert.

From information gathered through discussions with officers of Dynefwr Borough Council, it appears that the Nant Maen culvert was extended between points M and P during the late 1970's by the Owner of the Garage which is situated over a downstream length.

Dynefwr Borough Council indicated that as a result of flooding of the culvert through debris blocking it, they constructed an intake grille. This comprises an old cattle grid which has been adapted to suit and was installed about 1979.

4.3 SURVEY OF THE CULVERTS

The culverts were surveyed topographically in order to plot the positions of intake, outfall and intermediate manholes. Between such defined points, a compass and tape survey was carried out inside the two larger culverts.

The surveys of the Nant-y-Gath and Nant Maen culverts are shown on Figures 4.1 and 4.2.

In general, the culverts are free from silt and debris but in certain areas of the two larger culverts, their inverts have been washed away.

A detailed description of the condition of the two larger culverts is given below. The various points defining each section of the culvert are as shown on Figures 4.1 and 4.2.

Nant Maen Culvert

Where the Nant Maen passes under the railway the culvert comprises stone walls and a roof constructed of sleepers. It is in a good state of repair.

Where the stream passes under Arcade Terrace road, the culvert comprises a brick arch 900 mm. high and 1200 mm. wide at its base, with a rubble base. The culvert is in a good state of repair.

A - B: 1.2 metre diameter precast concrete pipe 100 mm. thick. The gap at the joints between the pipes is large (50 to 75 mm) and these have been filled with mortar to about a quarter of the pipe depth.

B - C: As for the length A - B. Also, at point B, which is a manhole, roughly finished concrete has been placed on the outside of the bend in the culvert.

C - D: A semi-circular brick arch on stone walls with a recently reconstructed channel invert 225 mm. deep. This section of the culvert is in good repair. There is a step of about 150 mm. between the invert level of the 1.2 metre diameter pipe and 225 mm. channel.

D - E: The construction appears to be the same as the length C - D, but in addition, there are a number of steel portal frames installed, between which, galvanised corrugated steel sheets span and are held in place by means of 100x 50 mm. timbers. Such sheets evidently provide additional support to the semi-circular brick arch roof.

E - F: This section is of similar construction and state of repair as length C - D. Inscribed in the concrete near point F are the names of the workmen who repaired it. Unfortunately, the last figure of the date is blurred but appears to be February 1972.

F - G: At point F, an inspection chamber is situated over the culvert and which has a small diameter hole knocked through its base into the soffit of the culvert. Also a number of pipes enter the culvert at this point. Just upstream of point F, there is a step of 430 mm. in the invert of the culvert. The section changes to a circular stone culvert 0.9 to 0.95 metres diameter. The stonework is in need of pointing and the roof has been damaged by services passing through. At point G is a manhole.

G - H: Circular stone culvert 0.9 to 0.95 metres diameter. The stonework is in need of pointing. At point H is a manhole.

H - I: Upstream of manhole H, the culvert comprises stone walls with a semi-circular brick arch roof.

The invert is of gravel for the first four metres and a 230 mm. deep hole has been gouged out 4.0 m. from the manhole at point H. Beyond this, the invert of the culvert is of concrete shaped to form a 190 mm. wide x 100 mm. deep channel with benching each side. The walls and roof of the culvert appear to be in good repair.

I - J: This is of similar construction as the culvert between G - I, but the invert which was of concrete, has been badly gouged out. Near point J, the underside of the stone wall has been undermined over a length of 1.75 m, 220 mm. in height and the undermining extends 700 mm.

J - K: This is of similar construction as the culvert between I - J. The extent of gouging out of the invert of the culvert is not as bad but there is a 450 mm. deep hole just upstream of point J. At point K is a manhole.

K - L: This is of similar construction as the culvert between J - K, and is in a relatively good state of repair.

L - M: The culvert is slightly larger over this length and comprises stone walls, semi-circular brick roof and a concrete invert which are all in a good state of repair. At point M, is a large chamber about 2.0 m. x 1.5 m. in size, but which is not completely roofed over.

M - P: These lengths comprise 900 mm. diameter precast concrete pipes 75 mm. thick. There are 28 pipe lengths of which 12 have longitudinal cracks top and bottom. The longitudinal cracks along the invert of the pipe are also showing signs of being enlarged by the effects of the water.

