# **REGIONAL GASWORKS REMEDIATION STUDY**

# **FINAL DRAFT REPORT**

on

# SITE INVESTIGATION

LIMERICK GASWORKS SITE

Limerick Gaswork of Reserved Control of Re

**VOLUME 1 - REPORT** 

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- E Soil Analytical Results Metals, Total Sulphur and Sulphide.
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#### 1.0 INTRODUCTION

Ove Arup & Partners Ireland have been appointed by Bord Gais Eireann to carry out a study of remediation methods for regional gasworks sites at Cork, Waterford and Limerick. This report contains the desk study, geotechnical and chemical site investigation information obtained for the gasworks site at Limerick.

The report summarises the details of two environmental site investigations carried out on the site; that carried out by O'Connor Sutton Cronin/Gibb Environmental in 1991 (Ref. 1) and that carried out by Ove Arup & Partners Ireland/KT Cullen in 1995, the results of which are given in Volume 2 of this report.

The assessment of the chemical test results and the discussion on the remediation options for the Limerick site are based on two further reports by Ove Arup & Partners Ireland (Ref. 2 and Ref. 7), both of which should be read in conjunction with this report.

This report is prepared solely for the use of Bord Gais Eireann, in connection with the former gas manufacturing site at Limerick. The report takes into account particular limitations and requirements. Any third party using this report must satisfy themselves that the information provided is correct and that the recommendations are appropriate in all respects for their particular requirements.

#### 2.0 THE SITE

#### 2.1 Location, Topography and Present Use

The Limerick gasworks site is located on the south side of Dock Road, with return frontage to O'Curry Street, approximately 300 m west of O'Connell Street, Limerick City, see Figure 1. The south west of the site backs onto St. Alphonsus Street, and the south east backs onto the Garda Siochana station and site of the old Shannon Foundry (disused). The Shannon Foundry site was developed as 2-storey townhouse residences in 1994.

The gasworks site is approximately rectangular with dimensions of 130 m by 110 m. The site area is 3.5 acres (1.4 hectares).

The site is a former limestone quarry and rock quarry faces are evident around the southern boundary of the site. A site survey was undertaken in 1990 by Celtic Surveys for O'Connor Sutton Cronin, Consulting Engineers. The site slopes gently from about 5.0 m OD on Dock Road to 8.0 m OD at the southern side of the site (Malin Head datum).

Storm water flooding occurs at both the Alphonsus Street and O'Curry Street junctions with Dock Road, apparently due to poor road gradients and lack of, or blocked, road gullies. The maximum recorded flood level for Limerick city is 4.25 m OD.

Limerick gas company presently utilises offices and stores on the site. A small ESB substation occupies a position within the site. All above ground tanks and gasometers have been removed though the concrete base for one gasometer remains. The site is used as a distribution point for natural gas into the mains gas pipe network. Fill material from off-site excavation works has been deposited on the site.

#### 2.2 Archaeology

The site is expected to be of little interest in terms of Medieval Archaeology. However retent buildings on site may be of interest to architects as well as industrial archaeologists, (Reference 3).

#### 2.3 Site History

The development of the site, based on historical maps, aerial photography, and information supplied by the Client, is summarised below. A summary of the historical maps, drawings and aerial photographs is given in Appendix V. The development of the site is shown diagrammatically on the sketches in Appendix W.

The site is a former Limestone quarry, with quarry faces evident along the southern site boundary. By 1841 a small gasworks with 2 cylindrical tanks was in operation along Dock Road see SK1, Appendix W. The western part of the site was a field. A quarry is shown on the south eastern part of the site. By 1870 the gasworks had developed to cover the field to the west, see SK2. One of the original cylindrical tanks had been removed and replaced by 2 larger tanks (gasometers). The quarry had extended to the south. Water is indicated in the north western part of the quarry, suggesting that the quarrying was deepest in this area.

Development continued in the southern part of the site with the addition of a 27 m diameter gasometer, lime kiln and miscellaneous tanks by 1907, see SK3. The quarry appears to have been at least partially infilled. The 1919 site plan, see SK4, shows an electric station and rectangular structures in the old quarry area to the east of the site.

Very little additional site development occurred up to 1941, see SK5 and SK6. A Garda Síochana station and Shannon Foundry occupy the sites along the south eastern boundary.

The 1954 aerial photograph, see SK7, shows the 27 m diameter tank as being the only gasholder on site. The yard area close to Dock Road appears to be used for uncovered coal storage.

Coal based gas manufacture continued on site until the late 1960's. By 1977 the majority of structures along Dock road had been removed, see SK8, SK9 and SK10, presumably due to the change over from coal-based to naphthalene based gas production. A 36 m diameter above-ground gasholder was constructed close to Dock Road. The locations of many small tanks associated with the naphthalene gas production plant are evident from the 1:1000 Ordnance Survey map of the site.

In 1986 natural gas was introduced to Limerick. By 1988 the majority of gas production plant and gasometers were demolished, see SK11. The above ground installation (AGI) occupied an area beside the Dock Road entrance. During the late 1980's, the contents of the tar tank and some contents of the purifier beds were reportedly transferred to the disused underground gasholder on the southern side of the site. Approximately 350 tons of tarry liquids from this gasholder were later transferred to the bunded naphthalene storage tank and subsequently removed for disposal as toxic waste in the UK by a licensed contractor. The tar tank was reportedly filled in 1989 and was estimated to be 6 m to 9 m below ground. The 450,000 ft<sup>3</sup> (36 m diameter) gasometer on the northern side of the site and the naphthalene storage tank in a bunded area to the south corner of the site were demolished in 1994.

The current layout of the site is shown on SK12, Appendix W, and also on

## 2.4 Geology

Figure 3.

## 2.4.1 Solid Geology

The bedrock maps of the site area (6" to 1 mile, sheet 5a/3, 1890 and 1" to 1 mile sheet 143, 1901) show the site to be underlain by Middle and Upper Carboniferous Limestone. A section of the 6" map is shown on Figure 2. The map shows outcrops on the southern part of the site.

Recent unpublished research of the bedrock in the area, carried out at the Geological Survey of Ireland, suggests that the limestone beneath the site is Part of the "Northern Clean Shelf Limestones" and is an oolitic limestone. These limestones are clear, pale grey, well bedded fine grained limestones and are not associated with karstic activity.

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2.4.2 Drift

Recent (unpublished) sub-soil maps for the Limerick area examined at the Geological Survey of Ireland, show the site to be within an area where rock is less than 1 m from the surface.

The geological maps, see Figure 2, indicate alluvial deposits associated with the River Shannon immediately to the north west of the site.

### 2.5 Hydrogeology

The site area contains both cherty limestones and oolitic limestones according to Deakin (1994, Ref 5). Oolitic limestones are considered locally important aquifers which are generally moderately productive. Cherty and shaley limestones are considered locally important but generally unproductive, except for local cones. Both of these aquifer types are classified as minor in comparison with karst areas.

A groundwater vulnerability and bedrock map for Limerick City (Reference 4) shows bedrock as being within 1 m of ground surface. Therefore, the aquifer vulnerability rating is "extreme vulnerability".

There are no productive wells or boreholes recorded in the general area of the site. There is no available data on groundwater quality.

The City water supply comes from Clareville on the Shannon River via the Newcastle reservoir.

## 2.6 Site Zoning

Limerick Corporation's Development Plan 1992, show the site area zoning as "General Purpose". This zoning includes residential, commercial, industrial, and open space purposes. The development plan does not show any building or object on the site of special interest to be considered for protection.

#### 3.0 SITE INVESTIGATION

#### 3.1 **Previous Site Investigation**

A site investigation comprising 10 trial pits and 6 rotary cored/shell and auger boreholes was carried out by Irish Geotechnical Services and Gibb Environmental under the auspices of O'Connor Sutton Cronin in 1990. The work also included gas measurements and the taking of soil and water samples for chemical testing. The location of the testing is shown on Figure 3. The detailed results are given in O'Connor Sutton Cronin's Report of 1991 (Ref. 1) and are included in the discussions in the following sections.

#### 3.2 Present (1995) Site Investigation - General

The 1995 site investigation was ried out by KT Cullen and Company under the direction of Ove Arup & Partners Ireland. The test locations are shown on Figure 3 and the detailed results are given in Volume 2 of this report.

The investigation comprised the following:

- 16 No. machine dug trial pits,
- 1 No. hand dug trial pit,
- 6 No. shell and auger boreholes, 5 of which were extended in bedrock by rotary coring,
- 7 No. gas/water monitoring wells,
- 5 No. surface (scraped) samples,
- Taking of soil and water samples for chemical testing

The details of the sampling and testing are given below. The field work was carried out between 17.07.95 and 10.08.95, an interim report by KT Cullen was received by Ove Arup on 09.10.95 and the final report was received on 22.11.95.

### 3.3 Boreholes

Both the shell and auger drilling and rotary coring was sub-contracted by KT Cullen to Glover Site Investigations Limited.

The shell and auger boreholes were carried out using standard procedures to BS 5930 "Site Investigations". This included excavating a starter pit at each borehole location, taking bulk samples for logging purposes and carrying out Standard Penetration Tests at approximately 1 m intervals (see Table 1, Volume 2).

A feature of the drilling was the high levels of contamination encountered in the form of tarry liquids and sludge, particularly in BH's 7, 8, 10 and 11. This is illustrated on Plates 1 to 4 of this report. The contamination made drilling very difficult. The equipment had to be steam cleaned regularly, see Plate 5.

The borehole logs are given appendix B, Volume 2. The rotary coring was carried out using both a marine rock coring attachment to the shell and auger rig (BH's 7, 8 and 12). The latter proved more successful. No rotary coring was carried out in BH10 due to the fact that the contamination encountered would have caused significant surface contamination of the BGE storage area. As for the shell and auger holes, the contamination encountered caused severe practical difficulties for the personnel operating the equipment during the drilling. The coring logs are given in Appendix C, Volume 2 and photographs of the cores are given in Appendix Y of this volume. Falling head permeability tests were carried out in the overburden in three of the boreholes. Packer permeability tests were carried out in the bedrock in two boreholes. The results of both sets of tests are given in Appendix H, Volume 2.

## 3.4 Groundwater Wells and Gas Standpipes

Wells which enable the monitoring of gas and the sampling of groundwater were installed in each borehole. Some wells were installed in the overburden and some in the bedrock. Two wells were installed in BH12 in order to assess the hydraulic continuity between the overburden and bedrock. The details of the well construction are given in Appendix B, Volume 2.

## 3.5 Sampling Groundwater and Gas

Following installation, all monitoring wells were developed so as to remove disturbed water from the vicinity of the borehole and provide a representative groundwater sample. Approximately 1,200 litres were pumped from BH-12(s), BH-12(d) and BH-9 as they contained only minor quantities of tarry product. BH-7, BH-8, BH-10 and BH-11 were developed using a 1.0 Litre PVC Bailer as they were the most contaminated wells and proved difficult to develop from each well during developing.

The monitoring wells installed were sampled on 11 August 1995 in the order BH-12(S), BH-12(D), BH-9, BH-8, BH-11, BH-7 and BH-10 respectively. Details of the monitoring well sampling logs are shown in Appendix D, Volume 2. The sampling order was chosen in order to progress from the anticipated potentially least contaminated well to the anticipated potentially most-contaminated well.

Samples were collected using a PVC bailer. Bailers were designated to each borehole due to the high concentration of the oil/tar product present. The rope used to retrieve the bailer was replaced between wells. Approximately 15 litres of water were evacuated from each well before sample collection.

An infra-red gas analyser was used to record the concentration of oxygen, carbon dioxide, and methane. The hydrogen sulphide concentration was recorded using a draeger pump and a hydrogen sulphide draeger tube. Details of the vapour concentrations recorded are contained in Table 4, Volume 2.

