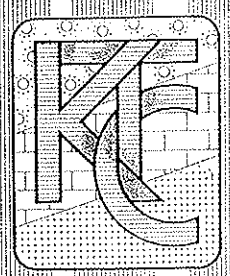
BALLYMURTAGH OPEN PIT

REPORT ON THE HYDROGEOLOGICAL SURVEY

OF

A PROPOSED WASTE DISPOSAL SITE.



Kevin T. Cullen

Hydrogeological & Environmental Services

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10 March 1987

Volume 1.

Summary

I Introduction

Wicklow County Council is responsible for the planning, organisation, authorisation and supervision of waste operations in its area under the European Communities (Waste) Regulations 1979. The Council's Draft Waste Plan for the county produced in May 1981 concluded that the waste disposal capacity at the existing Local Authority landfill sites was near exhaustion and stressed the urgent need to locate and develop additional waste disposal sites.

The search for new landfill sites begun by Wicklow County Council in 1985 identified a number of potentially suitable sites in both the north and the south of the county. The disused open pit mines at Avoca were selected for investigation because of their central location with respect to the main population centres in the south of the county, their concealed setting and their availability.

II Investigation

A brief preliminary report on the suitability of the open pits at Avoca was completed by the author in the summer of 1985. The initial survey concluded that the disused Ballymurtagh open pit in West Avoca would be suitable for development as a landfill and recommended that a detailed hydrogeological investigation be carried out at the old mine workings. This investigation was directed at establishing the overall structure of the open pit and determining what impact, if any, proposed development would have on local groundwater and surface water resources.

III Conclusions

The Ballymurtagh open-pit is an extensive surface excavation which is part of the abandoned and derelict mine workings that characterise this part of the Vale of Avoca. The very long history of base metal mining in both East and West Avoca is now reflected in the continuous contamination of the local groundwater by heavy metals and by the pollution of the Avoca River by mine discharges. The present hydrogeological survey of the Ballymurtagh open-pit concludes that it is a suitable site for development as a modern landfill with its location, structure and associated spoil heaps providing many operational advantages. Two methods of site development are discussed which are essentially characterised by different methods of leachate control and management. The unique hydrochemical conditions existing beneath West Avoca and in the Avoca River downstream of the mining district would allow the open-pit to be operated as a fully contained landfill or as a dilute and disperse site without affecting the overall quality of either the local groundwater or the Avoca River. In this respect, the final method of the site development and leachate management chosen for the Ballymurtagh open-pit must be considered in terms of the possible rehabilitation of this important river and the County Council's present policy on effluent discharges into the Avoca River below East and West Avoca.

The dis-used Ballymurtagh open-pit mine provides an air-space of approximately 200,000 m3 and offers a life of 25 years at an annual disposal rate of 8,000 tonnes. The excavation has been infilled to the present floor level by tailings from the former mill at the mine. These tailings have drained through the base of the open-pit and are now in a medium dense condition and capable of supporting

domestic refuse.

Two methods of site development are discussed which differ principally on the method of leachate control. One method would allow the site to operate as a dilute and disperse site with leachate generated within the refuse being allowed to migrate through the base of the site and pass into the groundwater within the underground workings beneath the open-pit. This leachate would be attenuated during its passage through the free draining tailings, diluted by the large groundwater throughout the flooded underground workings and futher diluted in the Avoca River following its discharge into the river via the mine overflow pipe. The present quality of both the groundwater beneath the open-pit and the Avoca River is such that the principal effect of the leachate on either of these bodies of water would be a possible discoloration.

The open-pit could be operated as a fully contained landfill by lining the base and sides of the excavation with a synthetic impermeable liner. Leachate generated by rainfall falling on the catchment of the landfill would be collected and treated by an on-site treatment plant and discharged to the Avoca River via the existing mine overflow pipe. The proposed design would allow for excess leachate production during periods of intense rainfall to be stored within the base of the excavation for eventual treatment and disposal. The proposed leachate treatment plant would provide a final effluent to acceptable standards and so would not detract from the water quality in the Avoca River either in its present state or in the event of this river being rehabilitated. The additional costs of lining the open-pit and operating the leachate

treatment plant must be seen in terms of the likelihood of a significant improvement ever being achieved in the water quality in the Avoca River downstream of the old mining district.

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BALLYMURTAGH OPEN PIT

REPORT ON THE HYDROGEOLOGICAL SURVEY

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10 March 1987.

I Introduction

I.I Scope of Report

This Report, dated 10 March 1987 describes the results of a hydrogeological investigation that was carried out at a disused open pit in West Avoca, Co. Wicklow. The various works and studies outlined in the report were commissioned by Wicklow County Council to determine whether the disused open pit could be developed as a landfill site for the disposal of domestic refuse.

Wicklow County Council as a Waste Disposal Authority, is required by the European Communities (Waste) Regulations, 1979 to plan, organise and supervise waste operations in its area. The present waste disposal capacity at existing Local Authority sites is nearing completion and the need to identify additional sites is now very pressing. In addition to the Co. Council requirements, the capacity of Arklow U.D.C.'s tip head is also nearly exhausted, with the result that a central waste disposal site is now urgently required to serve the southern part of the county.

Wicklow County Council began a programme of potential site selection in 1985 and this survey identified a number of suitable sites which included the various disused open pits associated with the abandoned mine workings at East and West Avoca. The Ballymurtagh open pit was

selected as the most suitable of the open pit excavations at Avoca due to its proximity to a public road, ease of access and concealed position. These aspects, in addition to its central location with respect to the area to be serviced and the abundance of cover material provided sufficient encouragement to warrant a detailed investigation of the full potential of the Ballymurtagh open pit as a landfill site.

Wicklow County Council commissioned the author in July 1985 to carry out a preliminary hydrogeological investigation of the open pits at Avoca to determine their overall suitability for development as landfill sites with particular reference to their physical features and hydrogeological regimes. During the course of this reconnaissance survey it became clear that most of the open pit excavations were unsuitable due to their elevated position and difficult access. However, the author's report of 15 September 1985 concluded that the Ballymurtagh open pit appeared to have both physical and hydrogeological characteristics that would allow for its development as a landfill site for the safe disposal of domestic refuse. A detailed investigation was recommended to confirm the initial findings and authorisation to carry out the necessary works and studies at the Ballymurtagh open pit was given by Wicklow Co. Council in a letter to the author dated 10 March 1986.

Note: The Ballymurtagh open pit has also been referred to as the Ballygahan open pit as the excavation straddles the boundary between these two townlands. The former description is adopted here to correspond with various mine drawings used in the preparation of this report.

1.2 Waste Disposal - Wicklow County Council's Policy

The following paragraphs are taken from the Draft Waste Disposal Plan prepared by Wicklow County Council and dated March 1981.

"1.1 In order to preserve the amenities of the county, and also to ensure that public health is not endangered, it is necessary that an adequate and efficient refuse collection service and disposal system or systems be established and maintained."

"1.1 Wicklow is a county of very high amenity value and contains some of the finest scenery in the country. It is of utmost importance that this gift of nature be protected and nourished. It is a valuable tourist attraction in addition to being a source of enjoyment to the people of Wicklow."

Also, some notes on the proposed central waste disposal site at West Avoca as prepared by Mr. M. O'Keeffe, Senior Executive Engineer, Wicklow County council and dated April 1986.

"General

1. Traditionally, Local authorities tend to go for a large number of small sites dotted around the county, with convenience of access being a major consideration. These dumps tended to be inadequately maintained, were usually filled beyond their natural capacity, and resulted in the creation of eyesores. Understandably, there was a resultant bad press for waste disposal in general.

2. There has been a strengthening of legislation in recent years, including under the Planning Acts and E.E.C. Waste Directives, together with a growing awareness and financial input by Local Authorities themselves. Development of standards and criteria

(e.g. Geotechnical guidelines on waste disposal site selection, design and management, by the Geological Survey Office) is also an on-going process.

3. There has been a growing awareness and sensitivity on environmental issues by the general public in recent years, including the emergence of specialist pressure groups etc.

4. The above factors combine to make it essential that any site being considered as a waste disposal site would have to fulfill far more stringent criteria than applied in the past.

5. The major factors influencing selection and development of new sites would include:

(a) Topography and geology, including subsoil conditions.

(b) Proximity of aquifer zones.

(c) Climatic conditions, i.e., rainfall and evaporation conditions (e.g. low residual rainfall sites minimise the problem of leachate control).

(d) Proximity to adjoining dwellings and private an public water supply sources.

(e) Environmental impact on adjacent area.

(f) "Social Factors" such as distance from sources of waste, ease of access, site acquisition etc.

6. Wicklow County Council policy is to locate, investigate, develop and manage new waste disposal sites on the basis of established criteria and guidelines, having particular regard to hydrogeological suitability,and the selection of sites which would have a minimum impact on the surrounding environment. It is also recognised that the development, operation, and day-to-day management of any such site would be of paramount importance in having it accepted by the general

public.

7. The costs involved in achieving the required standards are such as to preclude consideration of any sites other than those which could act as central waste disposal sites covering wide areas of the county.

Specific Factors Relating to Ballygahan Site

8. The location of the Ballygahan site is such as to serve the entire south of the county, i.e., from Wicklow through to Arklow to Tinahely, and ultimately as far west as Baltinglass. Arklow U.D.C. presently disposes to its own site at Clogga, but would ultimately relocate to Ballygahan. Even allowing for this relocation, the quantity of refuse generated would be relatively low, i.e. 8,000 - 10,000 tonnes per annum, hence the lengthy projected life span for the site. Given the population projections for this area set out in the ERDO study, trends in waste generated should remain fairly stable, with only slight percentage increases per annum."

1.3 Legislation On Waste Disposal

Seven directives have been adopted by the Council of Ministers on the subject of waste disposal. These are as follows:-

a) Council Directive of 16 June 1975 on the disposal of waste oils (75/439/E.E.C.).
Implemented in Ireland by; European Communities (Waste Oil) Regulations, 1984 (S.I. No. 107 of 1984).

b) Council Directive of 15 July 1975 on Waste 75/442/E.E.C.
Implemented in Ireland by; European Communities Waste Regulations, 1979, (S.I. No. 390 of 1979).

c) Council Directive of 6 April 1976 on the disposal of P.C.B.'s (76/403/E.E.C.).
Implemented in Ireland by; European Communities Waste No. 2 Regulations, (S.I. NO. 388 of 1979).

d) Council Directive of 20 March 1978 on toxic and dangerous waste (78/319/E.E.C.).
Implemented in Ireland by; European Communities (Toxic and Dangerous Waste) Regulations, 1982 (S.I. No. 33 of 1982).

e) Council Directive 78/176/E.E.C. on waste from the titanium dioxide industry.

f) Council Directive 84/631/E.E.C. on the transfrontier shipment of hazardous waste.

g) Council Directive 80/68/E.E.C. on the protection of groundwater against pollution caused by certain dangerous substances.
Implemented in Ireland through the Water Pollution Act 1977.

2. Site Location And History

The Ballymurtagh open pit is a disused mining excavation which is part of the very extensive Avoca mining area located in the Vale of Avoca, County Wicklow. The Ballymurtagh site lies in West Avoca on the west bank of the Avoca river which divides the extensive mining district into East and West Avoca. Both underground and surface mining has taken place at Avoca with the subsurface workings extending down to considerable depths. The main surface workings are at Cronebane in East Avoca and at Ballymurtagh in West Avoca.

The Avoca mining district is located in the eastern foothills of the Wicklow Mountains in rolling farm land at an elevation of 150-180 m. above sea level. The Avoca River forms the principal relief in the area as it occupies a deeply incised gorge between the "Meeting of the Waters" and Woodenbridge on its way to its estuary at Arklow Town. The site is very centrally located with respect to the main population centres in the south east of the county being some 25 kms from Wicklow Town, 10 kms from Arklow, 15 kms from Aughrim and 10 kms from Rathdrum.

The Avoca mines have a recorded history of orderly mining since 1752 for both copper and sulphur. The Avoca ore bodies were discovered at their exposure on the banks of the Avoca River and mining has since spread on both banks over a strike length of 3.5 kms. No significant discovery of new ore has been made at Avoca for the past 120 years, although during the past few decades the known ore bodies have been followed and exploited well beyond the limits known in the nineteenth century.

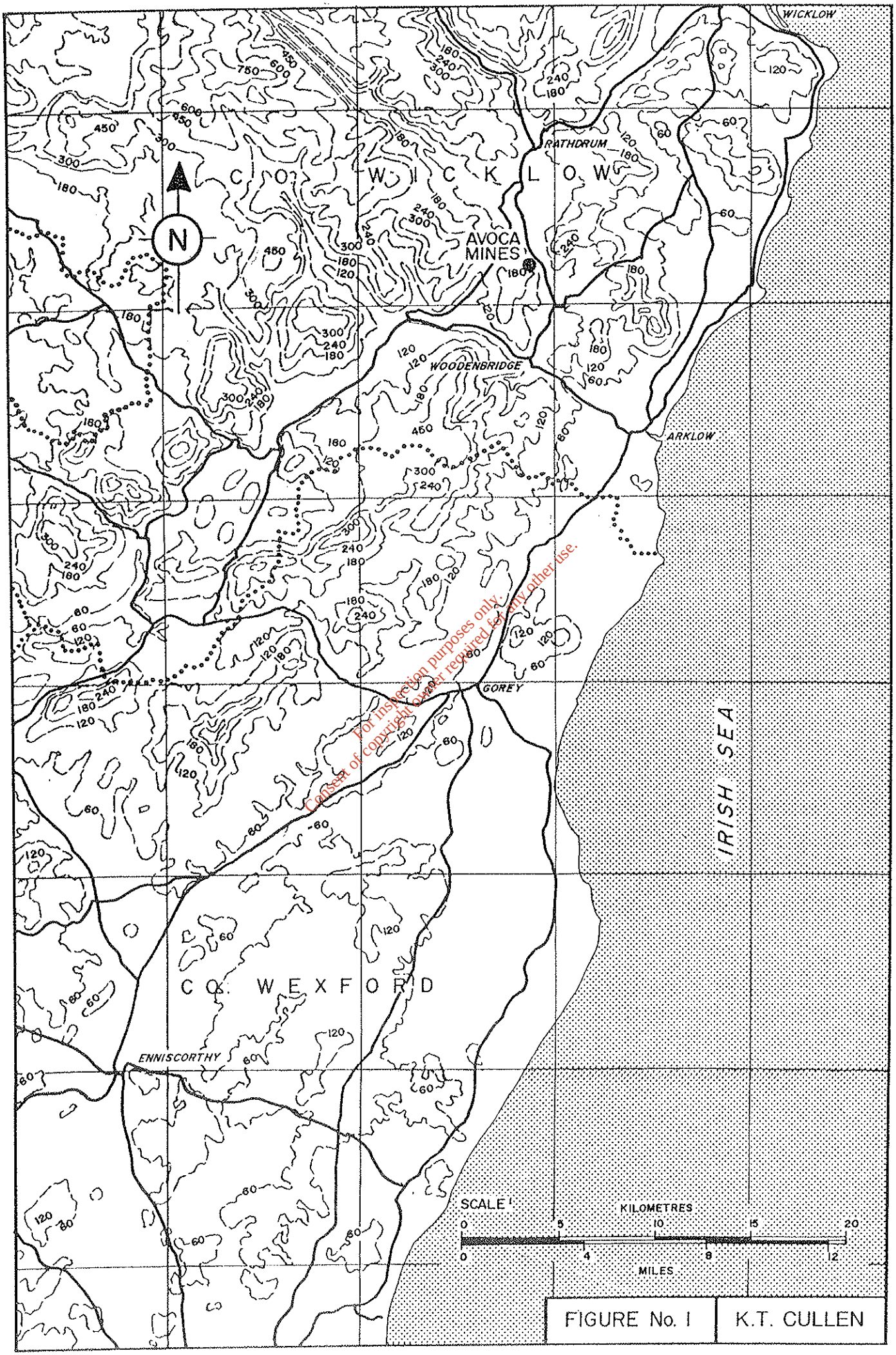


FIGURE No. 1 | K.T. CULLEN

Prior to the Second World War some 5 million tonnes of massive sulphides were mined at Avoca by numerous small workings. During the 1940's the state owned mining company, Mianrai Teoranta undertook extensive underground development on both sides of the Avoca Valley and proved substantial copper and pyrites reserves. The mine was operated during the period 1958-1962 by St. Patrick's Copper Mines Ltd. and in 1969-1982 by Avoca Mines Limited. A total of 16 million tonnes of base metal concentrates have been exported from the Avoca mines to date in addition to the substantial quantities of pyrite concentrates which have been sold to the N.E.T. fertiliser plant at Arklow for the manufacture of sulphuric acid.