P - Q: This length of culvert comprises stone walls, semi-circular brick arch and brick floor. It is in a very good state of repair except that near point P, there is a crack through the complete section of the culvert. This varies from 40 mm. width at the invert of the culvert to 100 mm. at the soffit.

Nant-y-Gath Culvert

A - B: This comprises walls of dressed stone, a semi-circular brick arch and a stone pitched invert. The culvert appears to be in a good state of repair although there is one isolated hole, 660 mm. deep in the invert of the culvert where the stone pitching has been lost.

B - C: The walls to this length of the culvert are of random stone. The roof is a semi-circular brick arch and the invert is of concrete construction.

C - E: This length of culvert comprises 1.32 m. diameter precast concrete pipes. The pipes are all in good condition. At points D and E are manholes.

E - F: This length of culvert comprises 1.20 m. diameter precast concrete pipes. The pipes are all in good condition.

F - G: Heavily corroded boiler tubes 1.42m. diameter. Concrete has been placed in the bottom of the tubes to form the culvert invert.

G - H: Circular stonework 1.52 m. diameter. The stonework appears to be in good condition. At point H, is a manhole.

H - I: Circular stonework 1.52 m. diameter. The stonework appears to be in good condition.

I - J: This comprises a semi-circular stone arch varying in diameter from about 2.32 to 2.35 m. The stonework of the arch itself appears to be in good condition. However, for about 17.25 m. upstream of point I, the invert of the culvert is strewn with large boulders and there is a hole 560 mm. deep and 4.0 m. long, in the invert of the culvert above the length strewn with boulders. The last 5.0 metres of the culvert bed up to point J, has a concrete invert.

J - K: Precast concrete pipe 1.37 m. diameter in good condition. At point K, is a manhole.

K - P: Precast concrete pipe 1.37 m. diameter in good condition. It should be noted that there is slight spalling of the concrete at the invert of the pipe at each joint.

4.4 HYDRAULIC ANALYSES OF CULVERTS

4.4.1 Introduction

The three culverts which serve the site have been analysed hydraulically in order to assess their capability of carrying the peak flow discharges from their various catchments as outlined in Chapter 2. In particular, the capability of the culverts to cope with the most onerous flow conditions has been examined.

4.4.2 Basis of Hydraulic Calculations

No allowance has been made for water entering the culverts along their lengths, either by infiltration or other piped systems. It is considered that such flows would not have a significant effect on the peak flows calculated in Chapter 2, because their times of concentration would be short compared with the time of concentration of the catchment as a whole. Also, the analysis has shown that where such pipes enter the culverts they are generally downstream of any lengths of the culverts which become surcharged. Peak flows for a storm with a return period of 100 years have been used in the analyses. The selection of a storm with a return period of 100 years has been made since this is the normal design criterion laid down by the Welsh Water Authority for new culverts constructed in urban areas.

No!

4.4.3 Method of Analysis

The equation used to model the flow was Manning's formula, viz:

$$Q = \frac{i^{1/2} \, m^{2/3} \, A}{n}$$

where:

where:	Q	=	Flow (cu.m/sec)
	m	=	hydraulic mean depth (metres)
	i	=	hydraulic gradient
	n	=	Manning's friction coefficient
	A	=	area of cross section

Table 4.1, gives the values of Manning's friction coefficients which were used for the calculations.

TABLE 4.1

VALUES OF FRICTION COEFFICIENTS

Material:	'n' value:
Spun concrete	0.013
Brickwork/Stonework	
a) pointed	0.016
b) not pointed	0.025
Gravel invert	0.025
Rubble invert	0.035
Corrugated Iron	0.025
Rusty Iron	0.020

Ideally, the flows through the culverts should be gauged in order to produce absolutely reliable figures, but this would need to be carried out over a great number of years. In the absence of such data, the analysis has to rely on subjective assessments and in this respect the values of friction coefficients have tended to err on the safe side.

4.4.4 Results of Analyses

There is no inlet or outlet control of any of the culverts.

All three of the culverts contained at least one section which throttled, (i.e. in order for the required flow to pass through it, a pressure head of water would be required). Table 4.2, gives details of the free flow capacity of each section of the culverts and compares this with the 100 ~~years~~ return period flows.