The wells were subsequently resampled on 25.09.95 (approximately 6 weeks after initial sampling), the details of which are given in the well sampling logs in Appendix D of Volume 2.

Gas concentrations were also recorded on 25.09.95, See Table 4, Volume 2,

The static groundwater levels measured on the two dates of sampling are given in Table 3, Volume 2.

### 3.6 Trial Pits

The trial pits were excavated using a 22.5t Hymac type excavator. The bucket of the excavator was steam cleaned between sampling locations. The pits were logged by KT Cullen and the logs are given in Appendix A, Volume 2. Photographs of the trial pits are given in Appendix X of this Volume.

Samples of soil and groundwater were taken for chemical testing and for routing geotechnical testing.

## 3.7 Surface Sampling

Surface samples were taken at five locations on site. The surface soil samples were collected using a stainless steel sampling knife, which was steam cleaned between sampling locations. The details of the samples taken are given in Table 2, Volume 2.

### 3.8 Sample Storage, Preservation and Transportation

Soil samples were collected at specified depths in trial pits and stored in airtight containers at less than 4°C prior to submittal to the Geochem Group for chemical testing. Additional samples from each trial pit were retained by KT Cullen and stored at less than 4°C.

Groundwater samples were shipped to Geochem by overnight courier.

Samples for BOD and COD analysis were submitted within 4 hours to

Mercury Analytical, Raheen Industrial Estate, Limerick, for analysis.

## 3.9 Laboratory Testing

## **Chemical Testing**

Specific suites of tests were selected for evaluation of the contamination of soil and water as follows. The detailed testing suites are given in Appendix Z.

### Soil

S1 : Spent oxide/organics screening analysis

S1x to S1z : Dependant Options on S1

S2 : Gasworks screening analysis

S3/S4 : Mineral Oils of the S5 : Volatiles of the S5

auth diffe

S6 : Leachate Testing

Water

W1 : S Gasworks screening analysis

W2 Supplementary analysis - metals

W3 Water quality analysis

The individual test schedule/chain of custody sheets for each trial pit and borehole are given in Appendix F, Volume 2.

## **Geotechnical Testing**

Selected soil samples were tested, in accordance with BS 1377, by Glover Site Investigation Limited, for coarse and fine grading. The particle size distribution curves are given in Appendix E, Volume 2.

#### 4.0 GROUND CONDITIONS

## 4.1 Stratigraphy

The two site investigations revealed the following succession of strata: Some geological cross-sections are shown on Figure 4.

	-	Thickness (m)
Stratum	Range	Average
Made Ground	0.2 - 8.6	2.6
Alluvium	0.0 - 1.4	TP7, TP27 and BH11 only
Limestone Bedrock	4.2 m proven	

Table 4.1: Summary of Ground Conditions

### 4.2 Made Ground

The made ground is very variable in nature and consistency. The made ground is usually granular in nature and contains spent oxide, ash material, brick and concrete fragments, and timber pieces. The material is often contaminated with tarry liquid and occasionally has a strong phenolic odour.

The deepest thicknesses of made ground are associated with either the old quarry or with former gas tanks which extended underground.

Standard penetration test results carried out in the made ground are shown on Figure 6. They confirm the material to be in a generally very loose to loose and occasionally medium dense condition.

Particle size distribution curves of samples of the made ground summarised on Figure 7, confirm that the material is predominantly granular in nature.

Moisture content values for the material, shown on Figure 10, are variable but are in the range 5% to 30%.

### 4.3 Alluvium

The alluvium, associated with the River Shannon, was encountered in BH11, TP7 and TP27 only. The material is a soft to firm brown plastic silty clay.

#### 4.4 **Bedrock**

The top 0.5 m to 1.0 m of the bedrock was usually proven to be weathered and to comprise gravel to boulder size blocks of limestone which were relatively easily excavated by the Hymac. The joints between the blocks were infilled with brown/black clay and frequently with tarry liquid, see photographs Appendix Y.

Below this level the bedrock comprises strong dark to medium grey coarse grained well bedded limestone. Total sore recoveries (TCR) were in the range 14% to 100% with an average of 76%. Rock quality designation (RQD) values were also in the range 14% to 100% with an average of 64%. These values indicate the rock to be in fair to good condition (BS 5930). The discontinuities in the bedrock were typically spaced at 0.1 m to 0.2 m and were stained with tar in boreholes 7, 8 and 11.

Figure 5 shows estimated contours of bedrock level from the boreholes and trial pits. The bedrock surface is very uneven due to the previous quarrying activities on the site and due to the excavation for underground tanks and tank foundations.

Bedrock is seen to outcrop near the southern site boundary. The natural slope of the bedrock is from approximately 7 m OD at the southern boundary to 3 m OD at the northern boundary. The hollows near boreholes 7, 8 and 10 are due to previous excavation for tanks. The hollows near BH11 and along the O'Curry Street boundary of the site are due to previous quarrying activities. Rock is deepest at BH11 and this is consistent with the area of water shown on SK2, Appendix W.

#### 4.5 Groundwater

Groundwater was encountered in all of the trial pits and boreholes at depths of between 0.3 m and 2.8 m in the made ground. The pattern of groundwater levels and flow direction is very difficult to establish because of the uneven nature of the bedrock, due to previous quarrying and excavation for tank bases and underground tanks.

Groundwater levels measured in the wells is considered to be the most reliable as the water level has some time to reach steady state. Contours of groundwater level for the made ground (overburden) and bedrock are shown in Figures 8 and 9 respectively. Both figures indicate that the general flow direction is north - northwest towards the River Shannon from a level of approximately 7 m OD on the southern side of the site to approximately 4 m OD on the northern side of the site of the River Shannon water level is typically 3 m OD near the site).

Two wells were installed BH12, in the overburden and the bedrock respectively. The water level monitored in both wells is the same confirming that there is hydraulic continuity between the overburden and bedrock.

A discussion of the degree of contamination of the groundwater, the occurrence of floating product etc. is given in Section 5.4.1.

#### 4.6 Hydrogeology

The in-situ permeability tests carried out in the made ground indicate that the material has a permeability of 2.0 x 10<sup>-6</sup> m/s to 3.0 x 10<sup>-6</sup> m/s which is classified as being "low permeability" and is typical for a silty sand (Ref. 6).

The packer permeability tests in the bedrock suggest that the mass permeability in the bedrock is of the order of 1 x 10<sup>-7</sup> m/s, which is classified as being "very low" (Ref. 6).

#### 5.0 **RESULTS OF CHEMICAL ANALYSES**

#### 5.1 General

The detailed results for the Phase 1 Site Investigation are given in Reference 1. The detailed results for the 1995 (Phase 2) site investigation are given in Tables 5 to 18 of Volume 2.

A summary of the results for both investigations are given in Tables C to P of this Volume.

A statistical analysis of all of the data is given on the summary tables Q and R. This statistically analysed data will be discussed under various categories in the following sections.

#### 5.2 **Screening Criteria**

A discussion on the various contamination guidelines in use internationally is given in Ove Arup & Partners Ireland Contamination Guidelines Report (1995, Ref. 2). The screening criteria recommended in this report have been adopted here.

For the traditional water quality parameters reference is also made to the European Community Directive 75/440/EEC concerning the quality of drinking water, so as to aid the reader in understanding the measured levels of the various parameters.

The tables below make reference to the minimum usually the detection limit, maximum, aritmetic mean, median and screening level.

# 5.3 Soil Testing

## 5.3.1 Organic Determinands

The results of chemical testing or organic determinands considered are presented on Tables C, F, G, H & I and are summarised on Table 5.1 below.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Total Phenois	mg/kg	Table C	72	0.01	634	44.49	4.25	5
TEM	mg/kg	Table C	72	68	632577	43510	7219	5000
Benzene	μg/kg	Table F	16	10	38704	7252	332	1000
Taluene	μg/kg	Table F	16	10	36816	8044	473	130,000
Ethyl Benzene	μg/kg	Table F	16	10	II /640 🚮	1501	108	50,000
Total Xylene	μg/kg	Table F	16	11	37550 He	8535	536	25,000
Total PAH	mg/kg	Table G	23	4 1	37550 37449	8730	882	500
Mineral Oils	mg/kg	Table H	16	32005	116029	18817	1392	5000
Total Extract	mg/kg	Table H	16	of soles,	270463	46281	5542	5000
Isoprenoid	mg/kg	Table H		OWI 2	4154	613	45	
Paraffins	mg/kg	Table H	₹º16YIB	9	10305	1445	624	(*)
Other/Organics	mg/kg	Table H	S 16	79	257129	43009	5154	
Combined Isoprenoids and Paraffins	mg/kg	Table H	16	11	13334	2961	669	5000
Total Volatiles	mg/kg	Table I	15	165	346343	78535	5981	70,000

Table 5.1 Summary of Organic Determinands in Soils

Organic contaminants were the most significant of those detected during the site investigation at the Limerick gasworks site.

Evidence of heavy staining by tars and tarry liquid with a phenolic odour was encountered in most of the boreholes and trial pits except over the south western part of the site around TP2, TP21 and TP26. The tarry staining penetrated into the bedrock joints in BH's 7, 8, 10 and 11.

Particularly elevated levels of organic determinands were encountered in TP1, TP2, TP8, TP15, TP19, TP22, TP23 and TP24 mostly beneath old tanks. The contamination is most likely due to spillages and leaks from the tanks.

### 5.3.2 Spent Oxide

The results of chemical testing for determinands associated with spent oxide are presented on Tables C, D and E and are summarised on Table 5.2 below.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Water Soluble Sulphate	g/l	Table C	11	0.09		Se. 0.53	0.54	1
Acid Soluble Sulphate	mg/kg	Table C	72	0.01	102000 that	21740	800	2000
Total Cyanide	mg/kg	Table C	72	1 35	200	402	20.5	250
Complex Cyanides	mg/kg	Table D	11	5 VITE CI	10000	2205	398	250
Free Cyanide	mg/kg	Table D	32	dorner.	110	12	2	25
Thiocyanate	mg/kg	Table D	Tod Nich	10	210	56	30	50
Sulphur	mg/kg	Table E	_ ∂6°	0.01	151000	14638	4150	5000
Sulphide	mg/kg	Table E	37	0.30	740	52.21	11	250

Table 5.2 Summary of Spent Oxide Determinands in Soils

Visual evidence of spent oxide and "blue billy" was encountered in TP3, TP8, TP10, TP12, TP13 and TP14 in the central area of the site, in the old quarry area. The material was possibly spilled in this area during early development of the gasworks.

Elevated sulphate levels generally occurred throughout the site with the exception of some areas in the western part of the site where some cleaner fill has been placed in recent years.

Elevated cyanide levels occurred mostly along the central strip of the site, particularly near TP8, TP12, TP13, TP15 and TP22.

Elevated sulphur and sulphide levels occurred randomly but mostly around the central part of the site.

## 5.3.3 Metals

Full details of the results of chemical testing for metals are given Table E and are summarised below on Table 5.3.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Arsenic	mg/kg	Table E	16	2	88	24	18	40
Cadmium	mg/kg	Table E	16	1	2	1.0	1	3
Chromium	mg/kg	Table E	16	2	68	19	15	1000
Copper	mg/kg	Table E	16	4	244	56	29	130
Mercury	mg/kg	Table E	16	1		1	1	1
Nickel	mg/kg	Table E	16	3	1460the	30	20	70
Lead	mg/kg	Table E	16		OTIO 211	212	75	2000
Zinc	mg/kg	Table E	16	1500	840	148	76	300

Table 5.3 Summary of Metal Determinands in Soils

Generally of significant elevated metal levels were found on the site with the exception of the area around the chimney in the original gasworks, the elevated levels apparently being associated with ash from burning.