Avoca Mines Limited is in receivership at present and no mining is taking place and the underground workings have been allowed to flood. Numerous mineral reserve studies have been carried out at the Avoca mines during its recent checkered history and the consensus of opinion is that the limited reserves beneath the existing workings cannot sustain an economic mining operation. The Avoca mineral belt still remains an attractive area for exploration for base and precious metals and further ore bodies may well be located here in the future. However, such ore bodies will be removed from the existing worked out areas of East and West Avoca.

2.1 Site Description

The Ballymurtagh open pit is a disused mine excavation which was developed to exploit the Pond Lode in West Avoca. The pit itself covers approximately 1 hectare which is fully enclosed by a high metal perimeter fence some 1,370 m long and covering some 8 hectares. The open pit is a long (180 m.), narrow (55 m) excavation which is nearly fully enclosed by high walls of rock and mine waste.

The floor of the Ballymurtagh open pit is a flat surface which results from its use as a settlement pond for liquid mine wastes, with up to 16.5 m. of tailings occuring beneath the present floor. The tailings, which are mainly in the silt range (0.002-0.06 m.m.), have infilled the deeper parts of the open pit and now have a thin covering layer of overburden. While the tailings were in a liquid state when pumped to the open pit for settlement, drainage through the base of the open pit has allowed the tailings to dry out and consolidate. Standard penetration tests carried out during the drilling operations associated with this study indicate that the tailings are now in a medium dense condition and only show signs of softening in the deeper levels below 6 m.. This process of consolidation will continue as further drainage takes place.

The present open pit floor is dry and except for a few seepages from the enclosing walls the excavation is devoid of water. Some isolated ponding of rainwater does take place on the open pit floor where the thin layer of overburden has been compacted by truck movements.

Plate No. 1, which is contained in Volume No. 2 of this report, shows the present entrance to the Ballymurtagh open pit together with the perimeter fence that fully encloses these surface workings. The present level of the open pit level is at 70 m. above Ordnance Datum

(M.O.D.) which is close to the level of the line shown in Plate No. 1. The mouth of the open pit has been dammed and blocked above this level by waste rock and earth from the mine spoil heaps.

Plate No.'s 2 and 3 are west looking views taken inside the open pit close to its entrance. These pictures highlight the steep faces which enclose the pit with sheer rock faces to the north and irregular mounds of overburden to the south. Plate No. 4 shows the western end of the open pit in detail with the recent rockfall clearly visible.

The narrow, near vertical character of the Pond Lode at West Avoca meant that the open pit designed to exploit this ore body acquired essentially the same shape as the mineral deposit. This has resulted in the Ballymurtagh open pit being narrow and bounded by steep and very high faces. Plate No. 5 indicates the height of the north face to the open pit with the present floor giving a completely flat surface within the excavation. In contrast, along the south face of the excavation the rock surface is nearly everywhere hidden by the tonnes of mine waste which have been bulldozed into the excavation from the upper levels along this boundary (Plate No. 6). This material consists of pieces of rock set in a matrix of finer rock fragments (Plate No. 7).

2.2 Site Exposure

The Vale of Avoca has great charm and beauty which has been recognised by the many visitors to this part of County Wicklow. The beautiful scenery of the Avoca Valley with its splendid deciduous woodlands has been severely affected by the mining spoil heaps, abandoned shafts and engine houses that dot the hillsides. The expansion of the mining operation since 1950 has seen the clearing of the woodlands to accommodate the spoil heaps and tailing ponds (Plate No. 9). The present demolishing of the mine buildings in West Avoca will leave a further scar on this beautiful landscape and the development of a landfill at the Ballymurtagh open pit should be used to bring some order to at least this part of Avoca.

Plate No. 10 is a general view of the surrounding countryside from the top of the southern face of the Ballymurtagh open pit. This view shows how the pit is excavated into the hillside and how the excavation is concealed from all directions except from the east bank of the Avoca River. The spoil heaps associated with the Cronebane open pit in East Avoca are clearly visible in the sky line.

Plate No. 11 is a view westwards, taken from the entrance to the open pit at the level of the old mine buildings between the mine and the Avoca River. Any future development of the open pit would include traffic movement at this level which is some 30 m. higher than the nearby county road. A view looking eastwards (Plate No. 12) from this same point shows how the demolition of the former mine building has exposed this level to views from housing situated on the opposite side of the Avoca Valley. Similarly, operations in the entrance to the open pit are presently visible from housing located

at lower levels on the east bank of the Avoca River (Plate No. 13). The housing located on the opposite valley side will always have had views of the mining operations when West Avoca was in production. However, as the public has a different perception of waste disposal operations, some consideration could be given to ensuring that only traffic movements associated with the proposed landfill will be visible from the opposite side of the valley with the tipping, compacting and covering operations screened from general view.

Plate No. 9 shows the present entrance to the West Avoca mine area off the county road R 752 from Rathdrum to Arklow. The mine road sweeps upwards, past the mine office before eventually turning to reach the level where the abandoned crane is parked. This road passes close by some single storey mine houses which are currently occupied. Future plans to develop the Ballymurtagh open pit as a landfill could include the provision of a direct route from the present entrance to the open pit via a new access road located to the south of the old Mill. This operation would require some earth moving to connect the lower road level with the higher open pit level.

3. Method of Investigation and Schedule of Works

The investigation of the Ballymurtagh open pit commenced in the summer of 1985 when the author visited the site and prepared a preliminary report on the overall suitability of the excavation as a landfill site. Subsequently, a series of topographical surveys, borehole drilling and water sampling programmes were carried out to investigate the site in much greater detail. These surveys were carried out during the summer and autumn of 1986 and were supervised by the author or by his staff.

3.1 Topographic Surveys

A topographic survey of the mine and surrounding lands was undertaken by Quill Services Limited using high level aerial photography from which a contoured plan of the site was prepared. This plan has been used as the basis for the cross sections presented in this report.

The positions and levels of the boreholes were established by ground surveys conducted by Stanislaus Kenny and Partners, consulting engineers. Additional ground survey data was used to calibrate the aerial photographic work.

3.2 Borehole Drilling

A contract for the completion of six boreholes at Avoca was given to Irish Geotechnical Services Limited in the summer of 1986. This work commenced in June 1986, employed a "shell and auger" drilling rig, and was completed the same month. The lightweight percussion rig was sufficient to drill through the unconsolidated sediments infilling the disused open pit, but was not capable of drilling through the underlying bedrock. A further series of three boreholes were completed during July in the base of the open pit using a water

well drilling rig operated by O'Donohue Bros. of Hollyfort, Co. Wexford. These boreholes were completed in the bedrock to below the water table and together with the shallow boreholes provided the necessary information on the geology and hydrogeology of the open pit.

3.3 Groundwater and Surface Water Sampling

A programme of water sampling was undertaken at West Avoca and its environs during the winter of 1986 and the results of this work became available in December 1986. The analyses were carried out by the Institute of Industrial Research and Standards at their water laboratory in Finglas, Co. Dublin. Groundwater samples were collected in the three boreholes completed in the open pit; the remaining six boreholes were finished above the water table. Three water samples were collected from the Avoca River both up-stream and down-stream of the West Avoca workings together with a sample of the main discharge from the mine. The locations of these sampling points are given in Fig. No. 2.

4. Meteorology and Surface Water Drainage Details

4.1 Meteorology

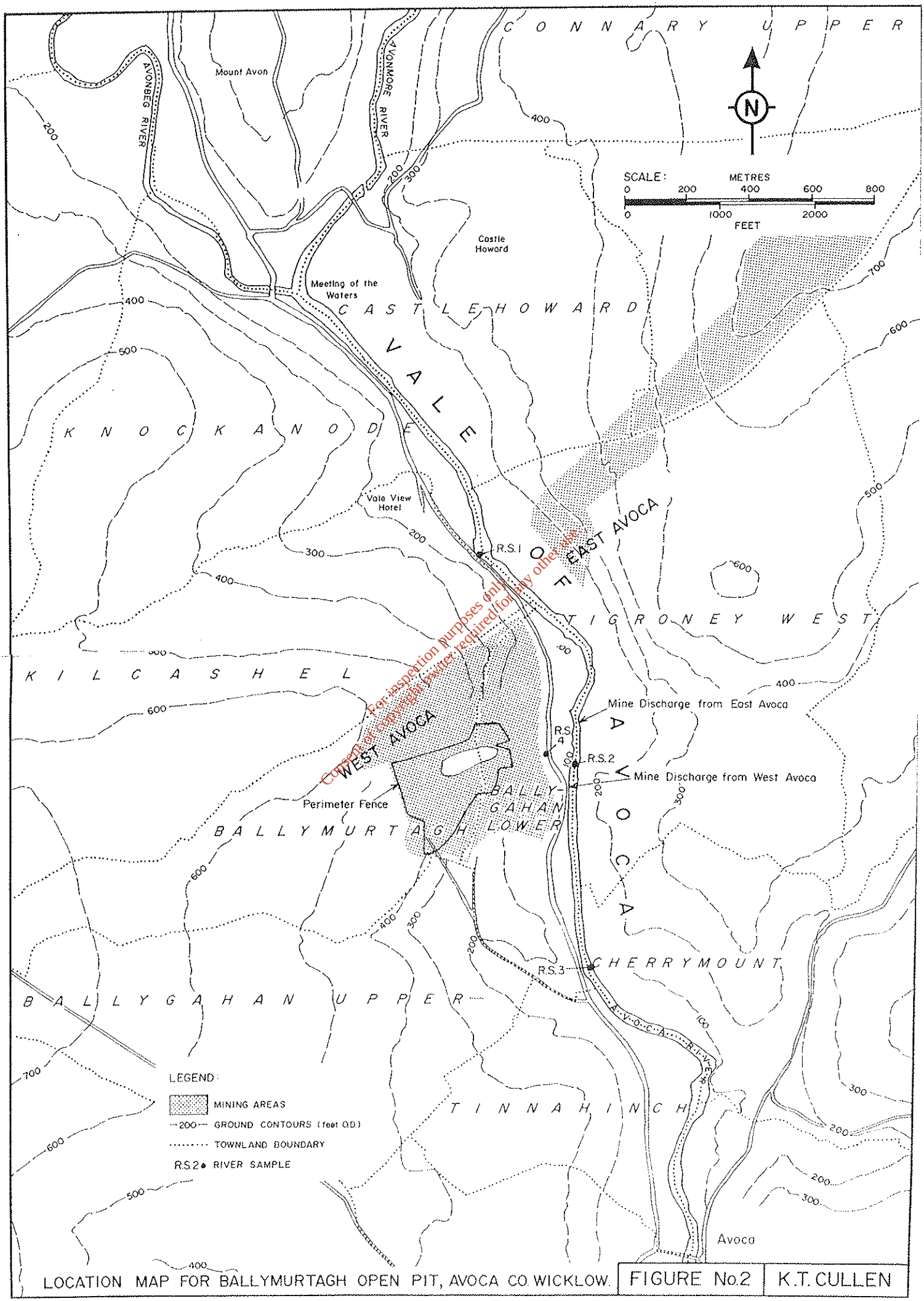
The 1984 publication by the Meteorological Service on the monthly and annual averages of rainfall for Ireland 1951-1980 gave rainfall data for a rain gauge at Avoca Mines, Co. Wicklow. This station was opened in 1971 and closed when mining ceased in 1983. The average annual rainfall at the mines during this period of observation was 1171 m.m.. The monthly averages recorded over the same period are given in Table 1.

Month	Precipitation (m.m.)	Month	Precipitation (m.m)
January	134	July	68
February	98	August	87
March	96	September	108
April	68	October	114
May	79	November	121
June	62	December	137

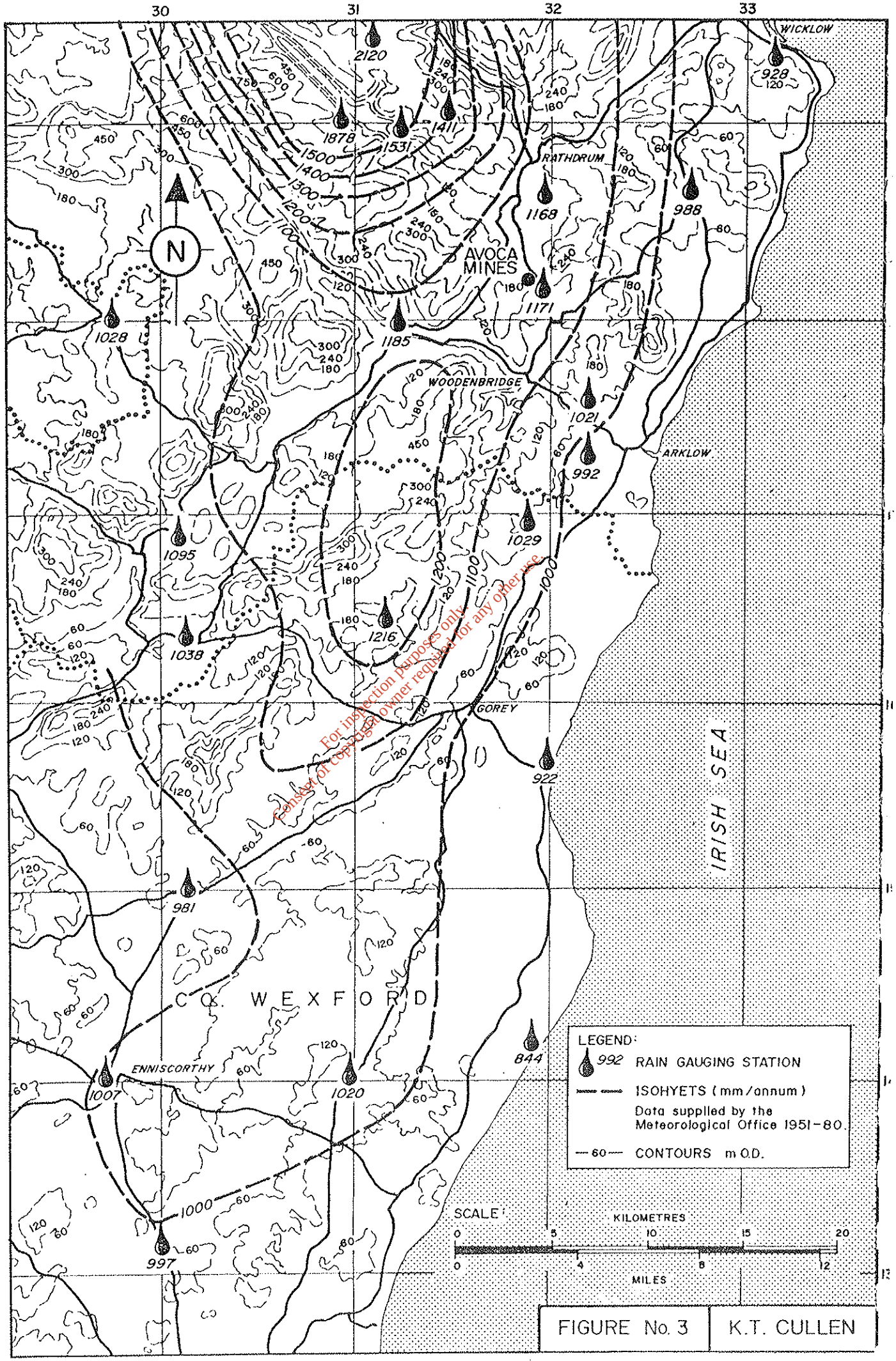
(From Meteorological Office; Climatological Note No. 7, 1984)

Table 1 - Average monthly rainfall figures for Avoca mines, Co. Wicklow (1971-1983).

The accompanying Fig. No. 3 gives the distribution of annual rainfall amounts in Co.'s Wicklow and Wexford. This diagram shows how the Avoca Mines are located on the fringes of the high precipitation area centered on the higher peaks of the Wicklow Mountains. Annual rainfall in the Glendalough and Glenmalure areas



LOCATION MAP FOR BALLYMURTAGH OPEN PIT, AVOCA CO. WICKLOW. | FIGURE No.2 | K.T. CULLEN



can exceed 2,000 m.m., while between the mountains and the Irish Sea the precipitation falls off to around 1,000 m.m. per annum. The Avoca mines are located in a belt where the annual rainfall would amount to between 1,1000 and 1,200 m.m. as recorded at three closely spaced stations, at Avoca Mines, Rathdrum and Aughrim. The wettest months recorded at these gauges are 389 m.m. at Augrim, 387 m.m. at Rathdrum and 340 m.m. at Avoca. These very high rainfall figures occured in 1978 and were nearly 400% of the monthly average and accounted for about 30% of the total annual rainfall that year.