TABLE 4.2

COMPARISON OF
FREE FLOW CAPACITIES OF CULVERTS
WITH 1 IN 100 YEAR FLOWS

Culvert Section:	Free Flow Capacity: cumecs	1 in 100 Year Flows: cumecs Present	On Restoration
Minor Catchment	0.94	0.9	1.0
Nant Maen			
at Railway	0.37		
at Arcade Terrace Road	3.3		
A - B	9.1		
B - C	11.9		
C - D	9.0		
D - E	2.0		
E - F	12.8	2.4	2.7
F - G	1.6		
G - H	1.6		
H - I	3.1		
I - L	2.5		
L - M	5.9		
M - P	4.4		
P - Q	6.5		
Nant-y-Gath			
A - B			
B - C			
C - D	24.4		
D - E	8.6		
E - F	3.5		
F - G	3.4		
G - H	4.2	5.8	6.1
H - I	14.8		
I - J	10.4		
J - K	15.0		
K - L	16.4		
L - M	10.7		
M - P	11.9		

It is clear from Table 4.2, that the Nant Maen and Nant-y-Gath culverts in their present state will be surcharged for the 100 year return period flows. Calculations, have shown that the head of water required in the Nant-y-Gath to obtain the flows through the throttle points can be contained safely within the culvert with no risk of flooding even for the 'on restoration' flows.

On the other hand, the throttle point at F - G on the Nant Maen culvert will cause the water to back up in the culvert to such an extent that it will flow out of the open section of the culvert at point M. This situation is true for the 100 year return period flow for the site in its present state. The throttle at D - E, due to the steel portal sections will not cause water to back up as far as point F for the most onerous case.

The 100 year return period peak flow that can be accommodated safely in the Nant Maen culvert without the risk of flooding has been evaluated to be 2.0 cumecs.

Where the Nant Maen passes under the railway, the existing culvert is inadequate to accommodate any present flows in excess of a two year return period. Enquiries made with British Rail indicate that frequent flooding occurs at this point and which is clearly tolerated by British Rail, as they have no intention of upgrading the culvert.

The Minor Catchment culvert has been found capable of accommodating the 100 year return period peak flow for the site in its present state. It can also safely take the 100 year return period flow for the site in its restored state although this will mean the build up of a head of water (0.36 m) at its entrance. It should be noted that the Welsh Water Authority's design criteria for culverts in rural areas is based on a 1 in 50 year storm and in this respect the Minor Catchment culvert satisfies the requirements.

?

4.5 REMEDIAL WORKS

The analyses of the culverts show that the Minor Catchment and Nant-y-Gath culverts can safely accommodate the calculated peak flows whereas the Nant Maen culvert will flood in its present condition if it has to accommodate a peak flow in excess of 2.0 cumecs. Section 2.4.3, identifies a number of available options to deal with this situation and these are considered here in greater detail.

4.5.1 Accept Increased Risk of Flooding

It is estimated that the main Nant Maen culvert is only capable of accommodating a peak flow for a 45 year return period. With an expected increase in flow from the restored site, the frequency of flooding will increase since it will then only be capable of accommodating a peak flow for a 22 year return period.

Flooding of the Nant Maen in its present condition is intolerable since it floods a garage and flows across the Cwmamman Road causing a great deal of disruption. Clearly an increased risk of flooding would not be acceptable.

4.5.2 Increase the Capacities of the Culverts

The capacity of the main Nant Maen culvert would need to be increased between points D - E, F - H and I - L, in order to eliminate the 'throttle' points.

Analysis shows that if only the length F - H is upgraded the culvert as a whole could safely accommodate a peak flow of 2.7 cumecs. The upgrading should comprise a new 900 mm. diameter spun concrete pipe laid to a fall of about 1 in 18. This fall can be achieved by eliminating the step of 430 mm. at point F. It has been estimated that the budget cost for these works would be £12,500.

Such works may require the diversion or re-routing of certain services by the Statutory Undertakers and may disrupt, for a period of time, the functioning of the Garage adjacent to the culvert. An allowance of £1,500. has been made in the above cost estimate for works by the Statutory Undertakers. No allowance has been made for any costs due to disruption of the working of the Garage.