#### 5.4 **Groundwater Testing**

## 5.4.1 General Description

Heavy oils and oozing tarry liquid was encountered in six of the sixteen trial pits excavated during the Phase 2 site investigation. These pits (TP's 16, 18, 19, 23, 24 and 25) were all located on the western side of the site in the area of the old gasworks.

Floating product with globules of tarry material was detected in three of sixteen trial pits. (TP's 12, 14 and 22).

No groundwater was encountered in seven of the pits.

Tarly liquid was discovered to have penetrated downwards into the joints of the bedrock in BH's 7,8 and 11 across the central area of the site.

## 5.4.2 Organic Determinands

The results of chemical testing for organic determinands are presented on Tables L and M and are summarised below on Table 5.4.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Total Phenois	mg/l	Table L	28	0.02	828 their	69.05	3.08	2
Amm. Nitrogen	mg/l	Table L	27	2.76	0117.540	91.16	58.36	3
Total PAH	μg/l	Table M	25	0,000	123749	21488	1042	

Table 5.4 Summary of Organic Determinands in Groundwater

Elevated levels of organic determinands in the form of phenols, ammoniacal nitrogen and PAH were present throughout the site. Significantly high levels were measured beneath old tanks e.g. BH7, BH8, BH10, TP13, TP15 and TP23 and also in BH9.

Low organic determinand levels were encountered in BH12, TP12, TP13 and TP27 all on the eastern boundary of the site.

## 5.4.3 Spent Oxide

The results of chemical testing for parameters associated with spent oxide are given on Tables L and N and are summarised on Table 5.5 below.

Elevated levels of cyanide were encountered in TP12, TP24 and TP27 through the central section of the site. Elevated sulphate and sulphide levels were found in some trial pits along the centre of the site and also beneath the area of the old gasworks.

It is possible that these values are associated with the spilling of waste materials in the old quarry areas during the early development of the gasworks. The elevated groundwater values were found in the same areas as the elevated soil values, possibly suggesting that the groundwater is not very mobile.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Total Cyanide	mg/l	Table L	24	0.01	43	و <sup>د.</sup> 2.87	0.10	1.50
Sulphide	mg/l	Table N	17	0.01	1.02 die	0.16	0.07	0.30
Sulphate	mg/l	Table N	20	31	3500	565	351	150

Table 5.5 Summary of Spent Oxide Determinands in Groundwater

5.4.4 Metals

The result of chemical tests for metal determinands are given on Table O and are summarised on Table 5.6 below.

Compound/Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
Arsenic	mg/l	Table O	17	0.05	1.54	0.23	0.05	0.06
Cadmium	mg/l	Table O	17	0.05	1.00	0.11	0.05	.006
Chromium	mg/l	Table O	17	0.05	1.00	0.11	0.05	0.03
Copper	mg/l	Table O	17	0.05	1.00	Ō.11	0.05	.075
Mercury	mg/l	Table O	17	0.05	1.00	0.11	0.05	.0003
Nickel	mg/l	Table O	17	0.05	1.00	0.11	0.05	.075
Lead	mg/l	Table O	17	0.05	1.00	0.14	0.05	.075
Selenium	mg/l	Table O	16	0.1	1.00	0.16	0.10	
Zinc	mg/l	Table O	17	0.05	3.00	0.30	0.05	0.80

Table 5.6 Summary of Metal Determinands in Groundwater

Generally no significantly high metal concentrations were detected in the groundwater except in TP15, TP18, BH7 and BH10 mostly in the area of the old gasworks.

## 5.4.5 Traditional Water Quality Parameters

The results for testing of groundwater samples for traditional water quality parameters are given on Tables K, N and P and are summarised on Table 5.7 below.

Compound/ Element	Units	Results Table	No. of Results	Min. Conc.	Max. Conc.	Arithmetic Mean	Median	Screening Criteria (OAPI, 1995, Ref 2)
рН	рН	Table K	22	6.85	9.75	7.80	7.51	< 5
Conductivity	μS	Table K	17	487	2280	1454	1539	1500
Temperature	°C	Table K	17	11.50	1,7305	13.70	14	22
BOD	mg/l	Table N	17	18 8	d 10249	1498	177	3
COD	mg/l	Table N	17	A Second	1126168	139508	2120	30
Aluminium	mg/l as Al	Table P	17	0.05	10.40	1.02	0.17	0.20
Calcium	mg/l as CA	Table P	17000	46.60	2955	497.47	222	200
Iron	mg/l as Fe	Table P	COLINGIA	0.38	53	9.76	1.89	0.20
Magnesium	mg/l as Mg	Table P	5 17	1.14	31.70	16.62	15.30	50
Manganese	mg/l as Mn	Table Port	17	0.05	12	1.55	0,65	0.05
Colour (True)	Hazen Units	Table P	14	28	1180	224	66.50	
Total Hardness	mg/l as CaCo <sub>3</sub>	Table P	16	48	2705	769	3.61	
Turbidity	NTU	Table P	13	75	6000	1808	10.75	
Non-Carbonate Hardness	mg/l as Caco,	Table P	12	19.80	123	77.59	86.55	
Potassium	mg/l as K	Table P	15	5.20	75.40	18.51	14.10	12
Sodium	mg/l as Na	Table P	15	12	258	97.99	68	150
Organic Carbon	mg/l as C	Table P	10	10	1000	306	140	
Chloride	mg/l as CL	Table P	15	16	1268	264	168	250
Nitrite	mg/l as NO,	Table P	15	0.01	2.80	0.26	0.08	0.03
Nitrate	mg/l as NO,	Table P	15	1.20	10.90	4.33	2.40	50
Total Alkalinity	mg/l as CaCo,	Table P	7	280	3270	1726	13.90	***

Table 5.7 Summary of Traditional Groundwater Quality Parameters

The "screening criteria" quoted on the Tables are taken mainly from the EC Directive 75/440/EEC. These values may aid the reader in understanding the data but they do not necessarily give "action " levels.

It can be seen the generally across the site the parameters exceed those required for drinking water quality.

The pH of the groundwater was mostly near neutral, being in the range 6 to 9.

## 5.5 Surface Samples

The results of the chemical testing on the surface samples scraped from the masonry walls around the site showed elevated levels of sulphates and various organic parameters.

## 5.6 Leachate Testing

The results of chemical testing on the eluate produced by leaching of the solid samples showed that the potential for leaching of the various compounds considered was very low, the measured concentrations being less than 0.1% of the original values. The exception to this is that 28% of the phenol in TP15 was extractable following leaching.

### 5.7 Repeat Groundwater Testing

A second set of samples of groundwater from the monitoring wells were taken about 6 weeks after the initial sampling and subject to retesting.

There were generally no significant differences in the two sets of results. The results showed a large degree of repeatability. One possible exception is BH8 where there was a significant increase in the phenol concentration, and a decrease in the PAH value. These results were associated with a significant decrease in temperature of the sample.

## 5.8 Gas Monitoring

Gas monitoring results by KT Cullen from Boreholes 7 to 12 recorded on 11 August 1995 and 25 September 1995 are given in Table 4, Volume 2. Subsequent readings were taken by BGE on 12 December 1995, 23 January 1996 and 12 March 1996 and by BHP Environmental Services on 23 January 1996 and 24 January 1996. The results are summarised below:

Gas	Units	Min.	Max.
CH₄	%	0.0*	86.6
CO₂	%	0.0	3.2
O <sub>2</sub>	%	0.0	20.8
H₂S	ppm	0.0	0.0

Table 5.8 Summary of Gas Readings, officers

The concentration of CH4 and CO2 were significantly higher on the second set of readings by KT Cullen, possibly because the gas concentrations had more time to build up in the sealed monitoring wells. The corresponding 02 levels were lowers reach case. A summary of the methane readings is given below:

Borehole (Date)	BH7²	BH8 <sup>1</sup>	ВН9²	вн101	BH11 <sup>1</sup>	BH12(s) <sup>1</sup>	BH12(P) <sup>2</sup>
11/9/95 (KTC)	3.0	0.1	0.4	0.4	0.1	2.1	0.2
25/9/95 (KTC)	74.0	17.1	0.4	34.0	0.0	¥.	86.6
12/12/95 (BGE)	0.0⁴	0.0	0.0	0.0	0.0	*	70³
23/1/96 (BGE)	0.0	0.0	0.0	0.0	0.0	7	80
23/1/96 (BHP)	1.0	1.0	1.0	1.0	1.0	127	84
24/1/96 (BHP)	1.0	1.0	1.0	1.0	1.0	-	84
12/3/96 (BGE)	0.0	0.0	0.0	0.0	0.0	-	90

Table 5.9 Summary of Methane Level Readings (given in %)

#### Notes:

- Screen in overburden.
- 2. Screen in bedrock.
- 3. Dropped to 20% later in day.
- 4. Instrument reading was zero.

The velocity of the gas emissions was also measured by BHP on 23 and 24 January 1996 and was found to be negligible.

A tube sample of the gas from BH12 was also take on 23 January 1996 and subjected to GCMS analysis by BGE. It was possible to identify traces of Kinsale Natural Gas in the sample, thus suggesting that the high concentrations measured are due to a leak in a gas main.

An investigation of the nearby gas pipe network is currently being undertaken by BGE. No leaks have been found in the immediate vicinity of the site. However, as the gas has been detected in the bedrock it is possible that the source of the leak is on the higher ground to the southeast of the site, where the rock is close to the surface. The gas may have then been transported downstream by the flow of water towards the River Shannon to the north-west.

Methane (CH<sub>4</sub>) is explosive at concentrations between 5 and 15% v/v. The highest levels recorded in Borehole 12 were significantly higher than the explosive limit. Until the source of the high methane levels is confirmed, careful consideration should be given to the impact of these levels on the current site usage as well as on future development of the site. The methane level in BH7, for instance, which is approximately 35 m from the existing offices was 74% on 25 September 1995. Consideration should be given, for example, to removing all possible sources of ignition, prohibiting work in enclosed spaces and well venting all work areas.

Carbon dioxide (CO<sub>2</sub>) is an asphyxiant and can be toxic at relatively low concentrations. It is commonly encountered as a soil gas when peat or organic contamination is present in the ground. Concentrations between 1.7 and 3.2 percent v/v were found in the gas standpipes installed in boreholes 7, 8, 10 and 12. These concentrations are below the Action Concentration of 5% v/v in the current UK Building Regulations for new development. Higher concentrations could occur in "hotspot" areas of organic material.

Oxygen (O<sub>2</sub>) is normally present in air at about 21 percent. Oxygen levels were reduced significantly in all boreholes on 25 September 1995 and were accompanied by elevated levels of carbon dioxide and methane.

Hydrogen Sulphide ( $H_2S$ ) can cause a health risk at concentrations in excess of 50 ppm. No hydrogen sulphide was found in the 7 gas standpipes.

The above results are generally in conflict with those measured during the Phase 1 site investigation by O'Connor Sutton Cronin/Gibb Environmental. In the Phase 1 investigation CH4 levels, measured in trial pits, were all 2% or less. CO<sub>2</sub> levels were less than 0.5%. These low values are likely to have been influenced by the well ventilated nature of the trial pits.

## 5.9 General Descriptive Summary of Chemical Testing

Elevated levels of the various soil and groundwater determinants were found throughout the site. In particular significantly elevated levels of the determinants were found in the old gasworks site, through the central area of the site in the former quarry area and beneath the various old tanks.

The areas along the eastern boundary of the site and in the south west corner of the site were found to have the lowest levels of the various contaminants.

### 6.0 GEOTECHNICAL RECOMMENDATIONS

Proposals for development of the site are at an early stage. However, it is understood that the site is being considered for a mixed development of relatively lightweight industrial and commercial buildings.