There are no published figures for potential evapotranspiration (P.E.) for meteorological stations on the east side of the Wicklow Mountains. The best available figures for P.E. are from Meteorological stations at Rosslare and from Dublin and Casement airports which give values of 571 m.m., 555 m.m. and 504 m.m. per annum respectively.

4.2 Surface Water Drainage Details

The Avoca Mines lie within the catchment of the Avoca river, which covers some 653 sq. kms and which is by far the largest river catchment in Co. Wicklow. The Ballymurtagh open pit lies some 1.5 kms south of the Meeting of the Waters where the Avonmore and Avonbeg rivers join to form the Avoca River and 5 kms north of Woodenbridge where the Aughrim River joins the Avoca River before it discharges into the Irish Sea at Arklow.

The Avonmore and Avonbeg Rivers rise in the higher parts of the Wicklow Mountains and drain the famous glacial valleys of Glenmalure and Glendalough. River flow measurements supplied by An Foras Forbartha give low flows at Rathdrum and Woodenbridge of 0.9 m3/sec

and 1.27 m3/sec respectively. The catchment over the Rathdrum station is measured at (233 sq. kms) with some (383 sq. kms) feeding the Woodenbridge station.

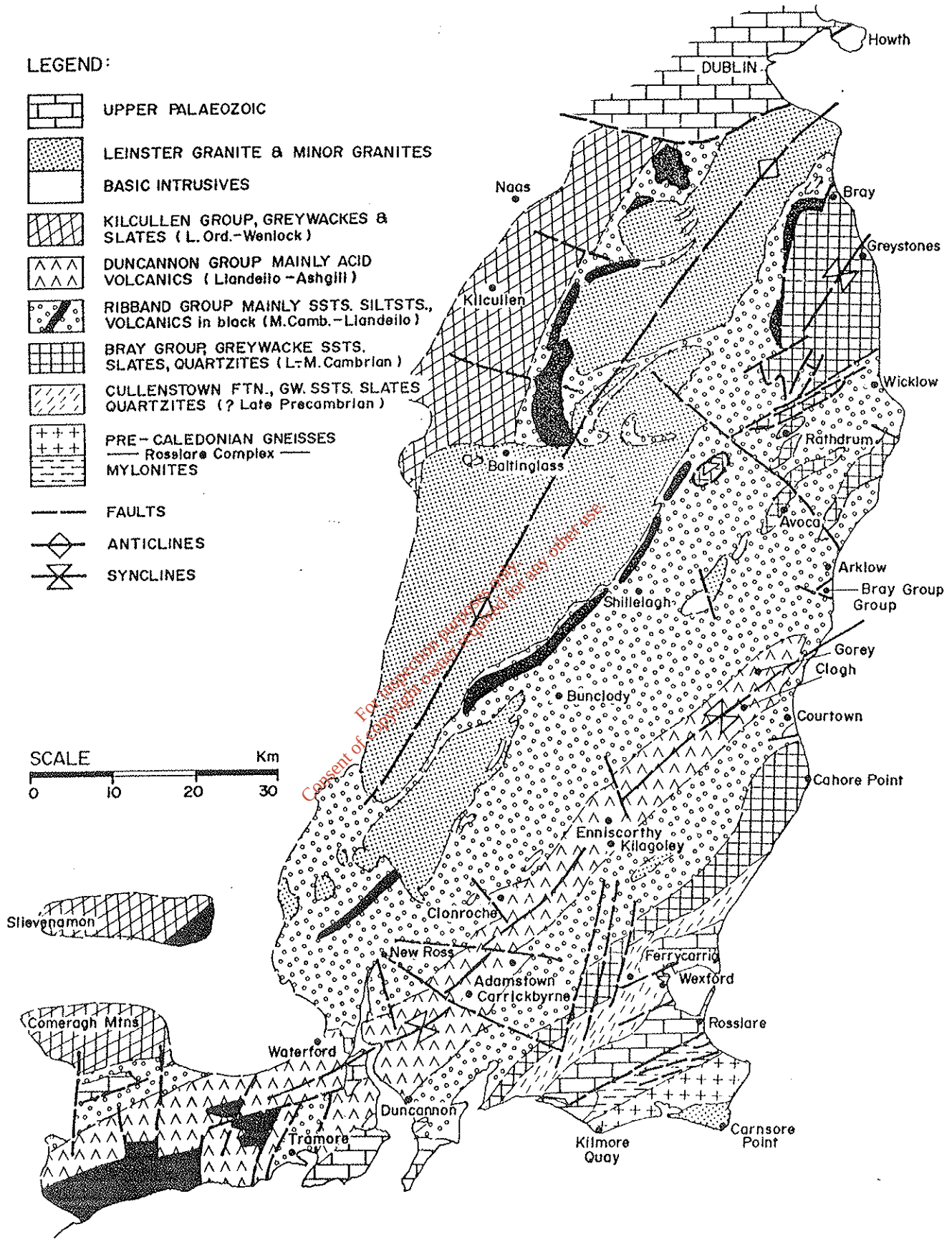
Besides the main tributaries to the Avoca river the sides of the Vale of Avoca are also drained by a number of small streams which discharge directly into the Avoca River. The East Avoca mining district is drained by a surface discharge that feeds the main river via a mill race (Fig. No. 2). The West Avoca mine workings discharge into the Avoca River to the south of the main mine entrance via a small man-made drain that runs parallel to the county road. The discharges from the mine workings in both East and West Avoca are a direct result of the flooding of the underground operations in these two mining districts. Groundwater levels in both areas rose to their present heights when the dewatering pumps were switched off and are kept at these levels by the man-made overflow conduits to the Avoca River.

5. Geology

5.1 Bedrock Geology - Regional Setting

The regional geological stratigraphy of south east Ireland is given in Fig. No. 4 and shows how the greater part of this area is underlain by Lower Palaeozoic rocks which range in age from Lower Cambrian to Middle Silurian. The geological structure of the area is dominated by a major synclinal, the Campile Syncline, structure that runs from Waterford in the south east to near Arklow in the north-east. While this feature not only controls the overall distribution of the rock formations in the region it also conveniently divides the Ordovician strata into two distinct groups; the Ribband Group and the younger Duncannon Group. The former is characterised by huge thicknesses of slates and sandstones while the latter is made up of mainly volcanic rock types. Pockets of the Duncannon Group are scattered throughout the region outside the central core of the synclinal structure and the Avoca Belt is one such outlier.

The Avoca ores have been worked underground at West Avoca and until recently in the Cronebane open pit at East Avoca. The ores occur within the Duncannon Group volcanics which here are some 500 m thick and consist of felsitic crystal and lithic tuffs, rhyolite, rhyolite breccias, mudstones and dolomitised sericitic and carbonaceous beds. The ores consist of both massive and stringer deposits. The massive sulphides comprise mainly a banded chalcopyrite-pyrite ore and a pyritic lead-zinc-copper ore. The stringer ores underlie the massive sulphides and comprise braided veinlets of quartz with sulphide. The association of massive sulphides with stringer ores suggests a volcanogenic origin.



Regional Geology of South East Ireland.

FIGURE No. 4

K.T. CULLEN

The detailed geology of West Avoca, as supplied by P. McArdle of the Geological Survey of Ireland, is given in Fig No. 5 This drawing shows the distribution of the various volcanic rock types at West Avoca together with the principal mining structures. The various lava flows, tuffs and shales, within the Avoca volcanic pile are considered to have been deposited in connection with volcanic centres in the immediate area of Rathdrum and the areas surrounding East and West Avoca. These volcanic rocks have been subjected to intense structural deformation and all show varying degrees of metamorphism. The regional north-east south-west structure controls the distribution of the various rock types which also display tight isoclinal fold structures. The base metal ore bodies associated with the volcanic pile at Avoca West are tabular or lens-shaped features which broadly follow the south east dipping slaty cleavage associated with the isoclinal fold structures.

Late stage faulting has also been important in determining the distribution of the various volcanic rocks at West Avoca. The important Avoca Fault is seen to cut across the open end of the Ballymurtagh open pit.

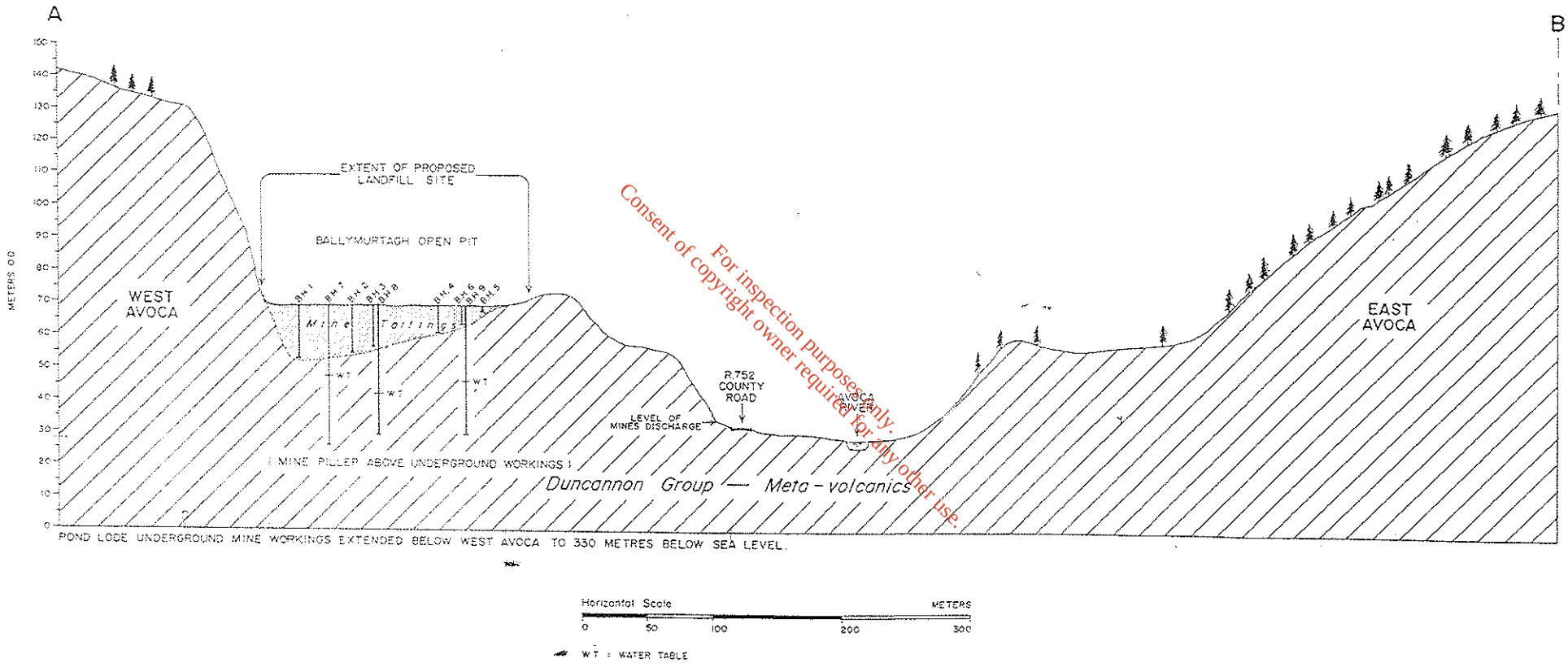
5.2 Unconsolidated Deposits

As with most parts of Ireland the Avoca area was heavily glaciated during the two major cold stages to have affected Ireland in the past 200,000 years. However, while the topography of the Vale of Avoca shows many glacial landforms this part of the valley is nearly devoid of glacial sediments with rock outcropping over much of the mine area. Therefore, no further attention will be paid in this report to the occurance of glacial sediments in the Avoca area.

5.3 Bedrock Geology - Ballymurtagh Open Pit

A series of 9 boreholes were completed during this study to provide information on the content of the lower parts of the Ballymurtagh open pit, the underlying bedrock and the position of the local water table. Six of the boreholes were located to define the base of the infilled open pit while the remaining 3 boreholes were used to test the underlying bedrock. The logs of these boreholes are given in Appendix I together with the finished design of the boreholes. The locations of the boreholes are given in Figure No. 5 and interpreted in the cross-sections in Fig. No.'s 6 and 8.

Borehole No.'s 1-6 were drilled to the base of the mine tailings and these indicate a depth to sound bedrock varying from 16.5 m. at the western end of the open pit to less than 2.0 m. at the entrance to the excavation. The tailings consist of a fine, mainly silt sized sediment which is the settlement portion of the sludge pumped to the Ballymurtagh open pit from the former mine mill. It represents the waste products from the primary and secondary crushing of the ore after the base metals have been abstracted. While the tailings were in a liquid state when they were pumped into the open pit they have become quite dense and consolidated as drainage has taken place



CROSS SECTION TROUGH WEST AVOCA & THE AVOCA RIVER.

FIGURE No. 6	K.T. CULLEN

through the base of the open pit. In situ standard penetration tests carried out during the drilling operation indicate that the tailings are currently in a medium dense condition at upper levels, only showing signs of softening at levels below about 6 m.. The available information indicates that domestic refuse could be placed on the dried tailings without significant perforation of the crust. However, the use of a semi permeable synthetic membrane and a 500 mm granular foundation are recommended for temporary access roads across the tailings surface.

The boreholes drilled to the base of the tailings were completed with standpipes to indicate the level of water contained in these deposits. These standpipes have remained dry to date indicating that the drainage of the wet tailings through the base of the open pit has been complete. This picture is confirmed by the water levels recorded in the boreholes drilled into the underlying bedrock. These indicate a water table below the base of the Ballymurtagh open pit controlled by the discharge from the underground workings.

The three boreholes completed in the bedrock below the base of the open pit encountered a blue grey metamorphosed volcanic tuff. This agrees with the present geological picture of the excavation which shows a series of chloritic and sericitic tuffs separated by a zone of massive sulphide ore. All three boreholes encountered sound bedrock to their finished depths confirming that underground workings have left a thick unworked pillar below the open pit.

6. Hydrogeology and Hydrochemistry

6.1 Hydrogeology

The previous items have described in some detail the geological setting of the Ballymurtagh open pit. The present situation will outline the main hydrogeological features of the mine and the nature and composition of the groundwaters presently discharging from these abandoned workings.

Unlike many areas of Ireland the hydrogeological framework of the open pit and underlying workings is relatively simple as:

(i) The area is quite elevated.

(ii) Little overburden covers the bedrock.

(iii) The excavation is on the side of a major river valley.

(iv) The discharge from the old underground workings is controlled by a man-made over-flow pipe.

These features, together with the extensive network of underground shafts, stopes, haulage ways and declines, provide eventual access for both rain water and groundwater to the nearby Avoca River. Also, the overflow pipe controls the level of the groundwater in the bedrock beneath the open pit, and while some water table fluctuations will occur this conduit will help to dampen the effect of these seasonal changes.

During the active mining of West Avoca a primary crusher was located at approximately 335 m. below sea level with the base of the main conveyor system located a further 30 m. lower at 365 m. b.s.l.. A major pumping operation was required at West Avoca to maintain dry working conditions in all the levels above the conveyor and primary crusher. This pumping station resulted in a cone of depression

within the local water table which was centered on the deepest point of the underground workings. All water encountered in the various mine workings was channelled down to the main pumping station for final pumping to the surface and eventual discharge.

When the mine was put into receivership the dewatering pumps were eventually turned off and the underground allowed to flood. An over-flow pipe was constructed in the upper levels of the mine to allow the flood waters to drain directly into the Avoca River. The discharge from this pipe is seen to come to the surface along side the public road close to the main entrance. The discharge from the mine during this study was estimated at between 2000 and 3000 m3/day. The particularly wet summer of 1986 did not provide an ideal opportunity to gauge the effect of dry periods on this discharge. However, the vast storage of groundwater within the underground excavations is likely to ensure that the discharge from the mine is kept at a fairly constant rate even during dry periods.

As mentioned previously, the Ballymurtagh open pit and surrounding ground are essentially devoid of water, i.e. all rain water quickly percolates through the thin soil cover or bare rock down into the old mine workings. The extensive excavations and blastings associated with the long history of mining have provided ample openings for surface water to rapidly find its way to the water table. Similarly, the tailings in the open pit have been able to drain completely through the base of the excavation into the underground workings.