Another option to increase the capacity of the culvert would be to seal the opening at point M as well as all other drains entering the culvert in order to contain the flow so that the culvert would function under a pressure head. This option is not recommended as it could prove difficult to maintain the integrity of the culvert over the pressurised length.

4.5.3 Improve Maintenance of Culverts

It seems that flooding in the past has been due to the culverts becoming bocked by debris and rubbish entering them. This problem has largely been overcome by the introduction of trash screens and other than routine maintenance nothing further is recommended. This however does nothing to increase the capacities of the culverts or to reduce the risk of flooding due to high peak flows.

4.5.4 Redistribute Catchment Areas

During the restoration of the site, the possibility exists of adjusting the catchment areas. To reduce the peak discharge into the Nant Maen culvert to a flow it can safely accommodate (i.e. estimated to be 2.0 cumecs) would require 28.6 percent of its catchment area to be drained to the Nant-y-Gath culvert.

Analysis has shown that the Nant-y-Gath culvert can safely accommodate the additional flow from the 28.6 percent (0.127 sq.km) of the Nant Maen catchment. The advantage of this option is that it creates a benefit by reducing the risk of flooding of the culvert in its present state. A separate capital cost for this option cannot be readily identified because such work would be carried out as part and parcel of the land restoration scheme.

4.5.5 Attenuation of Flow by On-Site Storage

To keep the peak flow into the Nant Maen culvert to a safe level (2.0 cumecs), storage lagoons could be provided to accommodate the excess flow.

Depending on the particular arrangement of the lagoons, up to 2,500 cu.m. of storage would be required. Such storage could be 'on-line'; in which case controlled outlets would be required. Again, a separate capital cost for this option cannot readily be identified since it would form part of the land restoration scheme.

The estimated capital costs, exclusive of V.A.T. for each of the options considered above, have been based on prices ruling in January, 1985.

4.6 REPAIR WORKS

Repair works are not necessary to the Minor Catchment culvert.

Repair work is required to the Nant Maen culvert between points F and K.

Ideally, the 900 mm. diameter stone culvert between points F and H should be lined either by the insertion of structural segments such as Glass Reinforced Cement or Glass Reinforced Plastic, and filling the remaining void with grout, or rendering of the stonework with some form of cement. Discussions with specialist contractors for refurbishing sewers indicate that the cost of lining the culvert between F and H would be very expensive due to its short length; so much so that it would be cheaper to replace it. However, simple repointing of the stonework could be carried out and this work could be done at an estimated cost of £3,000.

With regard to the culvert between points H and K, it is recommended that precast concrete channel sections be installed. This could be carried out at an estimated cost of £2,500.

An inspection of the large crack in the Nant Maen culvert near point P, indicates that this has probably developed as a result of lateral displacement of the old culvert head wall. With the stream now culverted downstream of this old headwall and the site generally filled, there is unlikely to be any further movement. The crack should therefore be sealed.

Of concern, is the condition of the 900 mm. diameter concrete pipes installed between points M and P of the Nant Maen culvert. These pipes were installed about ten years ago and are showing signs of distress. It has not been possible to determine if this is due to the pipes being improperly installed with incorrect bedding and surround, or that the wrong strength pipes have been used. Ideally, the pipes should be replaced, but this is considered not to be necessary at present as the pipes have not noticeably deformed despite being cracked.

It is recommended that either these pipes be monitored by periodic inspections and if their condition deteriorates further, they be rehabilited by the installation of a lining, or that the pipes be rehabilitated immediately by the installation of a structural lining. The cost of the installation of a lining is likely to be of the order of £500. per metre which, for the length M to P,would amount to £14,000.

For the Nant-y-Gath culvert, the only length in need of repair is the length I - J. Of interest is that this particular length was identified by Laing Design and Development Centres as being in need of repair in a survey of the culvert which they undertook in 1969. The problem appears to have been similar with the invert being ripped out and the debris scattered in the downstream length of the section. It is recommended that the debris be removed and the gouged out hole be filled with mass concrete. The new invert of this length of the culvert should then receive a fibre concrete finish. The estimated cost of this repair, exclusive of V.A.T. has been assessed at £5,000.