The made ground material is not suitable for the support of building foundations. The buildings should be supported either on conventional pad and strip footing on the bedrock or a piled foundations where the bedrock is deeper than about 3m. Bearing pressures of up to 1000 kN/m² could be supported on the bedrock. Typically precast concrete piles in the Limerick Docks are used to support loads of 800 kN (270 mm x 270 mm) and 1000 kN (300 mm x 300 mm).

Careful consideration should be given to the design of concrete to resist chemical attack and in particular attack by sulphates.

Methane protection measures will be regulired for all buildings.

# 7.0 REMEDIATION OPTIONS FOR THE LIMERICK SITE

#### 7.1 Considerations

#### 7.1.1 General

As noted in OAPI (1995, Ref 7), the selection of the most appropriate technique, or combination of techniques, for remediation of a site depends on the assessment of a wide combination of site-specific factors. For the Limerick site, the principal factors that must be considered are:

- 1. The location of the site;
- 2. The ground conditions;
- The depth and nature of contamination;
- 4. The proposed future use(s) of the site;
- 5. The suitability of proven techniques;
- 6. The time available for ground remediation; and
- 7. The relative costs, benefits and liabilities of the alternatives.

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The impact of each of these factors on the remediation options outlined in Chapters 3.0 and 4.0 of OAPI (1995, Ref 7) are discussed below.

## 7.1.2 Summary of Site Conditions

The site is located within a mixed urban residential and industrial area in Limerick City. The sensitive nature of the surrounding land uses will require close control of dust, noise and odour and will require that the quality of the groundwater naturally migrating from the site is compatible with the quality and utilisation of the local water resources. Since there are no suitably licensed local landfills for soils contaminated to the levels found on this site, the mass excavation and off-site disposal (landfilling) of such material is not an available option. Off-site treatment and disposal of substantial volumes of significantly contaminated soil to Northern Ireland, the UK or elsewhere in Europe is not a viable option due to EU restrictions on the transfrontier shipment of wastes and the high cost of transport and disposal. However, this is an option for small volumes of heavily contaminated material.

The ground conditions on the Limerick site are characterised by typically 2.5m of variable but essentially granular made ground over much lower permeability limestone rock. Deep (3m to 6 m) excavations have been made into the bedrock for gasholder foundations and to quarry for rock. These areas of deep excavation probably represent 30% to 40% of the site area. At the north eastern corner of the site alluvial deposits also occur beneath the made ground. The groundwater table is generally about 1m below the surface in the made ground and is in hydraulic continuity with groundwater in the limestone bedrock.

The results of the recent site investigations undertaken by Ove Arup & Partners Ireland/K T Cullen & Company Limited and the previous site investigation carried out by O'Connor Sutton Cronin/Gibb Environmental have shown that the made ground is heavily contaminated throughout the site with a range of organic determinants, sulphates and complex cyanides. The groundwater is also heavily contaminated by organics cyanides and sulphates. The areas along the eastern boundary of the site and the south west corner of the site were found to have the lowest levels of contamination.

### 7.1.3 Possible Treatment Methods

These ground conditions require remediation methods which are able to accommodate moderate to heavy organic contamination and contamination by cyanide in a highly variable "soil". Therefore engineering based methods, biological treatment and thermal treatment are viable pations. Soil washing or solidification treatment methods are less suited to the site due to the high levels of organics of interest.

The proposed future use of the site will continue to be "industrial/commercial" but the use of the site for residential or open space purposes cannot be ruled out. Industrial/commercial end-use minimises the pathways between residual contamination and future users of the site. Therefore options involving cover layers and engineered on-site burial can be considered, subject to groundwater quality constraints.

The availability of suitable technologies and the time available for treatment are essential factors which can be considered in combination. It is understood that Bord Gais have no specific time frame in mind for the site development. All of the engineering based methods involve proven technology which would be able to be implemented within a given time frame. However, many of the process based options, with the exception of soils washing, thermal treatment and ex-situ bioremediation in treatment beds, would either be unsuitable or would involve high risks on their success. Ex-situ bioremediation also involves uncertainties on the time required to achieve agreed "clean-up" concentrations and a substantial area of site is needed to lay out the treatment beds. Biological treatment would only really be effective in the warmer 6 months of the year.

Finally the relative costs, benefits and liabilities of the viable alternatives must be considered. In the case of the Limerick site, the selected strategy should be the most cost-effective solution that provides:

- A safe site for future occupiers;
- No significant off-site effects of any residual contamination; and
- Minimum constraints on future site redevelopment for similar uses.

### 7.1.4 Experience with Bioremediation

Biotal Limited, in conjunction with Grace Dearbourn are currently carrying out a trial bioremediation exercise on some soil samples (approximately 25 kg) taken from the Cork Gasworks site.

The soil originally had 1,866 mg/kg total PAH's and 495 mg/kg total carcinogen PAH's (cPAH's). Several treatment methods have been used in the trial. To date (day 207) between 41% and 55% of the total PAH's have been removed and 12% to 28% of the total cPAH's have been removed.

The results are encouraging and although the time involved is longer than originally anticipated, Biotal feel an average target concentration of 500 mg/kg (ie. the OAPI, Screening Criteria) can be achieved.

#### 7.2 **Proposed Reclamation Strategy**

With due consideration to all the factors noted above, and following consultation with a representative number of specialist contractors in the field, the recommended remediation strategy is excavation from discrete contamination "hot spot" areas and either removal/encapsulation of contaminated soils or on-site treatment by biological processes. Consideration should be given to the provision of an engineered cover layer over lightly contaminated areas. Allowance should also be made for treatment of heavily contaminated groundwater where this occurs on the site. The need for provision of a out-off wall to prevent migration of contaminated groundwater in the made ground from the site should also be considered, although the successful implementation of the other measures are likely to make this unnecessary.

# 7.2.1 Heavily Contaminated Areas

Note: The tentative contamination zones discussed below are shown on Figure 11. These zones are best estimates based on a general assessment of the site history, the field data form the site investigation and the chemical test results. They are subject to alternation during the site works.

Heavily contaminated areas can pose significant health risks to construction workers and future occupiers, and are the principal sources of groundwater contamination. The proposed strategy for these areas is:-

- 1. Excavation of heavily contaminated "soil" in discrete areas identified by the desk study and site investigation. Soil requiring excavation will be defined as that exceeding site-specific Treatment trigger concentrations for designated contaminants of concern to be determined by the on-going risk assessment.
- 2. Treatment of the excavated material by either:
  - (a) Ship the heavily contaminated material overseas. Alternatively construct a lined cell on the Limerick site. The use of the underground tar tank on the southern side of the site could also be considered.
  - (b) If adequate time is available dig out all of the moderately or heavily contaminated material on the site, in stages, mix together and carry out biological treatment. Return the treated material to the excavation areas.

In both cases the treated areas should be covered by paving and buildings. Depending on the results of the current BGE investigations, future buildings may require protection by passive methane protection measures (e.g. a gas proof membrane underlain by a ventilation layer).

Significant floating product including tarry oils and heavy tars should be removed with skimmers in open excavation areas.

On site soil washing is not considered suitable or economic for the Limerick site due to the relatively small size of the site and the heavy organic contamination present. This method of treatment could be carried out on spent oxide and moderately contaminated tarry soils at a plant set up at the Cork site.

# 7.2.2 Moderately Contaminated Areas

The proposed strategy for these areas is :-

- 1. Treatment of the excavated material by either:
  - (a) Ship the heavily contaminated material overseas. Alternatively construct a lined cell on the Limerick site. The use of the underground tar tank on the southern side of the site could also be considered.
  - (b) If adequate time is available dig out all of the moderately or heavily contaminated material on the site, in stages, mix together and carry out biological treatment. Return the treated material to the excavation areas.

In both cases the treated areas should be covered by paying and buildings. Depending on the results of the current BGE investigations, future buildings may require protection by passive methane protection measures (e.g. a gas proof membrane underlain by a ventilation layer).

# 7.2.3 Slightly Contaminated Areas

Areas of the site with ground contamination below site-specific Treatment concentrations, but above site-specific Threshold concentrations can pose health risks to construction workers and future site users in potential contact with the ground or by ingesting dust arising from the ground surface. The proposed strategy for these areas is provision of an engineered cover layer over the ground surface to break the pathway between the underlying contamination and the users and neighbours of the site. The design of this cover layer would depend on the details of the particular proposed development but would principally comprise:

- Sub-base and paving in car parking, roads and open storage areas;
  - Clean soil layer(s) in landscaping areas.

#### 7.3 **Groundwater Migration**

If the development of the site is to proceed it will be necessary to initiate a programme of monitoring to establish what off site migrations are occurring. As there are no known productive wells in the area, the only target for underground contaminated water migration is the River Shannon. However, this river has large flows and there would be significant dilution of discharges. Consideration would then be given to the need for surrounding the site with a cut-off trench.

#### 7.4 **DEVELOPMENT OPTIONS**

## 7.4.1 General

Three possible development options are envisaged for the Limerick site as detailed in order of increasing cost below.

It is not possible to develop the site as a high grade residential area. Gardens would not be permitted due to the possibility of entry of contamination into the food chain. It would be possible only to develop the site for apartment type residential use with no gardens or with lightweight industrial units.

Option 1 Develop Site as a Public Park/Car Park

Option 2 Part development

Option 3 Full development of site

These three options are discussed in detail below.

## 7.4.2 Contamination Zones

The various contamination zones shown on Figure 11 are best estimates based on a general assessment of the site history, the field data for the site investigation and the chemical test results. They would be subject to amendment during site works.

The approximate area and volumes of contaminated soil associated with each of the three zones is as follows:

Zone	Area (m²)	Volume of Contaminated Soil
		(t)
Slightly Contaminated	2,210	8,000
Moderately Contaminated	6,84Qs <sup>e</sup> .	24,500
Heavily Contaminated	only 125,120	24,000

Table 7.1 Contamination Zones

# 7.4.3 Option 1: Develop Site as a Public Park/Car Park

This option would involve abandoning the site, as far as commercial usage is concerned, and converting the site into a public park/car park.

It would be necessary to build a cut-off wall around the perimeter of the site to prevent ground water seepage. The cut-off wall would need to penetrate into the underlying limestone bedrock rock by means of a technique such as a bored piling system.

A typical system would comprise a 900 mm dia. secant pile wall with a 2.5 m rock socket. Consideration could also be given in a detailed assessment to utilising a large excavating machines, such as the American "rock saw machines", to rip out the rock to a sufficient depth or to grouting the rock surface beneath a cement bentonite slurry wall.

The site would then be capped. The 0.5 m soil capping layer would include a HDPE liner with an associated surface drainage system. Alternatively a paved cover layer comprising 300 mm of hardcores capping beneath 100 mm of tarmac would be suitable.

## 7.4.4 Option 2: Part Development of Site

This option would involve part development of the site in the slightly contaminated area as shown on Figure 11 with building frontage along O'Curry Street and St. Alphonsus Street.

The soils beneath the building footprint would need to be subject to a treatment process. It would seem that the most suitable treatment process for the Limerick site would be bioremediation. A bioremediation trial would be required prior to the main site works. The bioremediation works would be time consuming and weather dependent.

A cut-off walk and a cover layer similar to that described in Option 1 would be required around the remaining part of the site.

Some additional measures such as protecting concrete against sulphate attack and including gas venting pipes may also be required.