Water levels have been collected in the various boreholes completed during this study and they indicate a water table located below the

base of the open pit. These water levels are given in the borehole logs and shown graphically in Fig. No. 6. The water levels reflect the variation in the topography surrounding the open pit and clearly show a water table above the level of the mine overflow but below the base of the open pit. These levels can be expected to rise with rainfall and fall during dry periods, with the lowest level controlled by the overflow pipe elevation.

6.2 Hydrochemistry

Landfills generally are associated with the generation of leachate which has the capacity to pollute and contaminate both surface water and groundwater if its disposal is not properly controlled. Therefore, it is important that in any study of this nature that the chemistry of all waters in and around a proposed landfill site be assessed. Such information is required to determine whether the various waters at and beneath a possible landfill constitute a useful supply of fresh water.

Samples of both surface waters and groundwater were collected at West Avoca in the Winter of 1986 and forwarded to the I.I.R.S. water laboratory for full chemical analyses. The results of these analyses are tabulated in Tables 2 and 3 of this report. The surface water samples were collected in the Avoca River both up-stream and down-stream of the Avoca mining district, with one sample immediately upstream of the West Avoca mine discharge. A sample of the groundwater discharging from below the Ballymurtagh open pit was also collected and the chemistry of this water is compared to the Avoca River water in Table 2. Samples of groundwater beneath the open pit were collected from the 3 boreholes drilled into the bedrock below the open pit. The chemistry of this groundwater in West Avoca is compared in Table 3 with an analysis of mine waters from East Avoca.

6.2.1 Avoca River

It has been known for some time that the water quality in the Avoca River is of particularly poor quality below the Avoca mines. Discharges from the mine have been identified as the source of this contamination and the effect of these is sufficient to render

Parameter	Unit	Surface Water Samples				EEC GUIDELINES	
		Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Guide level	Admis Max
Calcium	Ca mg/l	6.0	3.0	4.8	Int	100	-
Magnesium	Mg mg/l	1.0	4.0	6.3	Int	30	50
Sodium	Na mg/l	5.0	5.0	5.0	10	20	175
Potassium	K mg/l	0.8	1.2	0.9	2.6	10	12
Bicarbonate	HCO3 mg/l	N.E	N.E	N.E	N.E	-	-
Sulphate	SO4 mg/l	13	19	32	5200	25	250
Chloride	Cl/mg/l	12	12	12	50	25	-
Ammonium	NH4 mg/l	<0.1	<0.1	<0.1	1.03	0.05	0.5
Nitrite	NO2 mg/l	<0.01	<0.01	<0.01	<0.01	-	0.1
Nitrate	NO3 mg/l	2.2	1.8	1.6	<0.1	25	50
Copper	Cu mg/l	<0.1	0.1	0.1	4.0	0.1	-
Iron	Fe mg/l	0.2	0.3	2.0	160	0.05	0.2
Manganese	Mn mg/l	0.1	0.3	0.4	105	0.02	0.05
P.V. @ 4 hours	O2 mg/l	3.9	4.2	4.2	Int	2	5
T.O.C.	C mg/l	4.7	5.7	8.1	2.9	-	-
pH	UNITS	6.3	4.6	4.5	3.7	6.5-8.5	-
Hardness	CaCO3 mg/l	20	24	38	Int	-	-
Colour	HAZEN	20	30	15	150	1	20
Turbidity	N.T.U.	1.4	4.9	4.3	7.5	1	10
Conductivity	Us/cm	56	72	100	5,200	400	-
Alkalinity	CaCO3 mg/l	3	<1	<1	<1	-	-
B.O.D.	O2 mg/l	0.9	1	1.3	23	-	-
Temperature	C	7.75	7.75	8.0	15.75	12	25

NOTE: N.E. = Not Examined; N.D. = None Determined < = less than Int = Interference

Table 2: Chemical Analyses of surface water samples at Avoca, Co. Wicklow (see Fig. No. 2 for sampling locations).

the river incapable of supporting fish life along the stretch of the river from the mines to its estuary at Arklow, a distance of 14 kms.

The extent and magnitude of this pollution was highlighted in a publication by the Water Pollution Advisory Council entitled "A Review of Water Pollution in Ireland" and dated June 1983. That report outlined the water quality position in regard to surface and groundwaters throughout the State and identified the Avoca River as a seriously polluted river below the Avoca Mines. Up-stream of the mine area the Avonmore river was shown by the report to be unpolluted from it's source in the Wicklow Mountains to it's confluence with the Avonbeg River at the Meeting of the Waters. No other river in the Eastern region, which also contains the Liffey, showed the same extent of pollution over such a considerable distance as the Avoca River.

Sample No. 1 from the Avoca River upstream of the mine area (Fig No. 2) given in Table No.1 shows a good quality water with a pH of 6.3 and a B.O.D. of 0.9 mg/l. The ammonia and nitrite levels are low as are the copper and the sulphate levels. However, sample No. 2 collected downstream of East Avoca but above the discharge from West Avoca shows a serious deterioration in the river quality as the pH has fallen to 4.6 and the copper level has risen to 0.1 mg/l. The situation gets worse downstream of West Avoca where the pH has seen a further decline to 4.5, the iron and manganese levels rise to 2 mg/l and 0.4 mg/l respectively together with an overall increase in the mineralisation of the river water. The latter point is reflected in the near doubling of the conductivity level of 56 Us/cm up-stream to 100 Us/cm down-stream of the mines.

The analyses given in Table 2 represent the river quality at a particular instant in time and therefore do not reflect the condition of the river quality through the year, this information could only be determined from a regular series of samples collected over a long period of time. However, an indication of the effect that the mine discharges have on the river quality can be obtained from a series of partial analyses completed by the I.I.R.S. in the period May 1979 to December 1980 as part of a mineral leaching experiment in East Avoca. These analyses indicate that samples of river water collected downstream of East Avoca but up-stream of the West Avoca discharge had a pH as low as 2.7 units with copper, iron and zinc concentrations up to 46 mg/l, 90 mg/l and 118 mg/l respectively in January, 1980. A somewhat similar result was obtained in June 1980 when the metal concentrations were 33 mg/l Cu., 35 mg/l Fe., and 113 mg/l Zn with a pH of 2.8. These analyses clearly indicate that conditions in the Avoca River can be particularly toxic to fish life.

The recent analysis of the mine discharge from West Avoca (Sample No. 4) given in Table 2 confirms that this part of the mining district also contributes a significant metal and organic load to the Avoca River. The effect of the very high iron, manganese, copper and sulphate levels are seen on the river water downstream of the discharge where the sulphate level in the river water (Sample No. 3) has increased to 32 mg/l and the iron concentration to 2 mg/l.

6.2.2 Groundwater

The analyses of groundwater given in Table 3 from the boreholes completed in the base of the open pit indicate that the groundwater

Parameter	Unit	West Avoca			East Avoca	E.E.C. Guidelines	
		B.H. NO. 7	B.H. NO. 8	B.H. NO. 9	Deep Adit	Guide Level	Admis Max.
Calcium	Ca mg/l	Int.	Int.	Int.	118	100	-
Magnesium	Mg mg/l	Int	Int.	Int	N.E.	30	50
Sodium	Na mg/l	6.0	11	6	1.0	20	175
Potassium	K mg/l	24	22	4.6	0.5	10	12
Bicarbonate	HCO3 mg/l	N.E.	N.E.	N.E.	N.E.	-	-
Sulphate	SO4 mg/l	3250	2500	2450	1020	25	250
Chloride	Cl mg/l	40	60	40	1200	25	-
Ammonium	NH4 mg/l	1.3	0.4	1.5	N.E.	0.05	0.5
Nitrite	NO2 mg/l	<0.1	<0.1	<0.003	N.E.	-	0.1
Nitrate	NO3 mg/l	<0.01	<0.01	<0.1	N.E.	25	50
Copper	Cu mg/l	0.3	6.0	50	21.6	0.1	-
Iron	Fe mg/l	200	120	25	50	0.05	0.2
Manganese	Mn mg/l	57	7	10	N.E.	0.02	0.05
P.V. @ 4 hours	O2 mg/l	<0.1	Int	<0.1	N.E.	2	5
T.O.C.	C mg/l	2.2	3.7	3.2	N.E.	-	-
pH	units	3.2	2.8	3.1	3.3	6.5-8.5	-
Hardness	CaCO3 mg/l	Int	Int	Int	N.E.	-	-
Colour	Hazen	10	50	<5	N.E.	1	20
Turbidity	N.T.U.	1.6	4.1	1.7	N.E.	1	10
Conductivity	Us/cm	3,400	2,700	2.200	2,050	400	-
Alkalinity	CaCO3 mg/l	<1.0	<1.0	<1.0	0	-	-

NOTE: N.E. = Not Examined; N.D. = None Determined < = less than Int = Interference

Table 3. Chemical analyses of groundwater samples at Avoca, Co. Wicklow.

beneath this excavation is similar to that discharging from the underground workings. The low pH and high sulphate, iron and copper levels recorded in the groundwater all correspond with similar elevated concentrations in the mine discharge analysis given in Table 2. Also, the analysis given in Table 3 from the I.I.R.S. work in East Avoca indicates that the groundwater beneath these old mine workings has the same character as now recorded in West Avoca, with the high sulphate and metal concentrations particularly interesting.

These exceptionally mineralised groundwaters at Avoca mines are due to bacteriological activity within the old mine workings. Naturally occuring bacteria, Thiobacillus ferrooxidous and Thiobacillus thiooxidons which exist in the Avoca mine waters, are capable of leaching copper, lead and zinc from the base metal ores. These bacteria can survive in very hostile conditions and have an optimum solution ph in the range 2.2 - 2.5. The I.I.R.S. leaching tests at East Avoca found that T. ferroxidons had sufficient nutrients in the form of ferrous sulphate in the mine waters to propagate successfully, but that T. thiooxidons only developed in sulphide rich microclimates within the ores. A particularly interesting finding of the I.I.R.S. work was how the concentration of metal within the mine discharge water correlated with the rainfall pattern; high metal levels corresponding with high rainfall events. Apparently, during periods of low rainfall the bacteria attack the ore but with the released metals being retained on the rock surface. Heavy rainfall increases the rate of flow of water through the mine workings and flushs the metal scale off the rock surfaces. The low activity or rest period would see a levelling off of the metal concentrations in the mine discharge waters while a heavy rainfall event would be accompanied by a surge

of high metal values initially as the heavy flows flushed the leached metal off the rock surfaces. Eventually, the high metal levels would decline to those levels experienced during low rainfall periods. When the heavy rains are finished the system reverts to a rest period and the rest/leach cycle starts over again.

This surge of high metal concentrations coinciding with high rainfall events explains the wide variation in metal levels recorded in the Avoca river during the I.I.R.S. monitoring period. Also, it means that regular monitoring of the river quality must take account of the rainfall pattern immediately before the sampling dates to ensure a proper analysis of the results.

7. Design of Proposed Landfill Operation

The physical, geological and hydrogeological features of the abandoned Ballymurtagh open-pit have been described in the previous items and the remaining part of this report will deal with the possible future development of the excavation as a landfill site for the disposal of domestic refuse, and possibly industrial wastes. The following items will outline the main features of the proposed landfill development but a site management statement would have to be prepared in the event of the decision to proceed with either of these proposals.

The principal physical and hydrogeological conditions at the Ballymurtagh open pit can be summarised as follows:

(i) The excavation is a long, narrow deep feature surrounded by high walls of rock and overburden.

(ii) The base of the open pit is underlain by between 6 m and 16 m of settled and partly consolidated mine tailings overlying competent bedrock.

(iii) The base of the open pit is dry and free draining with the permanent water table located at the rock head.

(iv) The position of the water table is controlled by an overflow pipe which discharges groundwater in the mine workings beneath the site to the nearby Avoca River.

(v) The Avoca River below the Meeting of the Waters is severely contaminated by mine discharges from East and West Avoca and the present conditions within the river below this point are toxic to fish life.

(vi) The groundwater beneath the open pit is highly mineralised with elevated levels of copper, iron, manganese and sulphate. This mineralisation is due to leaching of the sulphide ores by naturally occuring bacteria.

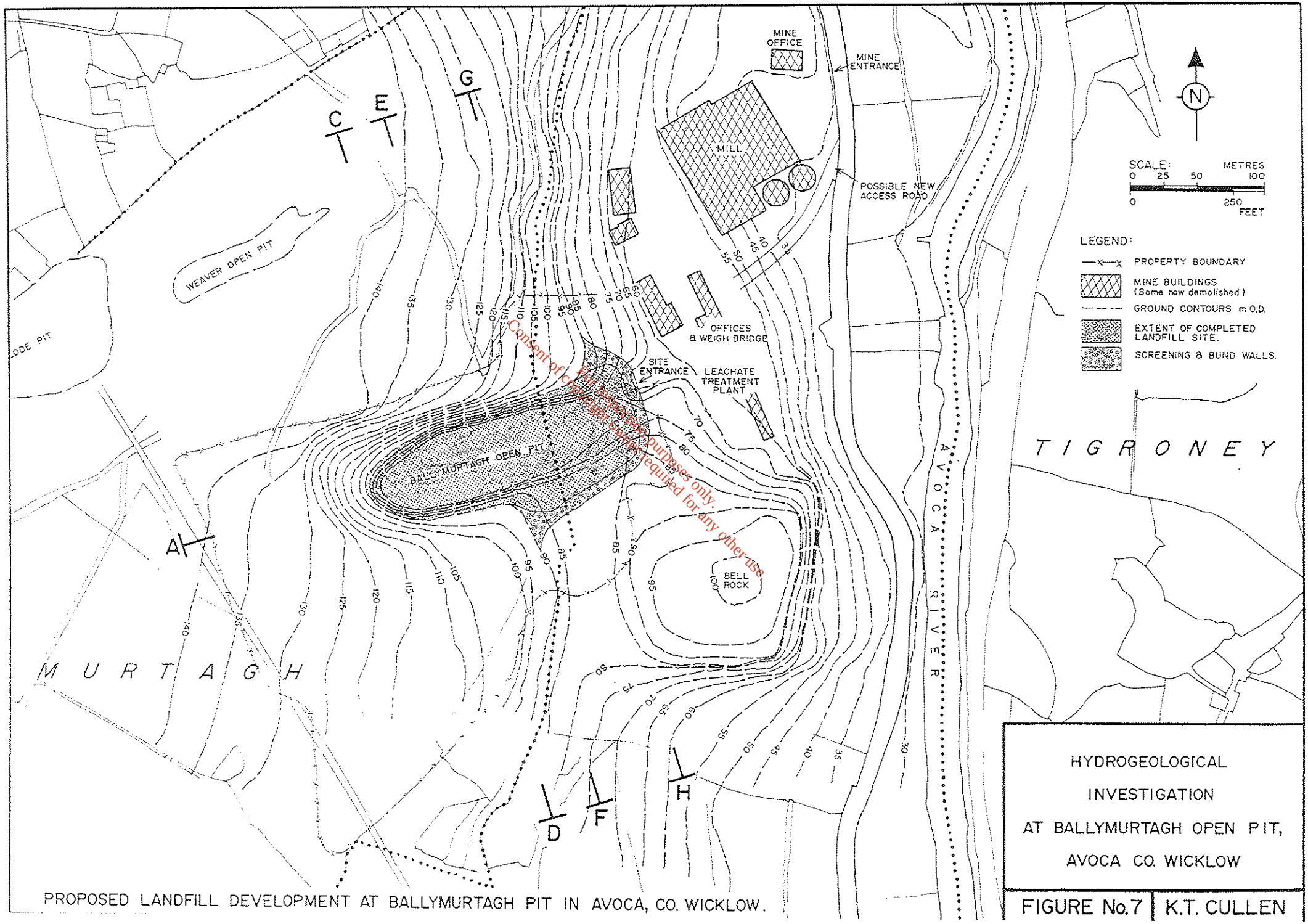
The various physical features of the open pit together with its central and concealed position make it a suitable site for development as a modern landfill. However, the unique hydrochemical status of the local groundwater and the Avoca River allows two different site designs to be proposed which differ only in the manner in which the leachate generated within the refuse is controlled. One design would allow the open-pit to be left in its present state and infilled with refuse with the resulting leachate allowed to drain through the unsaturated tailings and pass into the water table below the base of the open excavation. The second proposal would involve sealing the base of the open pit with an impermeable liner, collecting the leachate and following treatment discharging it to the Avoca River by way of the mine over-flow pipe. The first proposal can be considered as a "dilute and disperse "option with the leachate undergoing attenuation during its passage through the unsaturated tailings, being diluted firstly by the groundwater passing through the dis-used underground workings and then secondly by the flow within the Avoca River. The highly contaminated nature of both the groundwater beneath the mine and of the Avoca River allows this option to be worthy of serious consideration as the principal effect on the quality of either the mine overflow or the Avoca River would be a discoloration dependant on the nature and composition of the leachate. The second option can be described as a "contaminated site" with all leachate generated within the refuse being collected, treated and eventually

discharged to the Avoca River. Such a site would not add to the pollution levels already affecting the Avoca River and would therefore not effect any plans to rehabilitate this major river in the years to come. However, the costs of developing and operating a fully contained landfill site are significantly higher than those associated with a dilute and disperse site. These additional costs at Avoca must be considered in terms of the unique hydrochemical quality of the groundwater in West Avoca, the prospects of ever rehabilitating the Avoca River and the Council's policy on effluent discharges into the Avoca River between Arklow and the mining area.