CHAPTER 5

SUMMARY

The main points arising from the study are as follows:

1. In their present state, the Nant-y-Gath and Minor Catchment culverts can safely accommodate the peak flows for a 100 year return period storm. NO

2. In its present state, the Nant Maen culvert will flood at such an event due to its inadequate capacity.

3. The hydrogeological study indicates that the amount of ground water contributing to the peak flows is insignificant.

4. The hydrological study indicates that on restoration of the site, there will be an increase in peak flows as follows:

Nant-y-Gath	+ 4½%
Nant Maen	+ 16%
Minor Catchment	+ 10%

5. On restoration, the Nant-y-Gath and Minor Catchment culverts can safely accommodate the peak flows for a 100 year return period NO storm whereas the Nant Maen will flood at more frequent intervals than it does at present.

6. The capacity of the Nant Maen culvert is estimated to be 2.0 cumecs in its present state.

7. It is possible to increase the capacity of the Nant Maen culvert to accommodate a peak flow for a 100 year return period NO storm at a cost of £12,500 and in addition, repair work costing £2,500 would need to be carried out.

8. Alternatively, the peak flow into the Nant Maen culvert could be reduced to 2.0 cumecs and the excess flow either stored on site or routed into the Nant-y-Gath culvert which can safely accommodate the additional flow. The cost of these options are

not readily identifiable since they would form part of the land restoration works.

9. It will, in any event, be necessary to carry out certain repair works to the Nant-y-Gath culvert at an estimated cost of £5,000 and to the Nant Maen at an estimated cost of £5,500. However, should it be decided to increase the capacity of the Nant Maen culvert, then the cost of repair work will reduce to an estimated cost of £2,500.

10. Should it be decided to provide a structural lining to the recently installed 900 mm. diameter concrete pipes on the Nant Maen culvert, then this has been estimated to cost £14,000.

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Q.J.E.G, Volume 3, No. 4, 1970.

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In Anon (1969)

APPENDIX A

National Coal Board
No. 7 South West Region
Farm Road, Aberaman, Aberdare, Glam. CF44 6LX

Opencast Executive

NCB

Our ref OE/7/CON 31/7
Your ref

Sir Alexander Gibb & Partners,
124, Cathedral Road,
Cardiff,
South Glam.

1st October, 1984

Dear Sirs,

Hydrological Survey - Garnant Site

The National Coal Board Opencast Executive are considering the appointment of a Consultant to carry out a Hydrological Survey of Garnant Site and associated drainage points. Also to act as an expert witness at a Public Inquiry in connection with Garnant Site.

I attach copy of the draft Consultants brief for your consideration.

In connection with the above you are requested to attend a meeting at these offices on Thursday 11th October at 2.00 p.m. to discuss the above and your rates and fees. The Conditions of Engagement will be A.C.E. 1970 Edition.

Would you please acknowledge receipt of this letter and confirm the date and time stated.

Yours faithfully,

A.G. Brown

A.G. Brown
Regional Purchasing & Contracts Officer

SIR ALEXANDER GIBB & PARTNERS
CARDIFF
-2 OCT 1984
ANS BY

AGB/GMD

Telephone : Aberdare 874201 Ext.

PROPOSED GARNANT SITE

Draft Brief for Hydrogeological Consultant

The Executive wish to develop an opencast mine for the production of some 413,800 tonnes of anthracite coal at Garnant, near Ammanford, Dyfed. The proposed site is some 3.5 miles East of the town of Ammanford and immediately to the South of the village of Garnant, centered on grid reference 268,500E 213,800N (Reference Sheet SN61 of the 1:25,000 scale Ordnance Survey).

A planning application for the development of the opencast mine was recently submitted to the Mineral Planning Authority, the application was refused. An appeal to the Secretary of State of Wales, against the decision is to be made by the Executive. The appeal will result in a local Public Inquiry being conducted by the Inspector acting for the Secretary of State.

One of the major considerations at this Inquiry will be, whether or not adequate capacity exists in the three culverts, the entrances to which are marked 1, 2 and 3 on the attached Drawing No. 07D 8250, to convey any water generated within their catchment areas, during the working and following restoration of the proposed Garnant Opencast Site, without increasing the risk, which at present exists, of the culverts proving inadequate to convey the water generated in their catchment areas by storms of varying intensity and duration.