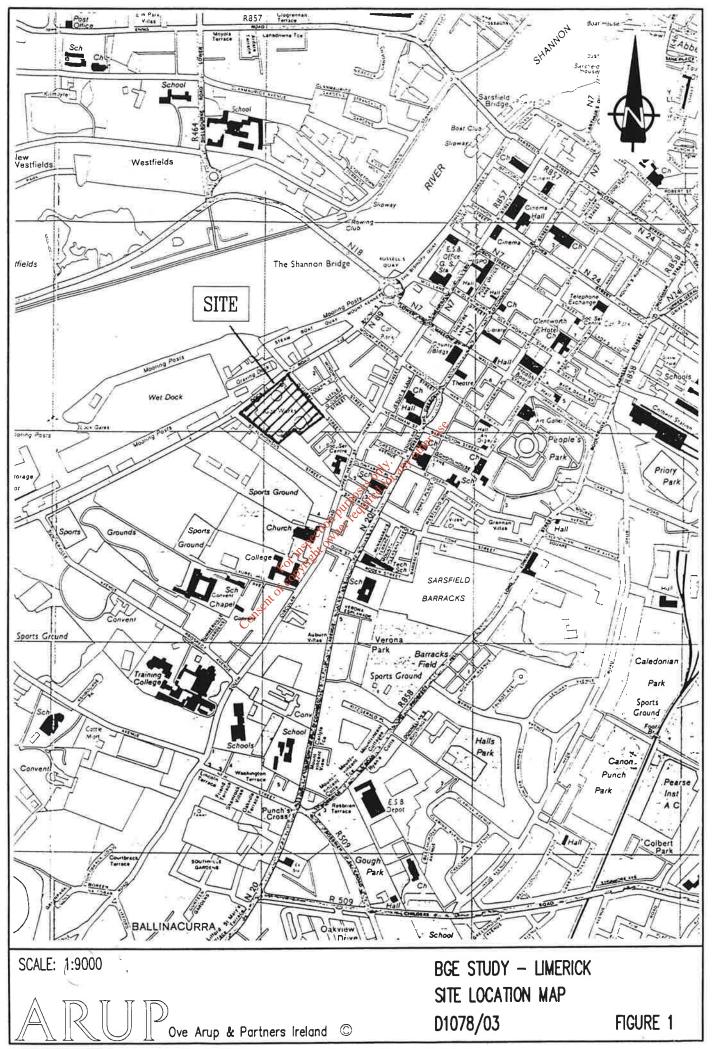
### 7.4.5 Option 3: Full Development of Site

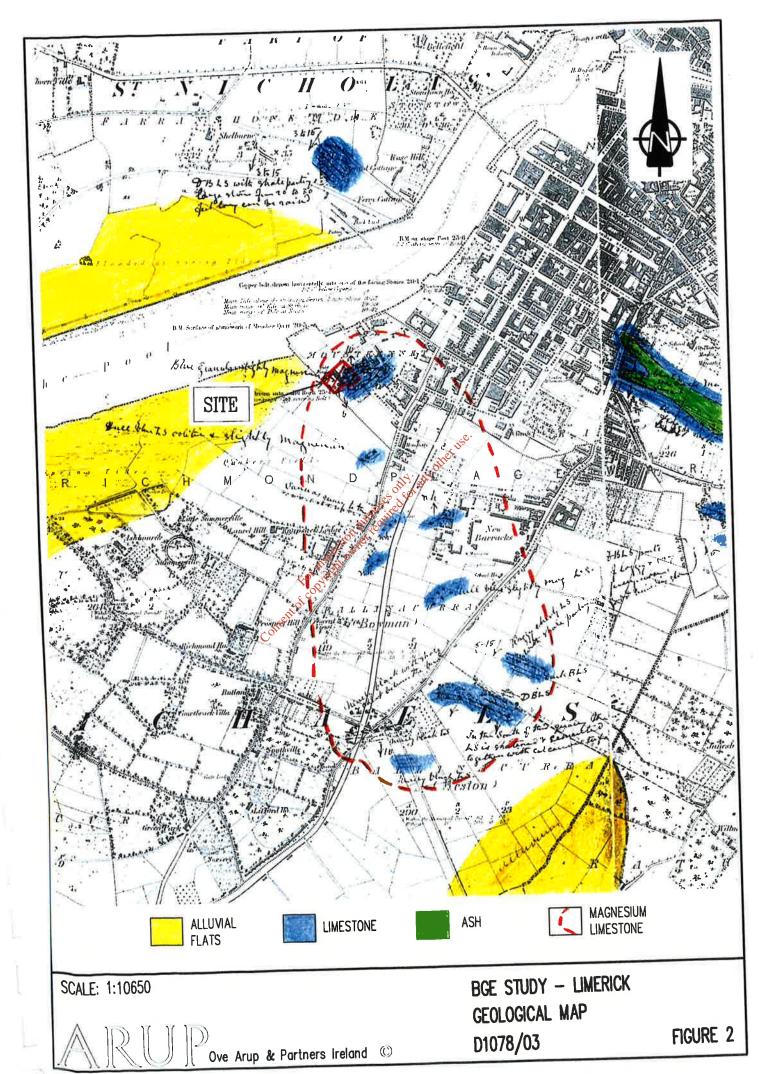
This option would involve treatment of the soils beneath the entire site so as to preclude the need to provide a cut-off wall around the site perimeter.

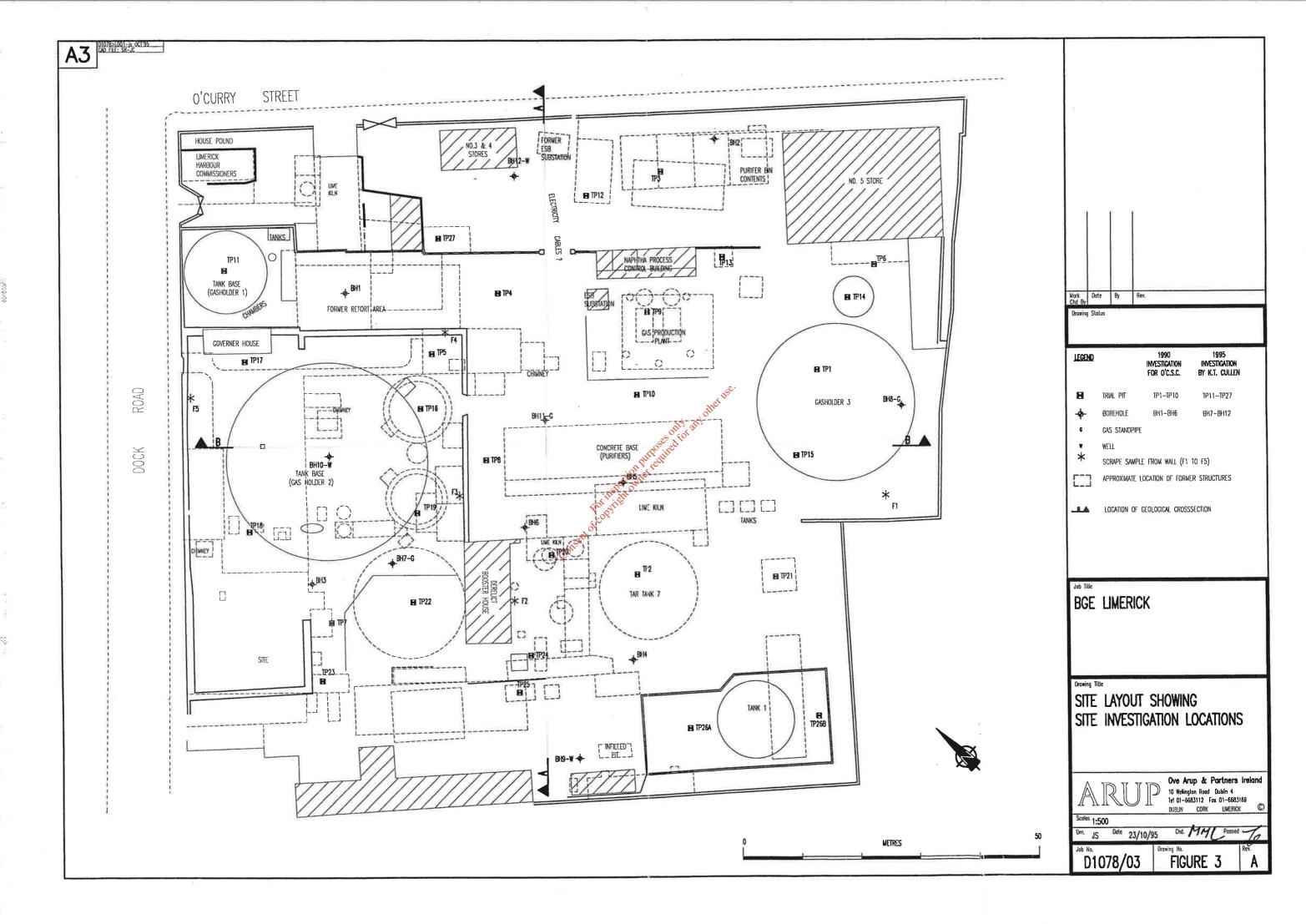
The soils in the heavily contaminated areas would have to be removed off site. The remaining soils would be subject to a bioremediation exercise similar to that described for Option 2. A cover layer similar to that described in Option 1 would be required.