7.1 Landfill Design

The shape and size of the Ballymurtagh open pit lends to its development as a single unit without the need for individual cells or sub-sections. The site has an air space capacity of about 200,000 m3 which at a filling rate of 8,000 m3/year gives a life of some 25 years. The capacity of the site is controlled by the level of the southern shoulder of the excavation which could be raised to about 90 m.O.D.. This would give a total depth of refuse within the pit of 20 m. (Fig. No.'s 7 and 8).

The previous items have indicated that two design options are available at the Avoca site due to the unique hydrochemical quality of both the local groundwater and the Avoca River. The site management procedures will be the same for both design options with the provision of an impermeable liner at the base of the open pit being the principal differance between the two designs together with the resulting storage and treatment of the leachate that is a consequence of the use of an impermeable liner. The following items



PROPOSED LANDFILL DEVELOPMENT AT BALLYMURTAGH PIT IN AVOCA, CO. WICKLOW.

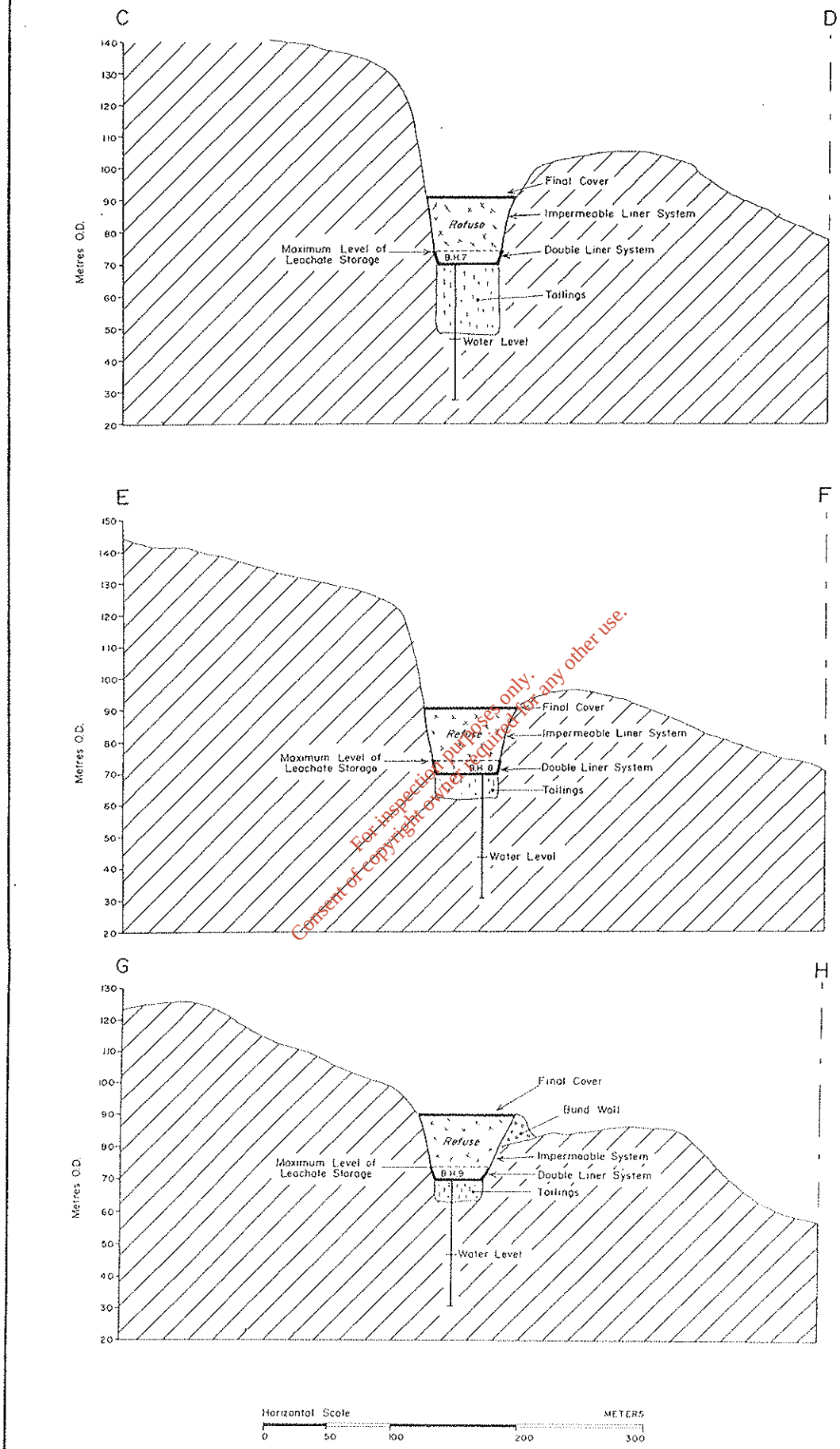


FIGURE No.8 | K.T. CULLEN

describe how the site could be sealed with a liner, the quantities of leachate that could be expected to be produced at Ballymurtagh and site management procedures which would be common to both design options.

7.2 Double Liner System

The provision of a containment landfill at the Ballymurtagh site would involve sealing off the base and sides of the landfill with a synthetic impermeable liner, with a double liner system incorporated into the bottom and lower sides of the excavation. The principal elements of the proposed double liner system are designed to provide for leachate collection and leak detection systems. The main components of the liner system are given in Fig. No. 9 and consist of ;

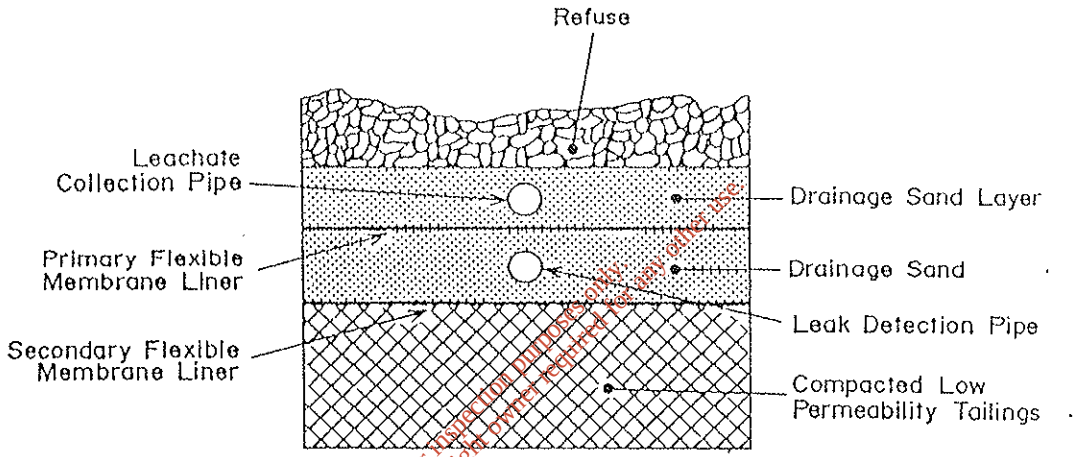
i) An upper primary liner which is covered by 0.3m of sand with a pipe network to collect leachate.

ii) A 0.3 m thick sand layer to separate the primary and secondary liners with a series of pipes to provide a leak detection system.

iii) The secondary liner should be placed on a layer of compacted tailings

7.3 Proposed Filling Schedule

As mentioned above, the shape and size of the open pit is best utilized by developing the entire excavation from the start of the landfill operation. This approach should allow the site to be developed in an orderly manner with consequent reductions in leachate generation and wind borne litter. It is proposed that a 2 m thick layer of refuse be placed over half of the site in the first



DESIGN ELEMENTS OF DOUBLE LINER SYSTEM

FIGURE No.9 | K.T. CULLEN

year with a clay or spoil bund separating the active part of the landfill from the unused portion of the site. On completion of this first lift the top of the refuse should be covered by a thin layer of clay or spoil to prevent wind borne litter originating in this portion of the site. The second year would see the remaining half of the base covered by a 2 m thick layer of refuse which in turn would be covered by a thin layer of inert rubble.

Landfilling would return to the other half of the site during the third year where another 2 m thick layer of refuse would be set down and eventually covered as before. Before the second layer of refuse is placed on top of the initial lift it would be important that the covering layer of clay or spoil lying on the previous layer should be either fully integrated with refuse or removed altogether. This requirement is necessary to prevent perched water tables becoming established within the refuse and so stopping the downward movement of leachate.

The fourth year would see the operations move back onto the part of the site with only the first 2 m. layer of refuse set down. In the following years the landfilling would move backwards and forwards across the excavation slowly bringing the level of refuse to the final level of 90 m.O.D.where the top of the refuse would be finally sealed, graded and grassed. This method of operation would restrict the active part of the landfill at any particular time to about 0.5 hectare,limit the height of the tip face to 2 m.and maximise the use of the intermediate cover material available within the open pit itself.

Methane gas generated within the landfill will have to be vented to the atmosphere during active landfilling and following the

completion of the site. This can be accomplished by the installation of suitably perforated pipes surrounded by coarse rubble. These pipes would rise with each lift of the refuse. The successful venting of methane at landfill sites contributes to the rapid stabilisation of the wastes and if sufficient gas is generated it can be collected and consumed on site to power such items as a leachate treatment plant. The proposed depth of refuse at the Ballymurtagh site would be ideal for methane generation and consideration could be given to such a scheme after the first 5 years of active landfilling.

7.4 Leachate Generation.

The development of the Ballymurtagh open pit as a landfill for the disposal of domestic refuse will result in the production of leachate as rainfall passes through the refuse. The quantity of leachate that will be generated at the Ballymurtagh site will be a function of the quantity of rainfall that has direct access to the landfill. This will depend on the effectiveness of the surface water cut off drains along the upper perimeter of the site which here are taken to limit the catchment of the open pit to about 2 hectares or 20,000 m2.

The quantity of leachate that could be produced annually at the open pit can be estimated by taking the average annual rainfall for the Avoca mines site (1171mm) and spreading it over the effective catchment. This calculation suggests that some 23,420 m3 of leachate could be produced annually at Ballymurtagh. This figure represents the maximum amount of leachate that could be produced in the average year as there are no other groundwater inputs into the system. However, this figure is an over simplification of the

situation and the following items attempt to provide a better understanding of the likely quantities of leachate that might occur during an average year at Ballymurtagh.

Disposal Rate = 8,000 tonnes/year.

Compaction Density = 1 tonne/cubic metre.

Depth of emplaced refuse = 1 m spread over the whole site.

i) Allowing for various levels of primary absorption capacities for the refuse the total amount of leachate production during an average year could be reduced by;

Primary Absorption	Leachate Reduction	Nett Leachate Production
100 litres/tonne	800 m3	22,620 m3
200 litres/tonne	1,600 m3	21,820 m3
300 litres/tonne	2,400 m3	21,020 m3

ii) Providing for different levels of evapotranspiration can reduce the gross leachate production even further;

Evapotranspiration	Period	Leachate Reduction
500 m.m/year	1 year	5,000 m3
400 m.m/year	1 year	4,000 m3
300 m.m./year	1 year	3,000 m3

These calculations indicate that with good site management practices achieving a density of 1 tonne/m3 and allowing for an effective rainfall of 671 m.m. and a primary absorption capacity of 300 litres per tonne that the annual quantity of leachate might be reduced to 16,020 m3 or about 44 m3/day. This compares with a possible daily average of 65 m3 using an annual rainfall of 1171 m.m..

In the event of the Ballymurtagh site being operated as a dilute and disperse site then the leachate passing through the base of the site would be firstly diluted by the mine overflow and then by the Avoca

River. Using an average mine discharge value of 2,000 m.3/day gives a 45 times dilution factor beneath the open pit itself. This combined leachate/mine overflow would then be subjected to a further minimum dilution of around 54 times using the lowest recorded flow in the Avoca River which was measured downstream of the Avoca Mines at Woodenbridge on the 3rd of September 1981 at 1.27 m.3/sec. While this figure supplied by An Foras Forbortha cannot be taken as a true dry weather flow it does none the less provide a good indication of the dilution capacity available in this major river, which even in periods of dry weather would provide a 2,500 times dilution factor for the average daily leachate flow.

Operating the Ballymurtagh open pit as a containment landfill will involve storing some leachate within the base of the landfill during wet periods prior to its treatment and eventual disposal. The necessary storage can be provided by bringing the double liner system up to 4 m. above the base of the landfill and by designing the treatment plant to cater for a possible maximum throughput of 130 m.3/day.

Unlike other landfill sites which can be operated on a cell basis with only small sections of the entire site active at any one time and where every cell is sealed when it is finished, leachate production will occur at Ballymurtagh throughout its life until the final cover eventually prevents all rainfall from passing through the refuse. Also, as the catchment area of the landfill is double the size of the refuse surface area the quantities of leachate will be much greater at Avoca than at shallower sites with smaller effective surface catchments.

8. Site Management

A full compehensive site management plan should be prepared for the Ballymurtagh site covering all aspects of the day-to-day operations at the site with particular emphasis on minimising the usual nuisances associated with waste disposal sites. In this respect the nature of the open pit and the availability of cover material should allow the landfill to be operated with only a minimum impact on the environment.

8.1 Wastes To Be Accepted at Avoca

It is proposed to operate the Ballymurtagh site for the disposal of domestic refuse originating in south east county Wicklow. However, in the event of this site being designed and operated as a fully contained landfill then the level of site development in this case would be such that it would also be possible to use the site for the disposal of most industrial wastes.

Should the County Council decide to accept industrial wastes at the Ballymurtagh landfill then the acceptance of a particular waste should depend upon the results of independent leachate tests carried out by the Institute for Industrial Research and Standards,or some other suitably recognised body. These tests should indicate that the wastes are essentially insoluble and that any resulting leachate will not affect the integrity of the synthetic liners.
Manufacturers should be required to pre-treat their wastes at source to the Council's satisfaction before the wastes can be accepted at the Avoca site.

The industrial wastes which could be accepted at the site include:

a) Metal Sludges
b) Organic Sludges
c) Asbestos

Wastes which should be prohibited would include:

a) Organic solvents
b) Radioactive Wastes

8.2 Monitoring

The design and management of the Ballymurtagh landfill should be directed at minimising the effect on the environment of leachate generated within the site. In the case of the containment option it would be important to insure that the double liner system is operating satisfactorily with regular checks on the leak detection system, on the quality of the treated leachate and on the quality of the Avoca River downstream of West Avoca. In the case of the dilute and disperse option being adopted a much broader monitoring programme would be required with regular checks on the chemistry of the mine overflow and on the quality of all water courses in the vicinity of West Avoca.

9. Site Development

The development of the Ballymurtagh open pit into a modern landfill would include some or all of the following works depending upon the final design chosen for the site.

i) The removal of the rubble crust on top of the tailings

ii) Various works to provide surface water cut-off drains, gates access road and weighing facilities.

iii) The provision of adequate volumes of inert cover materials as intermediate cover on the refuse and to act as screening.

iv) The establishment of a monitoring system for both surface water and groundwater quality.

In the case of a containment site the following works would be necessary;

v) The covering of the base and lower sides of the excavation with a double liner system incorporating leachate and leak detection pipe networks as shown in fig. No. 9

vi) Covering the sides of the excavation with a single layer of synthetic liner.

vii) The provision of a leachate treatment plant.

Items I-IV above refer to the initial development of the site. In the case of the dilute and disperse option no further development works would be necessary until the landfill is complete and ready for sealing and final restoration. Items V & VII would allow for the first 4 years of the site being used as a containment landfill. When this phase of the site is complete the next stage of development would involve covering some 4 m. of the surrounding

walls with a single layer of impermeable liner to provide a further 4 years tipping capacity. This process would continue for the duration of the site's life which is estimated at 25 years. On completion, the surface of the landfill should be graded , sealed and grassed.