The appointed Consultant will be required to investigate fully all aspectsd of the hydrology and related hydrology of the catchment areas prior to, during and after the restoration of the proposed Garnant Opencast Site. The investigation should include but not be confined to the following:

(a) Present drainage system

(i) Survey and gauge all streams and watercourses within the catchment areas to the point where they join the River Amman, obtain complete details including dimensions and shape of the streams/watercourses and culverts together with the structural details and condition of the existing culverts in the catchments.

(ii) Calculate the adequacy of the existing culverts and watercourses in relation to storms of varying intensity and duration, and obtain estimates of probability of flooding resulting from any inadequacy of the culverts and/or water courses with the Catchments. Research to obtain any known instances of flooding related to the culverts and/or watercourses and obtain details of original construction of the culverts and any later amendments to their construction.

(iii) The transportation of water into or out of the catchment areas due to geological structure and/or mining activity including infiltration enhancement and catchment storage.

(b) Future Drainage System

(i) Study the Executive's proposed method of working the proposed Garnant Opencast Site and to investigate the effect of such working during the operational life of the Site and on restoration, including any reduction in infiltration rate, ground storage and loss of surface storage.

(ii) Should increase flow be expected at any culvert and/or watercourse during the working of the site or following restoration, to investigate and propose together with costings, remedial actions, including any limitations which would be required to the rate of pumping from the excavations.

In addition the appointed Consultant shall prepare a detailed Report for the Executive prior to the Inquiry and will be expected to act as an expert witness on the Board's behalf on all matters related to the above at the Inquiry into the proposed Garnant Opencast Site.

The appointed Consultant will have free access to any relevant information in the Board's possession.

APPENDIX B

APPENDIX B

SCHEDULE OF INFORMATION

MADE AVAILABLE BY NATIONAL COAL BOARD

1. Newspaper cuttings concerning the Garnant Site from the South Wales Guardian, South Wales Evening Post and Western Mail for the following dates:

20.08.1981	25.08.1983
31.03.1982	01.09.1983
08.04.1982	17.09.1983
09.05.1982	22.09.1983
21.10.1982	23.09.1983
06.01.1983	28.09.1983
20.01.1983	29.09.1983
03.02.1983	13.10.1983
24.02.1983	27.10.1983
03.03.1983	24.11.1983
23.06.1983	30.11.1983
30.06.1983	01.12.1983
04.08.1983	08.12.1983
11.08.1983	19.01.1984

2. Rainfall Data for Upper Lliw Reservoir, Brynamman Meteorological Stations and Glyn Glas Site for the period 1976 - 1982. For Upper Lliw Reservoir and Brynamman Meteorological Stations, daily and monthly rainfall figures given. For the Glyn Glas Site only monthly rainfall figures given.

3. Application dated 14th March 1984, for planning consent under the Town and Country Planning Act 1971.

4. Abstracts from proposed contract specification, namely, clauses 33 to 66 inclusive and Addendums 3, 4, 5 and 14

5. Final Site Report for Garnant Site dated May 1982.

6. National Coal Board Leaflet entitled 'Opencast Operations 1'.

7. Article reprinted from "Colliery Guardian" February 1975, Vol. 223, No. 2, entitled 'Opencast Coal Mining in Britain: The First 32 Years' by R. T. Arguile, Chief Operations Engineer, NCB Opencast Executive.

8. Excerpt from Proceedings, Vol. LXXXVI No. 1, of the South Wales Institute of Engineers entitled "Some Aspects of Opencast Coal Mining in South Wales" by G. T. Whincup.

9. Article reprinted from "Colliery Guardian" August 1983, entitled 'Opencast - The history of a site, before, during and after production' by G. F. Lindley, Managing Director, NCB Opencast Executive.

10. Drawings as follows:

Geotechnical Borehole Plan	07D8156
Borehole Plan	07D7956
Cross Sections (3 No.)	07D7954
Cored Borehole Sections	07D7959
Topsoil and Subsoil Plan	07D8159
Rockhead Contour Plan	07D7961
Drift Thickness Plan	07D7962
Old Workings Plan	07D7996
Planning Application Drawings	G1 - G8