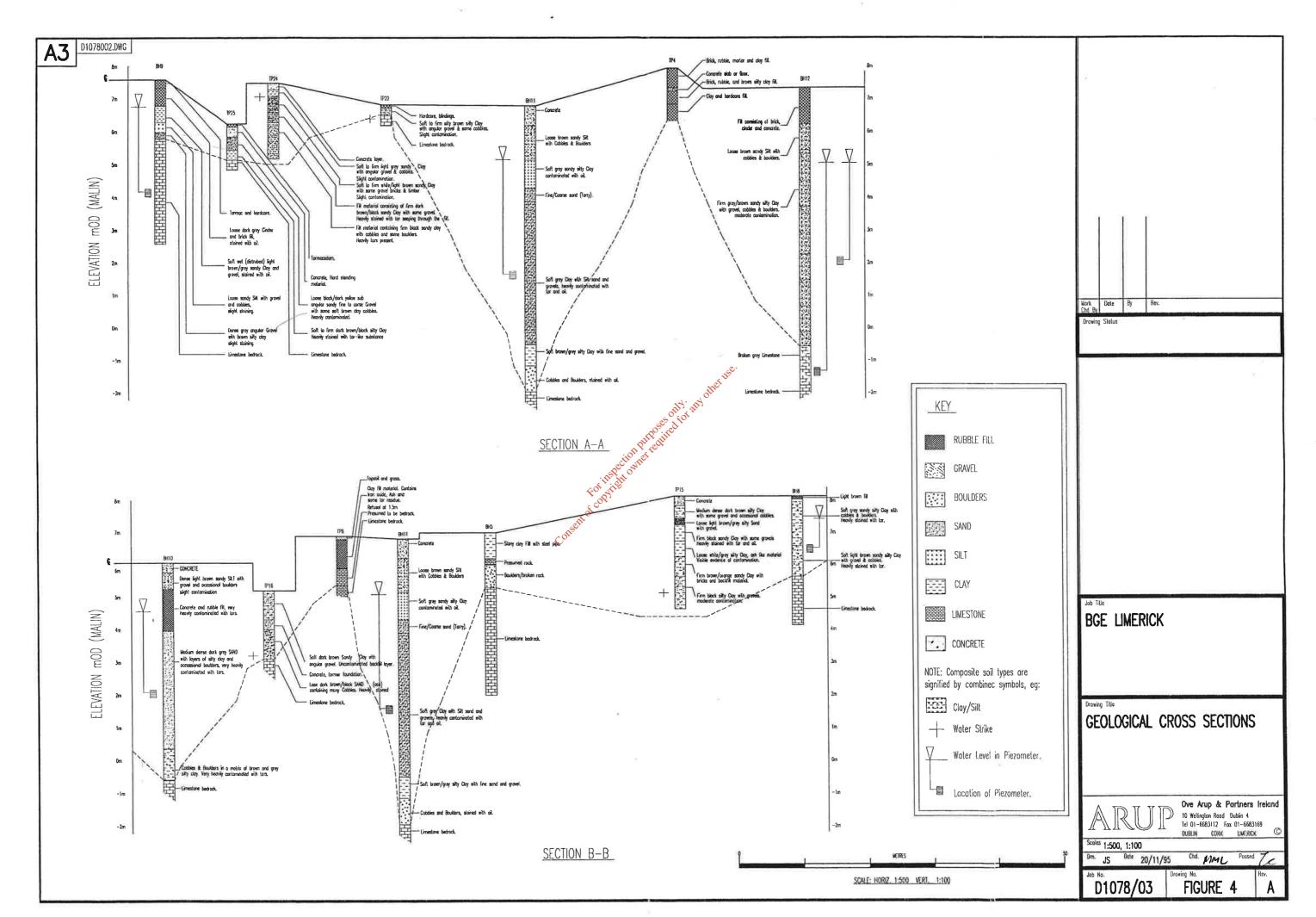
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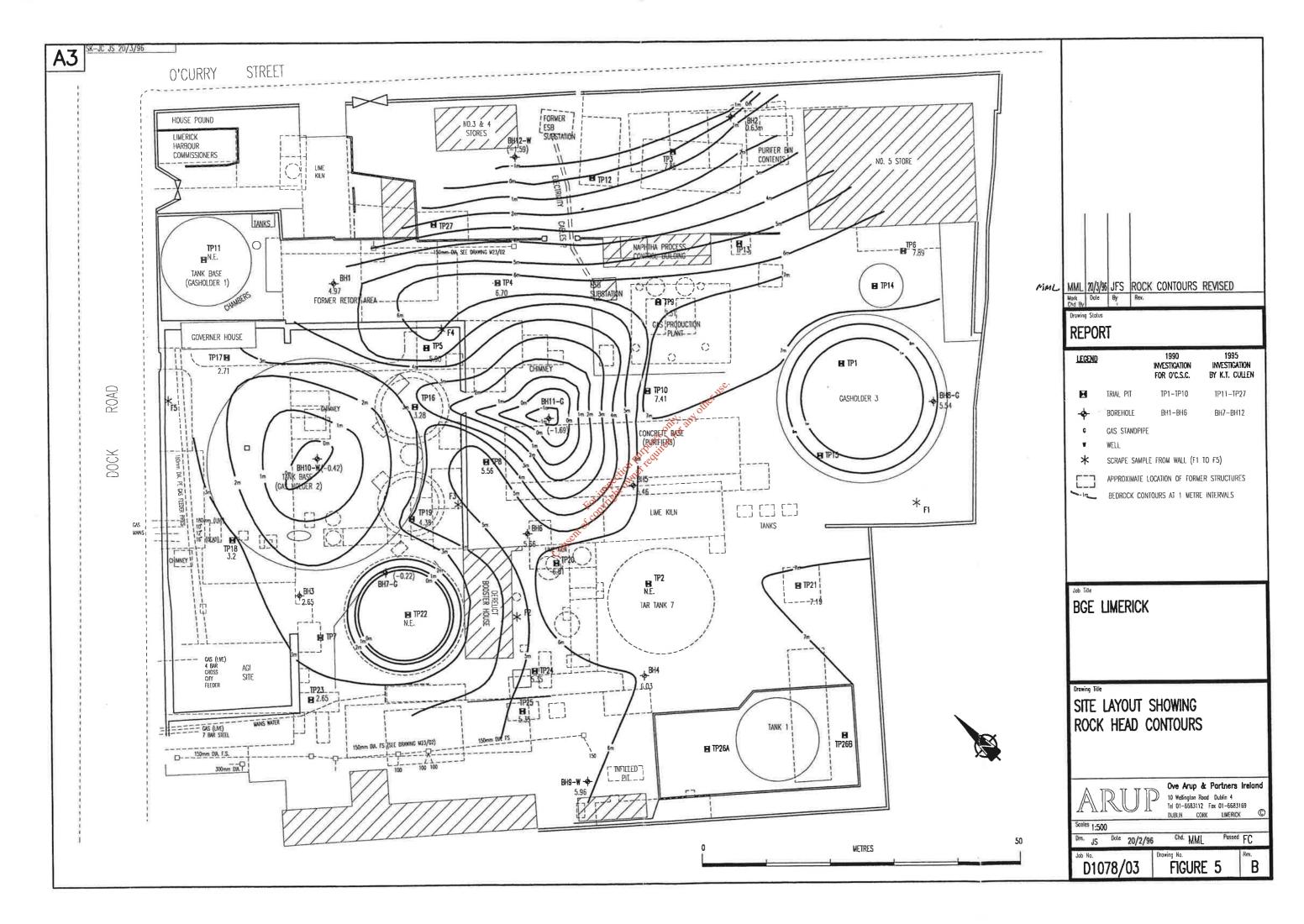
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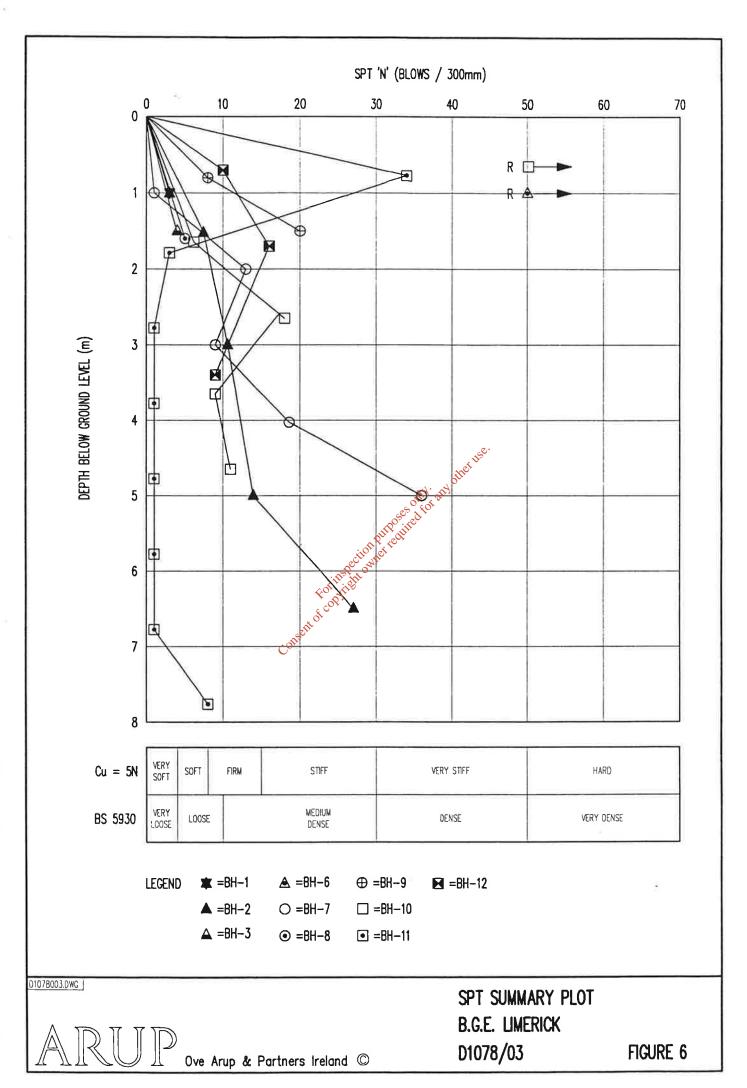