9.1 Development Costs

A detailed design and costing of the proposed development of the Ballymurtagh open pit is outside the scope of this report. The proposed development includes a number of major engineering structures including the possible construction of a new access road. However, an estimate of the likely costs that would be incurred during the proposed development are outlined in Table 4 below. Table 4 outlines the costs that would be involved in the development of the Ballymurtagh site irrespective of which leachate control strategy is finally adopted and involves a considerable amount of earth moving to provide adequate screening, landscaping, access roads, offices, weigh bridge etc.. This expenditure of £317,500 would provide tipping capacity for 25 years in the case of the dilute and disperse option but a further outlay of £180,000 would be required to develop a containment site with an initial capacity for 4 years. An additional expenditure of £12,000 would be required every 4 years to line the walls of the excavations as the open pit is progressively filled.

9.2 Operational Costs

The operational costs associated with the management of a modern low volume landfill are high as a certain level of staff and machinery are required to maintain acceptable standards irrespective of the

daily volumes of wastes disposed at the site. The operational costs at Avoca would be in the order of £180,000 per annum.

9.3 Total Cost

The total cost of the proposed landfill development at the Ballymurtagh open pit comes to £5 million or £25/m3 at a disposal rate of 8,000 tonnes/annum. This particularly high unit cost is due primarily to the low intake rate and is not sensitive to the initial capital cost of the development works. By doubling the annual disposal rate, the unit cost of disposal would be reduced to around £13/m3 and the life of the site would then be 12.5 years. While the inital development costs of a modern landfill are high due to the need to limit the impact on the local environment, the day to-day-operating charges play a major role in the overall economics of a waste disposal site. By increasing the daily intake at a particular site the operational costs are spread over a much larger tonnage of refuse and more efficient use is made of the site staff and equipment. However, the more efficient use of site facilities must be placed against the increased costs of transporting refuse over considerable distances.

Table 4 Estimated Site Development Costs at Ballymurtagh Open Pit

	£ p
i) Land purchase. (inclusive of additional spoil heaps to supply sufficient cover materials).	30,000.00
ii) Earth moving and site preperation.	50,000.00
iii) Road construction and improvements.	100,000.00
iv) Surface run cut-off drains.	10,000.00
v) Site office (serviced and including canteen)	17,500.00
vi) Weigh Bridge	40,000.00
vii) Wheel wash	10,000.00
viii) Landscaping	10,000.00
ix) Preliminary site assessment	20,000.00
x) Legal and design fees	30,000.00
	£317,500.00

APPENDIX I

BOREHOLE CONSTRUCTION DETAILS AND GEOLOGICAL LOGS

COMPLETED WELL DESIGN

Client : WICKLOW COUNTY COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

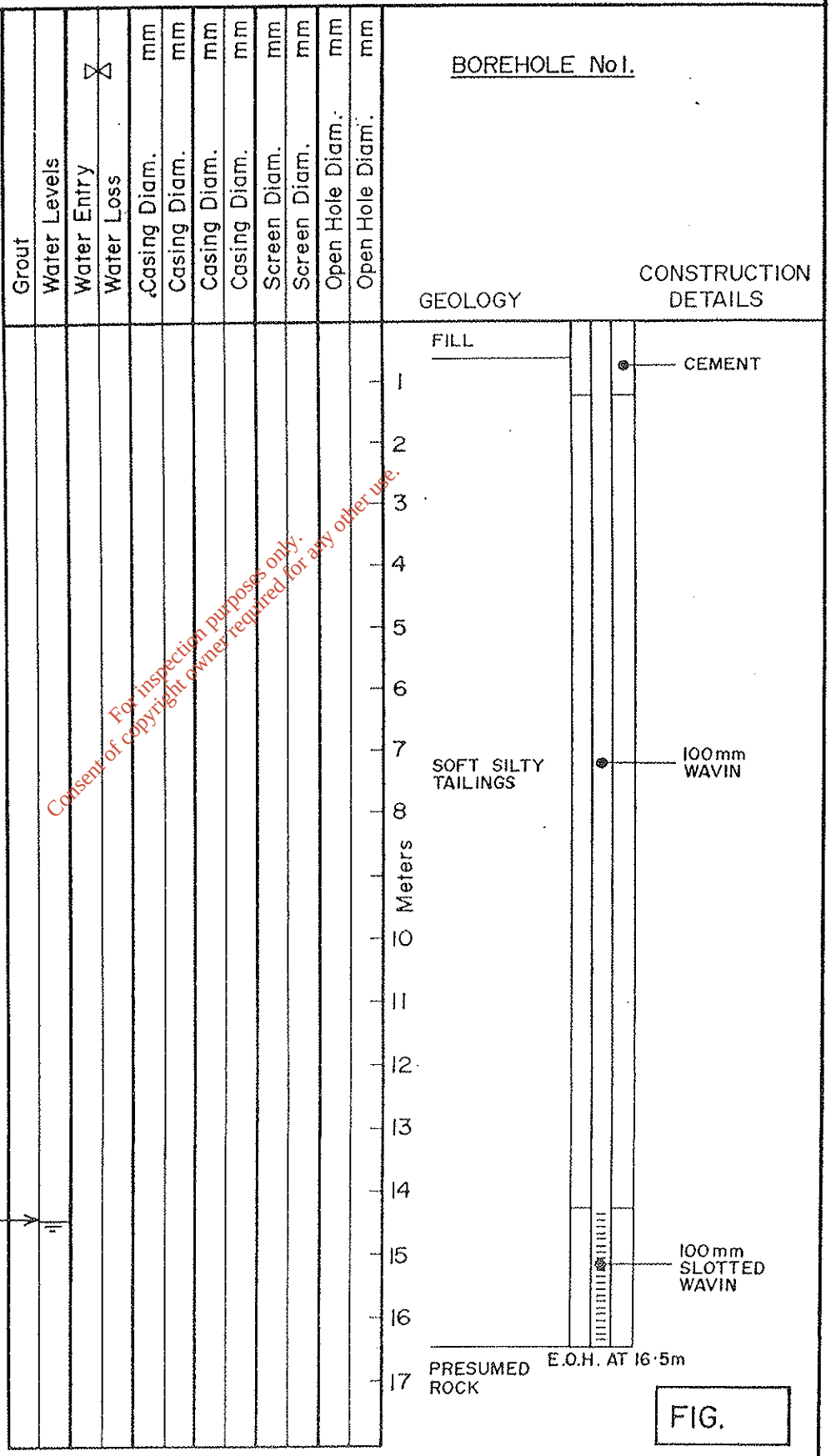
Aquifer : TAILINGS
Output : ____ m³/day
Specific Capacity : ____ m³/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 70·12 m O.D.
G.L. AT 69·77 m O.D.

S.W.L. AT 14·44 m

BOREHOLE No1.



K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

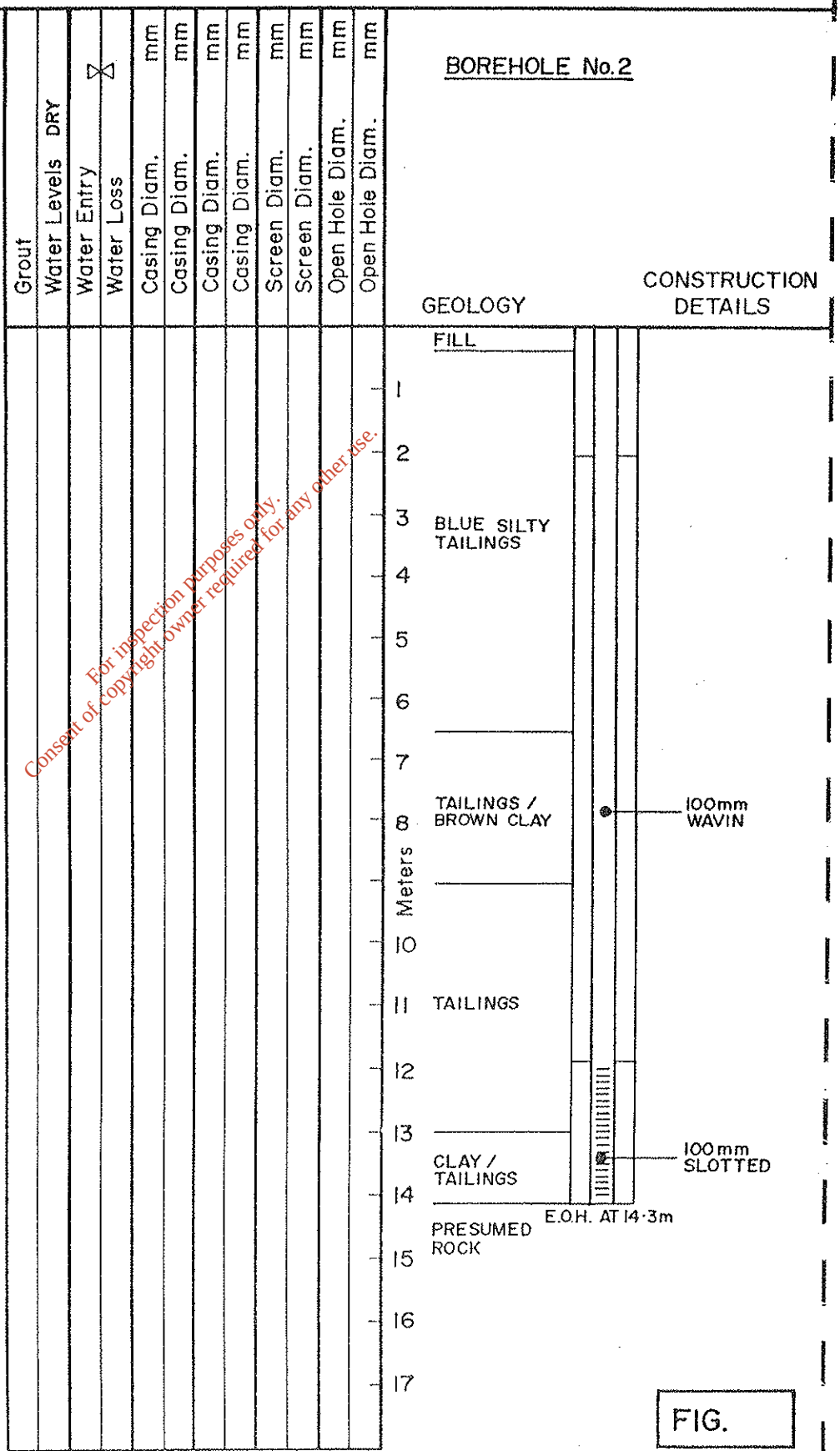
Client : WICKLOW COUNTY COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

Aquifer : TAILINGS
Output : _____ m³/day
Specific Capacity : _____ m³/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 70·11 m O.D.
G.L. AT 69·83 m O.D.

BOREHOLE No.2



K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

Client : WICKLOW COUNTY COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

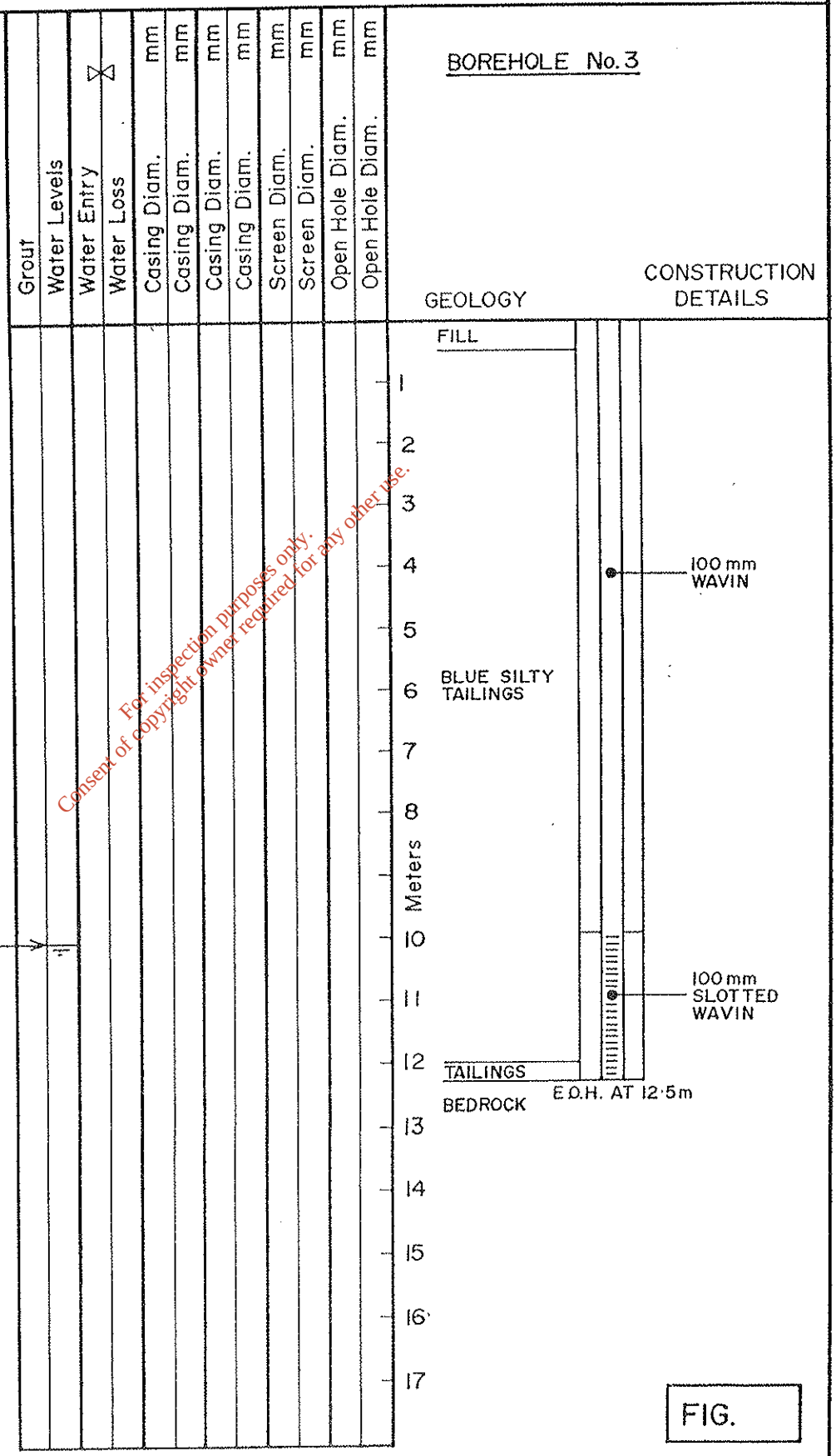
Aquifer : TAILINGS
Output : _____ m³/day
Specific Capacity : _____ m³/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 69·59 m O.D.
G.L. AT 69·44 m O.D.