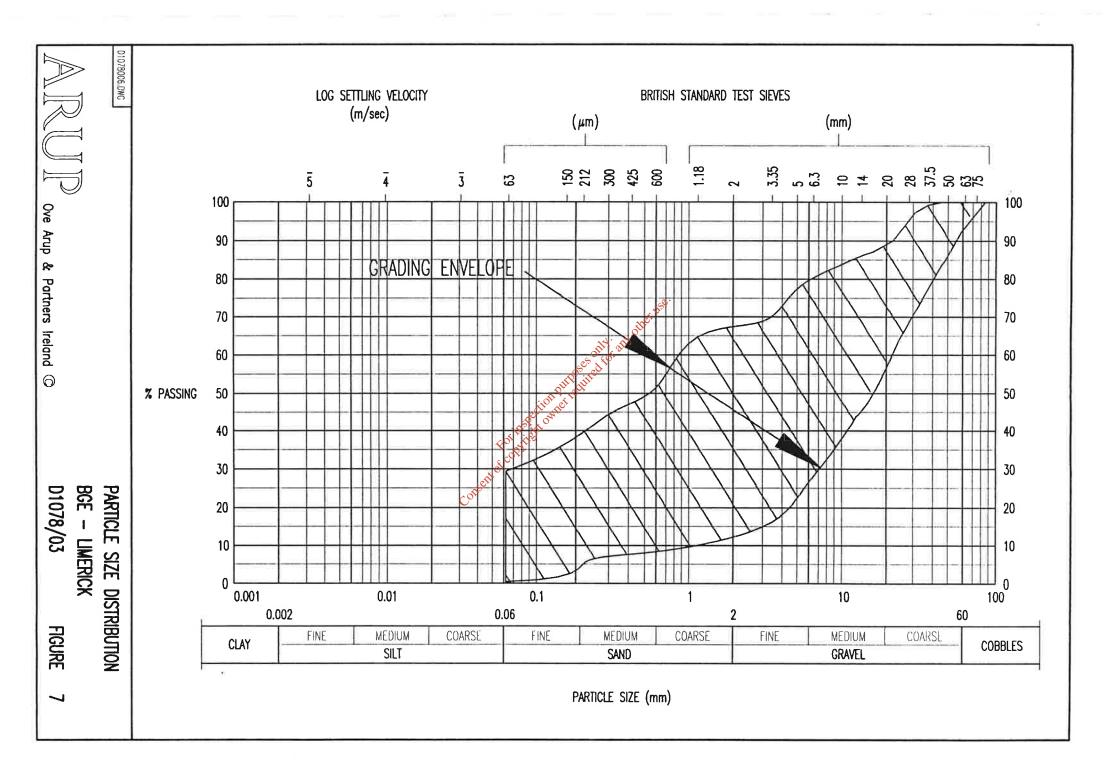


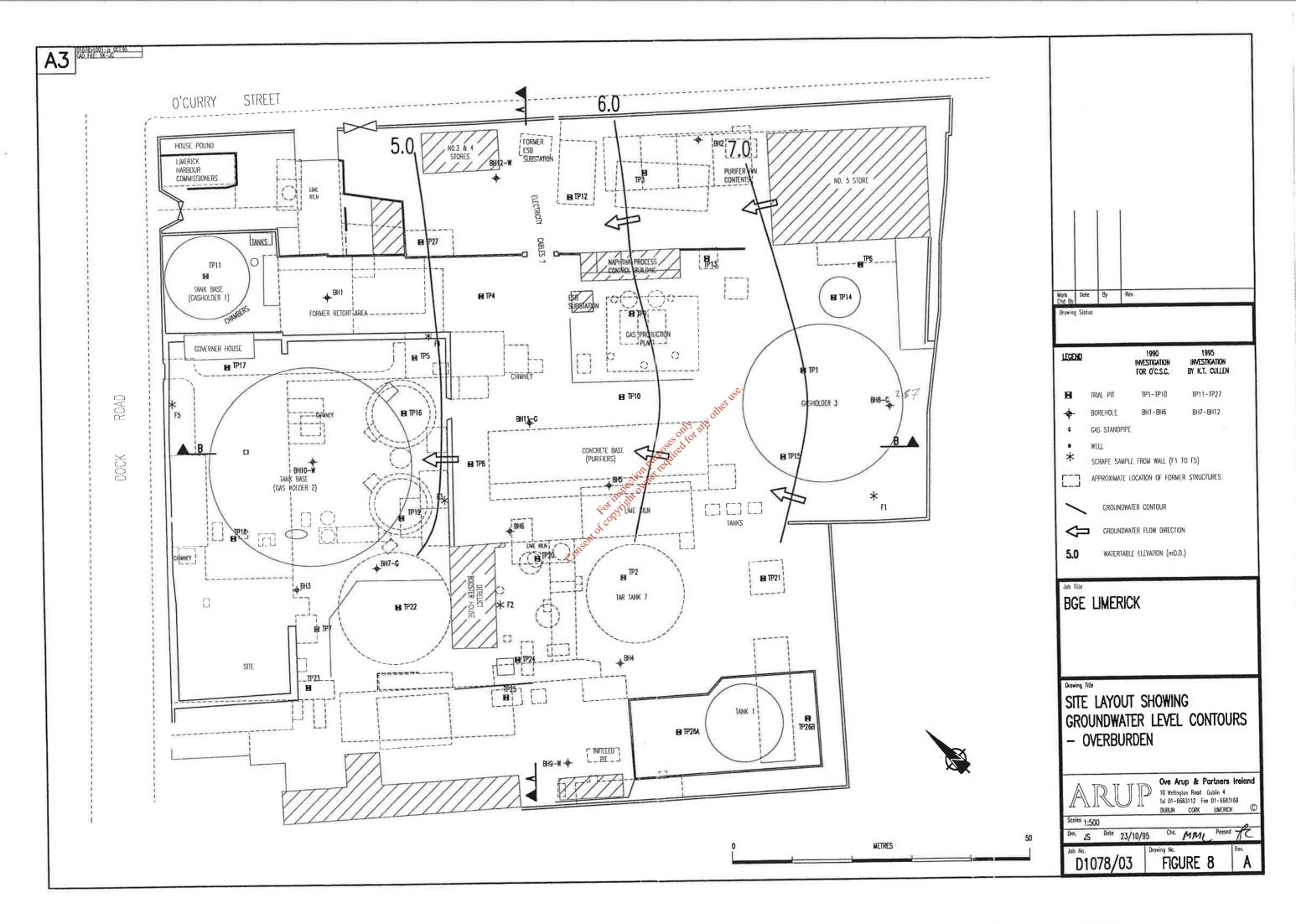


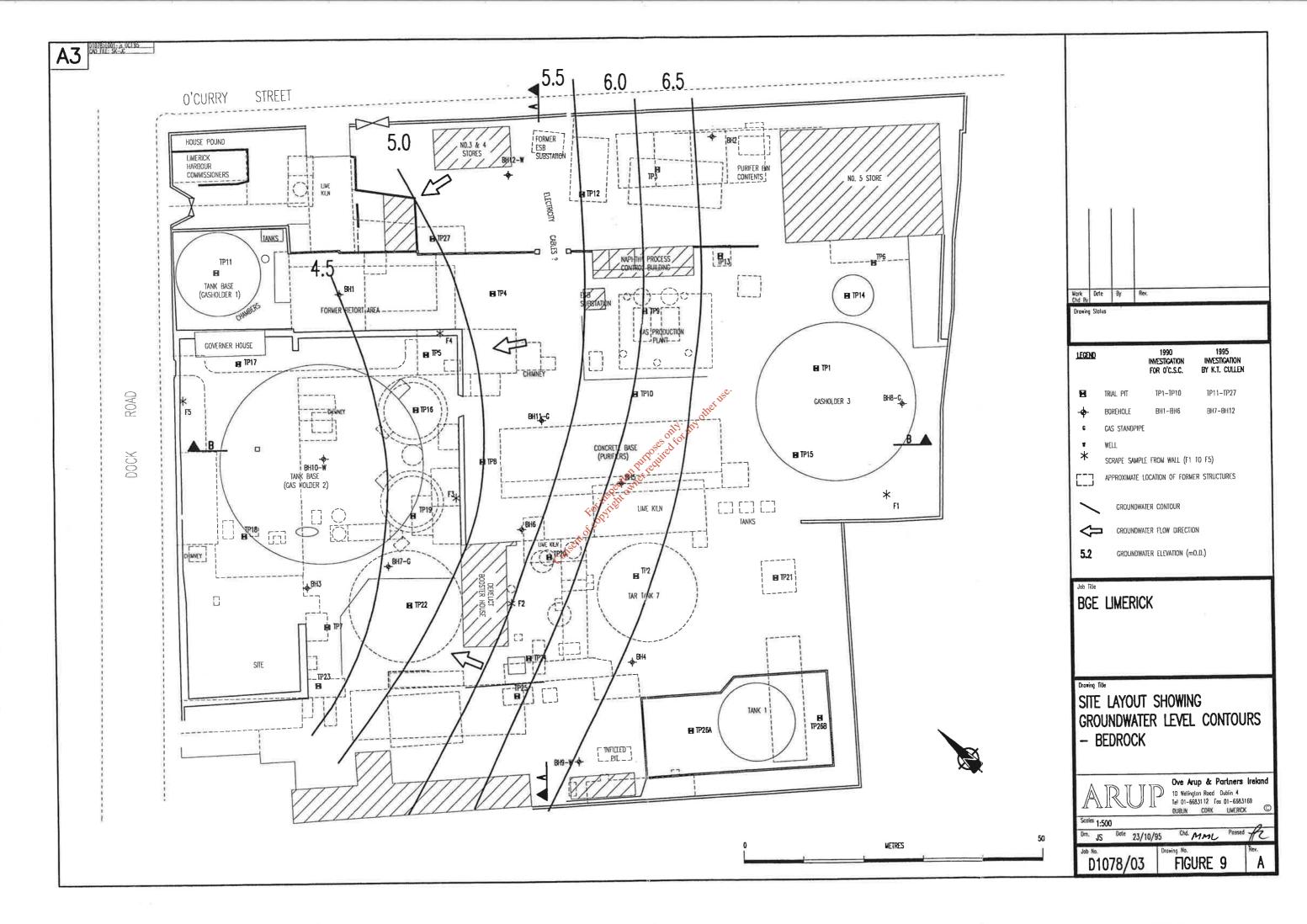


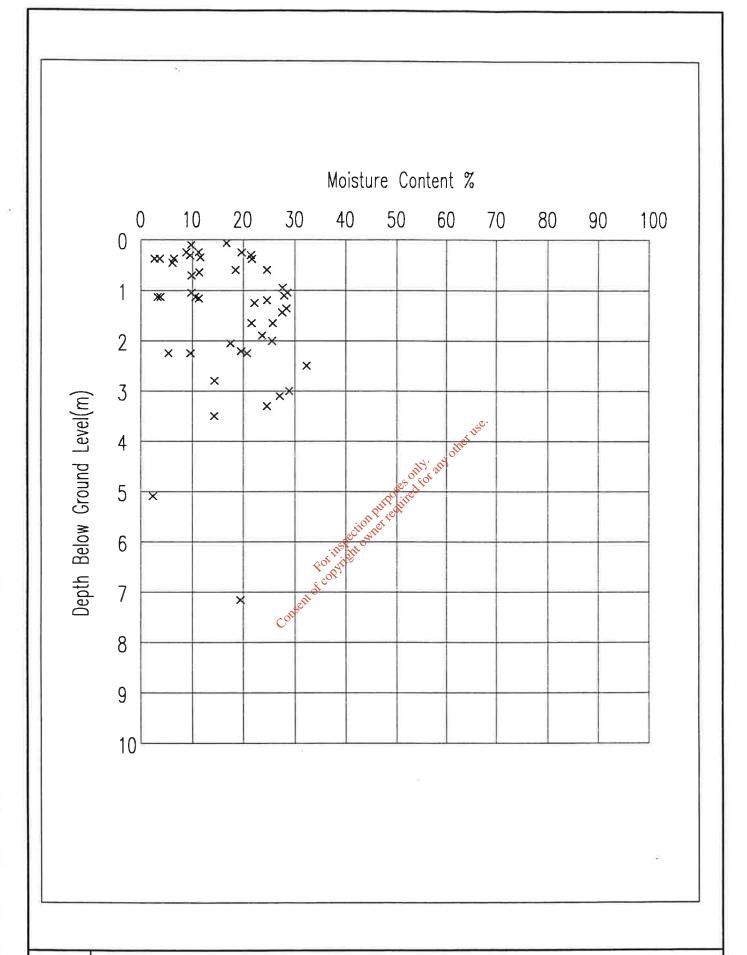












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ARUP

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SOIL MOISTURE CONTENT
BGE - LIMERICK

D1078/03

FIGURE

10

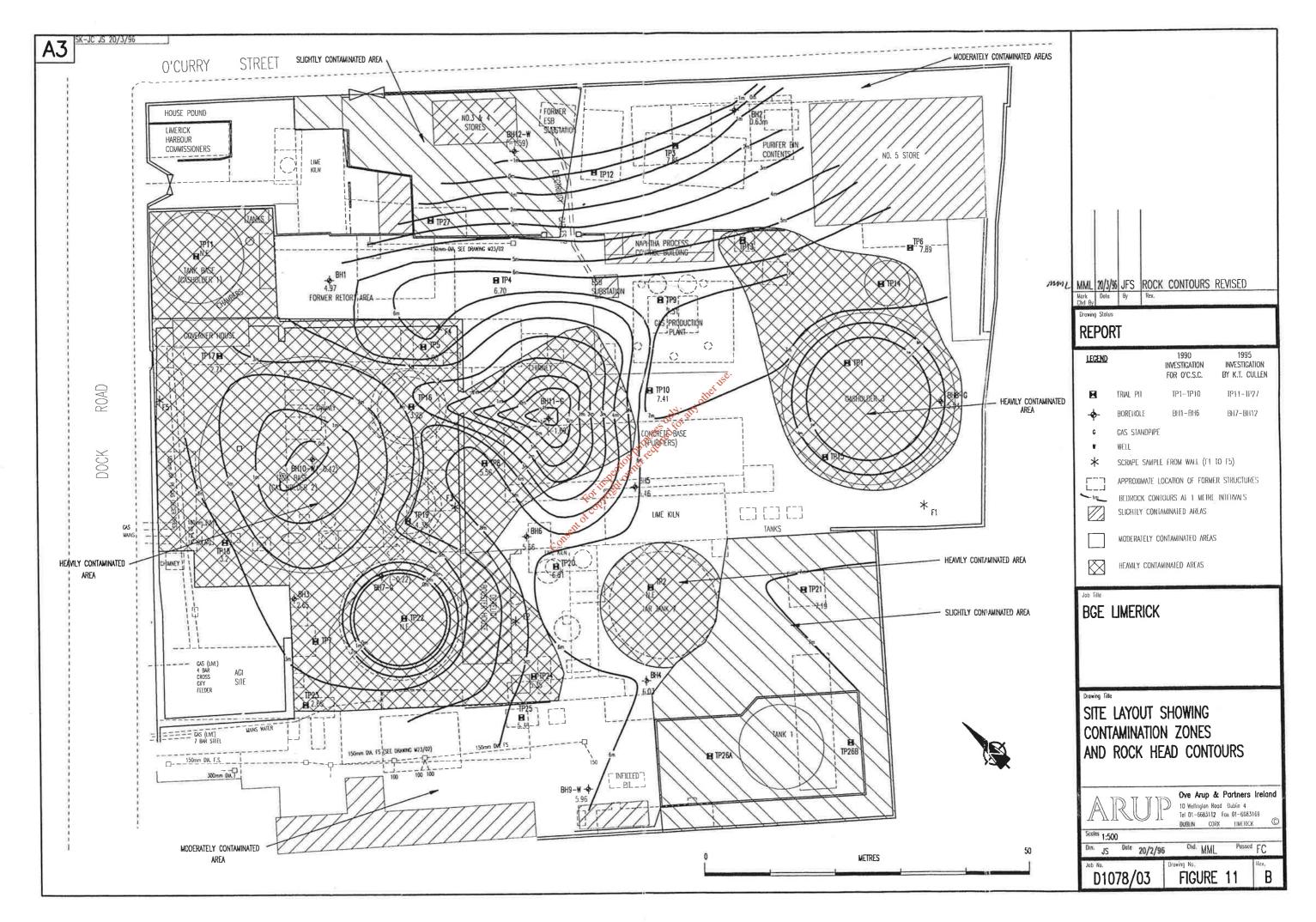


Table C (page 1 of 4): Soil Analytical Results - pH, Total Cyanide, Total Phenols, Sulphate, TEM and Physical Descriptions