S.W.L. AT 11·0m

BOREHOLE No. 3



K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

Client : WICKLOW COUNTY COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

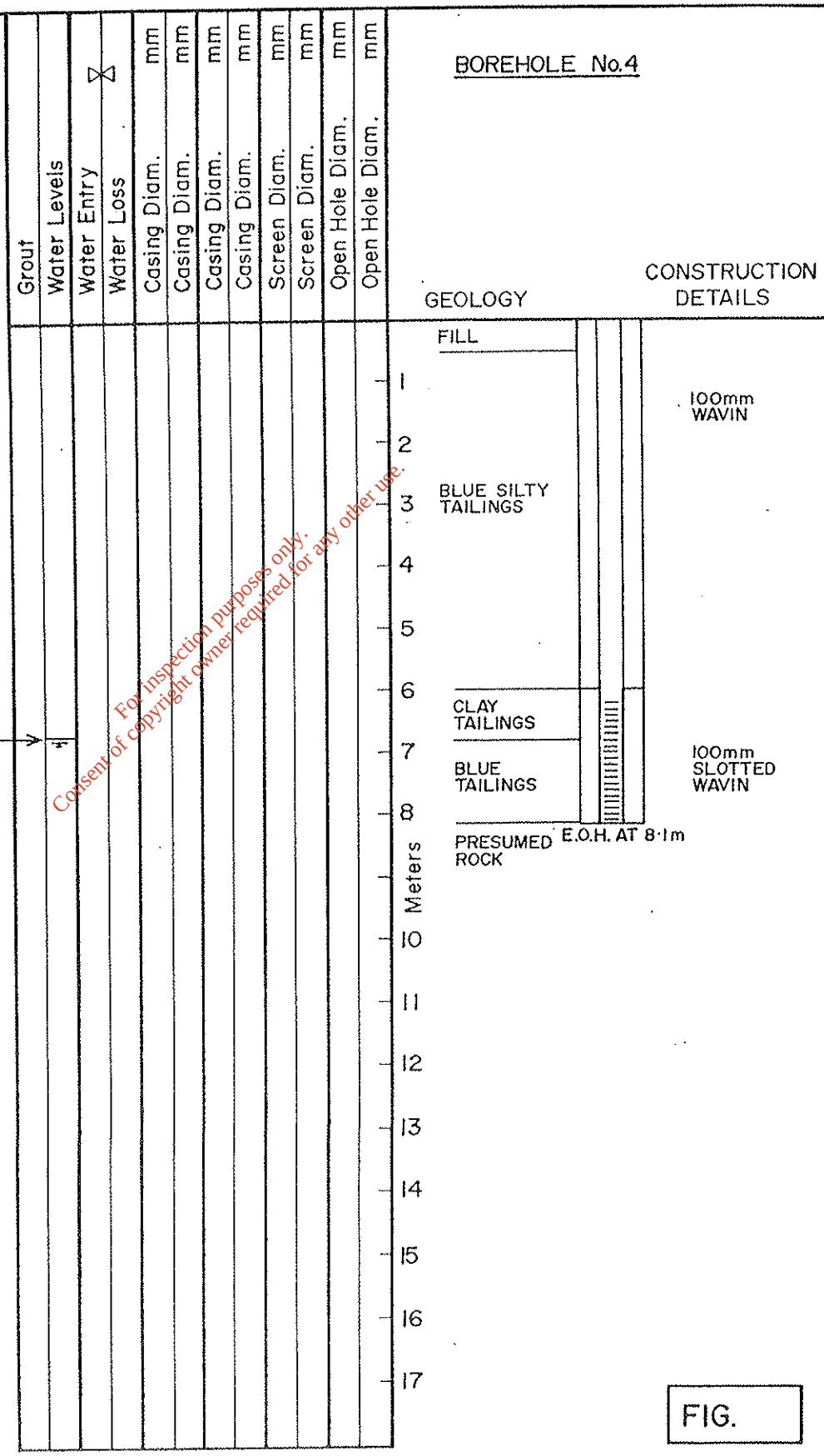
Aquifer : TAILINGS
Output : _____ m³/day
Specific Capacity : _____ m³/day/m
National Grid Co-ordinates : 318,700 E. 181,200 N.

REMARKS

W.H. AT 69·12 m O.D.
G.L. AT 68·87 m O.D.

S.W.L. AT 6·78 m

BOREHOLE No.4



K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

Client : WICKLOW CO. COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

Aquifer : TAILINGS
Output : _____ m³/day
Specific Capacity : _____ m³/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 69·18 m O.D.
G.L. AT 69·18 m O.D

BOREHOLE No.5

Grout	Water Levels DRY	Water Entry ⋈	Water Loss	Casing Diam. mm	Casing Diam. mm	Casing Diam. mm	Casing Diam. mm	Screen Diam. mm	Screen Diam. mm	Open Hole Diam. mm	Open Hole Diam. mm

GEOLOGY

CONSTRUCTION DETAILS

GRAVEL

CLAY & GRAVEL

PRESUMED ROCK.

E.O.H. AT 1·5m

1 2 3 4 5 6 7 8 Meters 10 11 12 13 14 15 16 17

K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

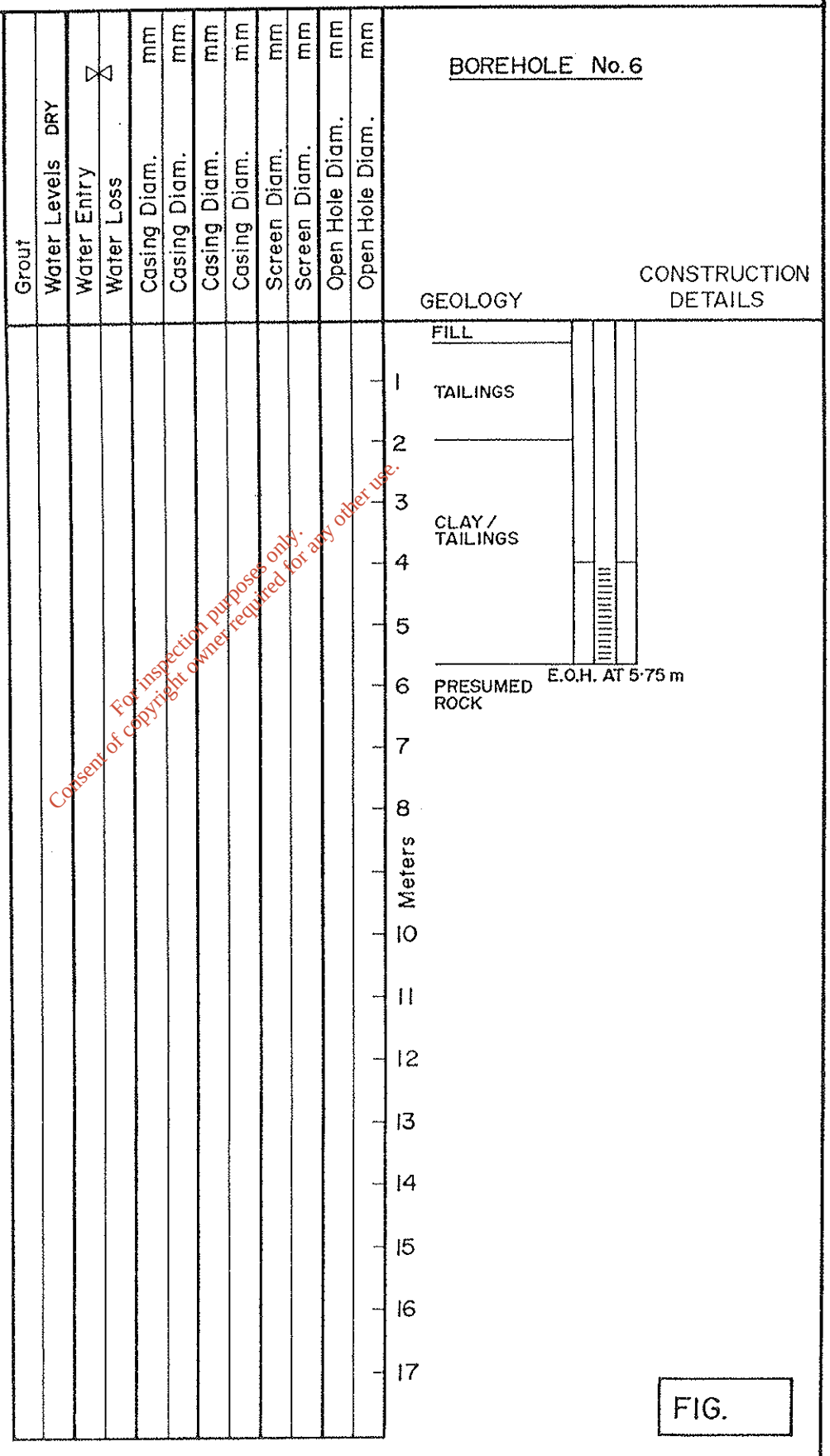
Client : WICKLOW COUNTY COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : I.G.S.L.

Aquifer : TAILINGS
Output : _____ m³/day
Specific Capacity : _____ m³/day/m
National Grid Co-ordinates : 318,700 E. 181,200 N.

REMARKS

W.H. AT 69·49 m O.D.
G.L. AT 68·99 m O.D.

BOREHOLE No. 6



K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

Client : WICKLOW CO. COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : O'DONOGHOE

Aquifer : SHALE
Output : 10 m^3/day
Specific Capacity : _____ m^3/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 70·06m O.D
G.L. AT 69·94 m O.D.

S.W.L. AT 21·66 m

Grout | Water Levels | Water Entry | Water Loss | Casing Diam. mm | Casing Diam. mm | Casing Diam. 150 mm | Casing Diam. mm | Screen Diam. mm | Screen Diam. mm | Open Hole Diam. mm | Open Hole Diam. mm

BOREHOLE No 7.

GEOLOGY

BLUE TAILINGS

META-VOLCANIC BEDROCK

CONSTRUCTION DETAILS

150mm STEEL CASING

E.O.H. AT 42.7m

5 10 15 20 25 30 35 40 Meters 50 55 60 65 70 75 80 85 90

K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

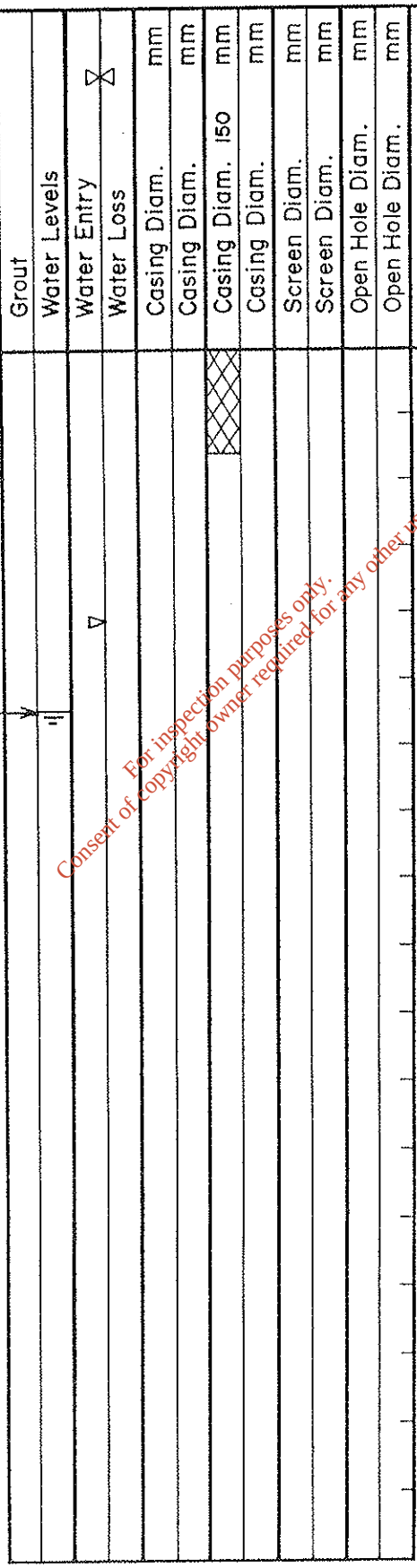
Client : WICKLOW CO. COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : O'DONOGHOE

Aquifer : SHALE
Output : TRACE m³/day
Specific Capacity : ____ m³/day/m
National Grid Co-ordinates : 318,700 E. ; 181,200 N.

REMARKS

W.H. AT 69·85 m O.D.
G.L. AT 69·60 m O.D.

S.W.L. AT 27·29 m



BOREHOLE No 8

GEOLOGY

TAILINGS

BROKEN ROCK & BOULDERS

META-VOLCANIC BEDROCK

E.O.H. 39.6 m

CONSTRUCTION DETAILS

150mm STEEL CASING

K.T. CULLEN

FIG.

COMPLETED WELL DESIGN

Client : WICKLOW CO. COUNCIL
Location : AVOCA
County : WICKLOW
Date : JUNE 1986
Driller : O'DONOGHOE

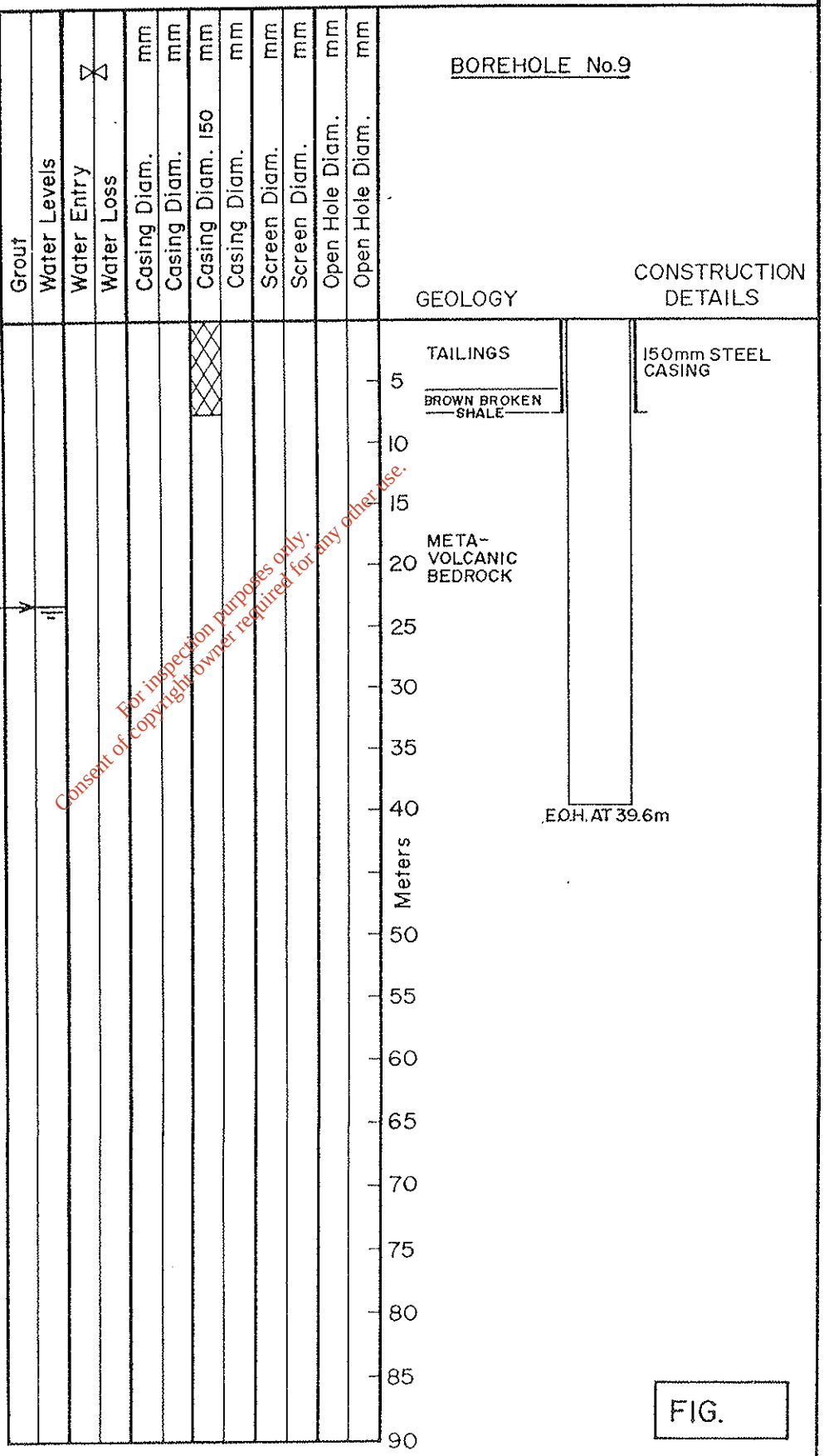
Aquifer : SHALE
Output : TRACE m³/day
Specific Capacity : m³/day/m
National Grid Co-ordinates : 318,700 E. 181,200 N.

REMARKS

W.H. AT 69·35 m O.D.
G.L. AT 69·05 m O.D.

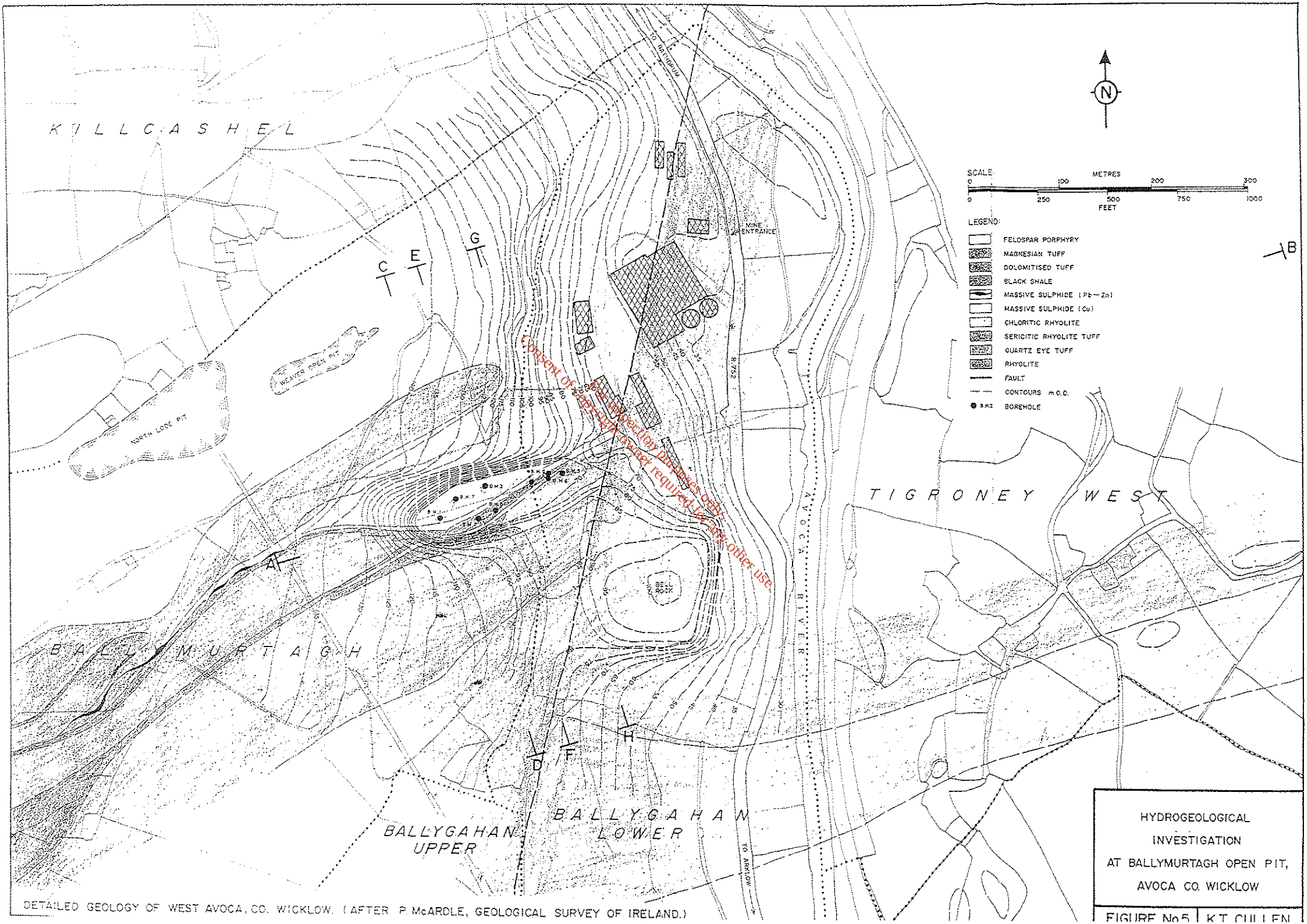
S.W.L. AT 23·4 m

BOREHOLE No.9



K.T. CULLEN

FIG.



DETAILED GEOLOGY OF WEST AVOCA, CO. WICKLOW. (AFTER P. McARDLE, GEOLOGICAL SURVEY OF IRELAND.)

BALLYMURTAGH OPEN PIT

VOLUME 2 - PHOTOGRAPHS

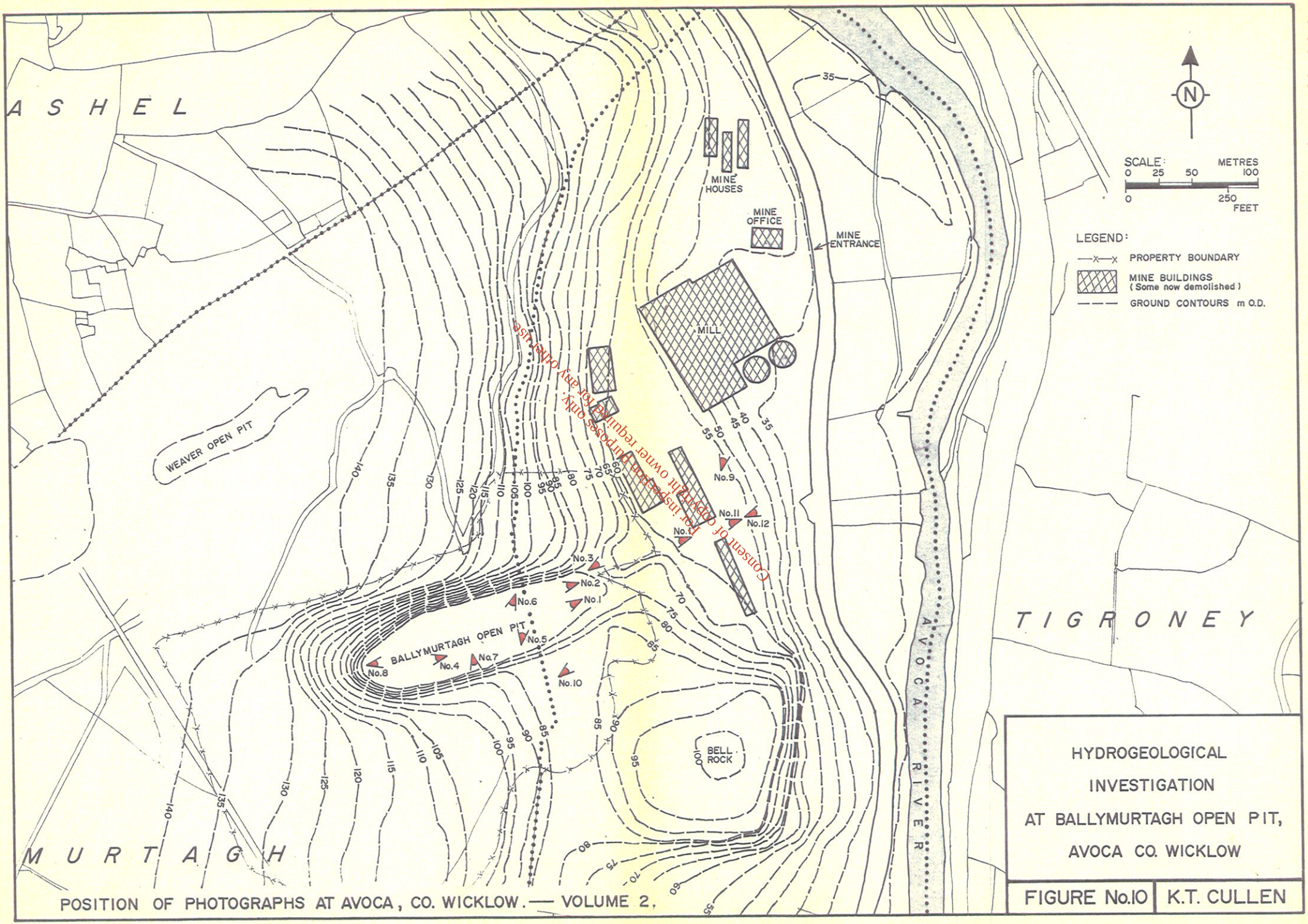


Plate No. 1 : West looking view of Ballymurtagh Open Pit, Avoca Co. Wicklow.

Plate No.2 : West looking view into Ballymurtagh Open Pit.

Plate No.3 : West looking view into Ballymurtagh Open Pit.

Plate No.4 : View of western boundary of Ballymurtagh Open Pit.

Plate No.5 : View of north face of Ballymurtagh Open Pit.

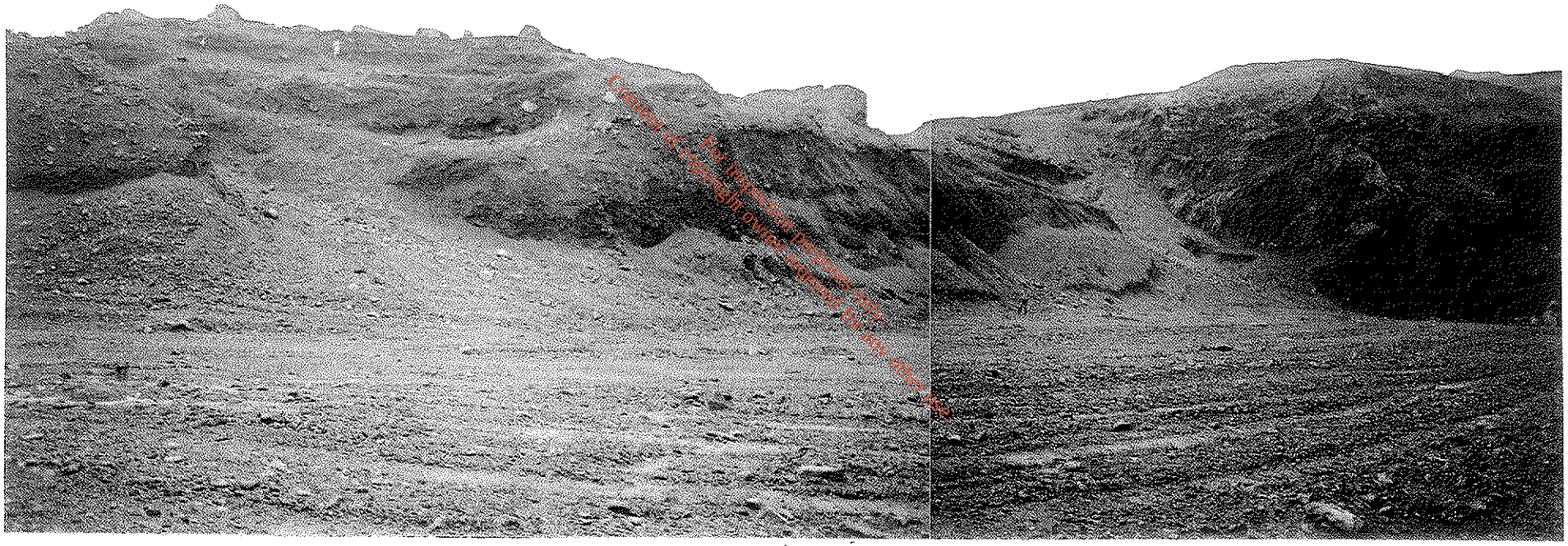


Plate No. 6 : View of south face of Ballymurtagh Open Pit.

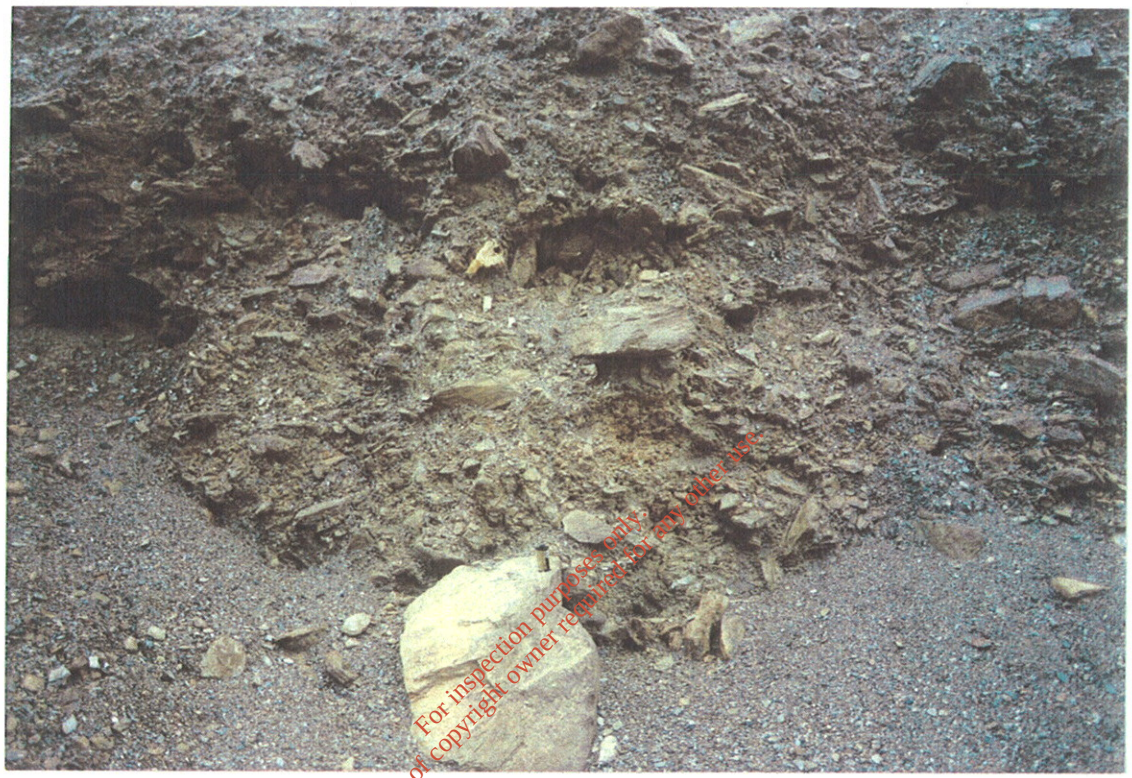


Plate No. 7 : Detailed view of overburden forming south face of Ballymurtagh Open Pit.

Plate No.8 : East looking view from inside the Ballymurtagh Open Pit.

Plate No.9 : Vale of Avoca looking east from the Ballymurtagh Open Pit.

Plate No.10 : Vale of Avoca from the east face of the Ballymurtagh Open Pit.

Plate No.11 : West looking view of the Ballymurtagh Open Pit.

Plate No.12 : East looking view across the Avoca River from the Ballymurtagh Open Pit.

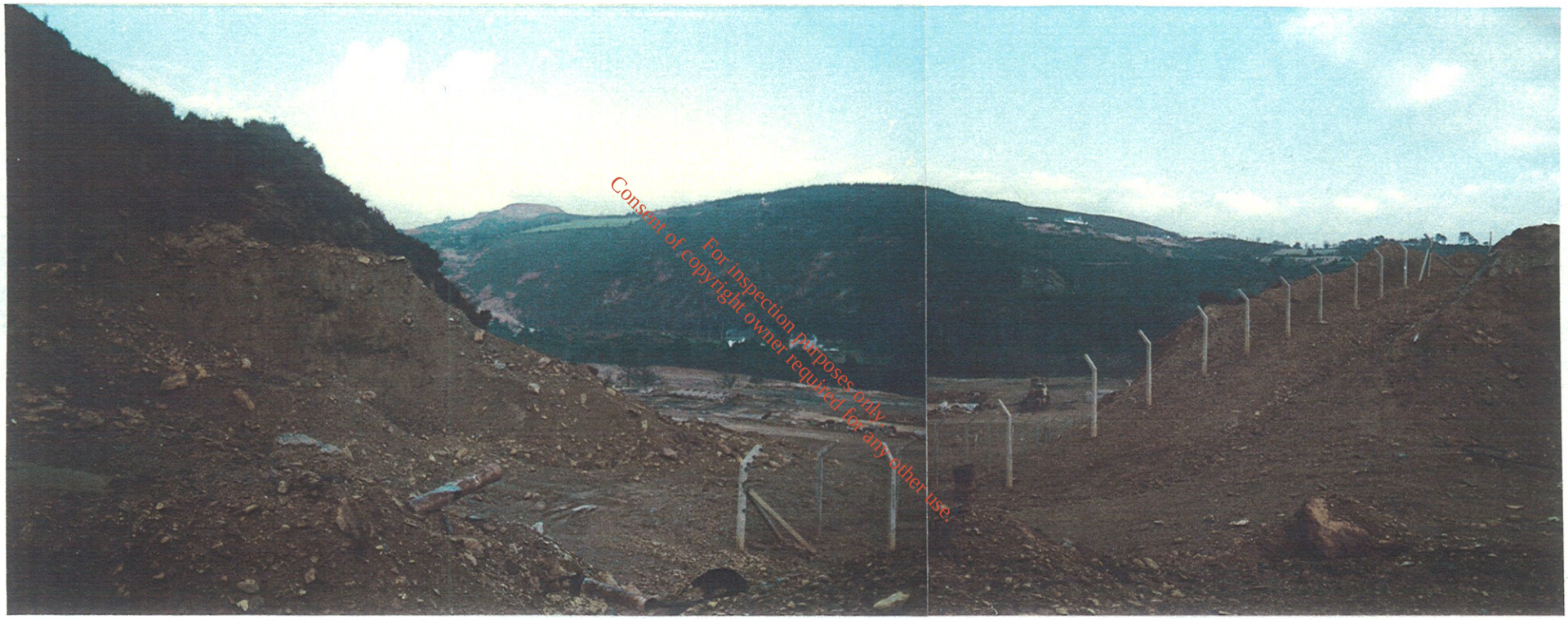


Plate No. 13 : East looking view across the Avoca River from the entrance to the Ballymurtagh Open Pit.