Sample No.	рН	Acid Soluble Sulphate (mg/kg)	Total Cyanide (mg/kg)	Total Phenois (mg/kg)	TEM (mg/kg)	Description of Material
TP 1 (Depth 1.4m)	8.65	9100	18.00	200	75000	Tar, soil and stones
TP 2 (Depth 0.2m)	7.30	1300	15.00	38	393000	Tar and rock
TP 2 (Depth 1,1m)	8.60	800	1.60	6	17500	Grey clay and stones
TP 2 (Depth 1.5m)	7.60	800	2.70	40	15000	Grey soil and stones
TP 3 (Depth 1.6m)	9.70	27200	2.30	3	650	Chalk(?), soil and ash
TP 4 (Depth 0.25m)	8.40	4100	5.00	10	26000	Soil and stones
TP 4 (Depth 1.0m)	8.60	13300	2.60	3	1500	Grey soil and stones
TP 5 (Depth 0.6m)	7.95	700	8.20	75	72000.0	Tar and soil
TP 6 (Depth 0.3m)	5.85	2500	35.00	23	21000	Soil, brick and ash
TP 6 (Depth 0.55m)	8.50	2500	1.70	9	9500	Grey soil and stones
TP 6 (Depth 0.8m)	8.35	4400	1.00	3	16500	Grey soil and concrete
TP 6 (Depth 1.6m)	7.80	22700	1.00	6 Securical	40500	Soil and stones
TP 7 (Depth 0.3m)	7.65	8300	1.80	6,50,00	4200	Grey ash, soil and stones
TP 7 (Depth 1.0m)	7.85	4000	2.80	NE CHIL	4900	Soil, stones and grey ash
TP 8 (Surface)	2,55	102000	260.00	. or 90	9200	Soil and stones
TP 8 (Depth 0.12m)	6.65	88600	370.00	dos seliced se	62000	Soil and stones
TP 8 (Depth 0.9m)	7.35	3800	4.40	8	89000	Ash, soil and coal
TP 8 (Depth 1.1m)	7.70	1700	4.40 m <sup>2</sup>	400	280000	Tar, soil and stones
TP 9 (Depth 0.7m)	10.35	17000	130.00	8	51500	Soil and concrete
TP 10 (Depth 0.8m)	7.35	65200		7	19000	Grey soil and ash
TP 10 (Depth 1.8m)	7.35	34800	69.00 69.00	7	22000	Grey soil and stones
			Co.			
Screening Criteria (OAPI, 1995, Ref 2)	<5	2000	250	5	5000	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation. Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

Table C (page 2 of 4): Soil Analytical Results - pH, Total Cyanide, Total Phenols, Sulphate, TEM and Physical Descriptions

TP-11 (0,3-1.3m) TP-11 (2,4-3,2m) TP-11 (3.3-3,7m)	9.48 8.53	(g/l)	(mg/kg) 1600	(mg/kg)			
TP-11 (2,4-3,2m)	8.53		1600		(mg/kg)	(mg/kg)	
30. 30	1		1000	38	0.10	2475	No odour and no soil staining
TP-11 (3.3-3.7m)	0.50	2	1800	5	0,10	239	No odour and no soil staining
	8.58	*	2300	5	1,30	6811	Moderately contaminated ash-type layer
TP-12 (0.9-1.4m)	7.65	1.13	7000	220	0.30	5959	Heavily stained with tar and oil, strong hydrocarbon odour
TP-12 (1.4-1.9m)	8.65		11000	430	0.10	3514	Visable evidence of contamination, moderate phenol odour
TP-12 (2,5-3,5m)	8.41	0.16	9200	5	0.70	2046	Moderate contamination with mild phenolic odour
TP-13 (0.4-0.8m)	7.06		88000	10000	0,60	18888	Moderate contamination with a mild phenolic odour
TP-13 (1.0-1.7m)	8.29	0.70	10400	112	0.10	NSC. 441	Moderate contamination with a mild phenolic odour
TP-13 (2.0-3.0m)	7.03	8	81500	390	3.90		Moderate contamination with a mild phenolic odour
TP-14 (0,0-0.5m)	8.22	9 9	1300	23	0.01 off	4474	No evidence of contamination
TP-14 (1.4-2.7m)	8.21	8	3100	5	Seriority.	7177	Moderately contaminated with slight phenolic odour
TP-14 (2.7-3.5m)	8.26	0.22	5500	108	2,90	3294	Heavily stained with strong phenolic odour
TP-15 (0.0-0.75m)	9.16	4 9	4900	420		22360	Uncontaminated, no odour present
TP-15 (0.75-1.5in)	7.87		8600	90 011	226.10 41.80	17556	Heavily stained with tar and oil, strong hydrocarbon odour
TP-15 (1.5-3.0m)	8.60		11500	380,00	265.50	23148	Visable evidence of staining, moderate phenolic odour
ΓP-16 (0.0-0.9m)	10.36	3 3	0.01	dect wife	0,50	1970	No odour and no soil staining
TP-16 (1,1-1,8m)	8.03	× (	1800	11371	4.60	921	Heavily stained with strong phenolic odour
TP-16 (1.5-1.8m)	9.16	*	0.01	COT VIND	1,00	68	Heavily stained with strong phenolic odour
TP-17 (0.0-0.75m)	7.56	€	59600	, co2, 2	1.80	1484	No odour and no soil staining
ΓP-17 (0.75-1.5m)	8.96	*	0.01	420 90 gil 380 grae 500 grae For 18581 out	0.10	116	No odour and no soil staining
TP-17 (1.5-3,0m)	8.62	*	0.01 ್ಲರೆ	5	0.20	365	Heavily stained with strong phenolic odour
TP-18 (0.0-0.75m)	9.02		0.01	5	0.20	70	No odour and no soil staining
TP-18 (0.75-1 <sub>-</sub> 5m)	9.01	*	0.01	5	0.10	90	No odour and no soil staining
TP-18 (1.5-3.0m)	8.56	*	0.05	14	2.00	1464	Heavily stained with moderate phenolic odour
Screening Criteria (OAPI, 1995, Ref 2)	<5	,	2000	250	5	5000	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

Sample No.	Hq	Water Soluble Sulphate (g/l)	Acid Soluble Sulphate (mg/kg)	Total Cyanide (mg/kg)	Total Phenois (mg/kg)	TEM (mg/kg)	Evidence of Physical Contamination
TP-19 (0.0-0.5m)	8.88	(#)	0.01	5	0.40	268	No odour and no soil staining
TP-19 (0.5-0.9m)	8.66	5.	0,01	42	1.40	4768	No odour and no soil staining
TP-19 (0.9-1.2m)	9.38	2	0.03	5	0.20	959	Heavily stained with tar and oil, strong hydrocarbon odou
TP-20 (0.0-0.64m)	8.35		0.83	13	0.40	33016	Slightly contaminated with a mild phenolic odour
TP-21 (0.0-0.5m)	9.13	(a.	0.01	5	0.40	2443	No odour and no soil staining
TP-22 (0.0-0.6m)	8.47	9	0.12	55	0.70	2438	Slightly contamination with a mild phenolic odour
TP-22 (1.0-1.5m)	7.39		8.18	10000	15.60	111957	Heavily contaminated with strong phenolic odour
TP-22 (1.5-2.5m)	7.99	÷	3.52	650	15.60 8.70	34309	Moderately stained with mild phenolic odour
TP-23 (0.0-0.5m)	8.52	0,12	0.32	14	A . 3.30	5182	Slight evidence of contamination within the ash material
TP-23 (0.5-1.7m)	8.15	=	0.57	97	of 14.10	38996	Heavily contaminated with strong phenolic odour
TP-23 (2.0-2.4m)	8.41	3	0.52	103 570 1308 740 140 118 118 118 118 118 118 118 118 118 11	1.90	9709	Heavily stained with strong tar odour
TP-24 (0.0-0.75m)	7.87	2	0.93	570	13.30	7261	Slightly contamination with a mild phenolic odour
TP-24 (0.9-1.2m)	8.18	72	0,93	1308	403.60	161290	Heavily contaminated with strong phenolic odour
TP-24 (1.5-2.3m)	7.98	ĉ <del>e</del>	2.18	740 net	76.50	140625	Heavily contaminated with strong phenolic odour
TP-25 (0.4-0.8m)	10.86	*	0.25	350,80%	341.90	34817	Heavily contaminated with strong phenolic odour
TP-25 (0.8-1.1m)	8.07	3	0.22	N 11 1915	38.10	1698	Heavily stained with moderate tar odour
TP-26a (0.0-0.2m)	8.00	=	0.02	570 1300 1300 1300 1300 1300 1300 1300 13	6.90	8596	No odour and no soil staining
TP-26b (0.0-0.15m)	7.49	. <u>.</u>	0.01	5	0.20	1063	No odour and no soil staining
TP-27 (0.2-0.5m)	10.72	0.92	0.36	22	1.80	3669	No odour and no soil staining
TP-27 (0.5-1.9m)	8.19	0,54	0.7675	124	0.20	20483	Unontaminated, no evidence of staining
TP-27 (3.2-3.4m)	7.51		0.36 0.76 hs 211.	1200	1.90	6315	Unontaminated, no evidence of staining
Screening Criteria							
OAPI, 1995, Ref 2)	<5	11	2000	250	5	5000	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

Sample No.	pН	Water Soluble Sulphate (g/l)	Acid Soluble Sulphate (mg/kg)	Total Cyanide (mg/kg)	Total Phenols (mg/Kg)	TEM (mg/kg)	Evidence of Physical Contamination
F1	8.07	0.58	4600	295	36.30	2237	Heavily stained with strong phenolic odour
F2	7.65		0.01	76	634.00 &	632577	Heavily stained with strong phenolic odour
F3	7.02	0.09	4200	76 53	61.50	246885	Dry, hardened tar-stained material
F4	NDP		NDP	NDP	NDE	NDP	Dry, hardened tar-stained material
F5	7.16	1.06	4500	19	205.00	270463	Dry, hardened tar-stained material
BH-7 (5-5.2m)	9.47	-	1500	40	15.30	2178	No evidence of contamination
BH-11 (7-7.3m)	8.40	0.30	3900	4 120	12 <sup>0</sup> 0.10	642	No evidence of contamination
Screening Criteria	а			citon puried			
(OAPI, 1995, Ref				10 Sp. Oth			
2)	<5	1	2000	250	5	5000	

LEGEND

This Table Summarises the results from both the 1991 O'Congo Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

TEM - Total Extractable Matter

NDP - No Detection Possible

Table D
Soil Analytical Results - Complex Cyanide, Free Cyanide and Thiocyanate.

Sample No.	Complex	Free	Thiocyanate
	Cyanides	Cyanide	
	mg/kg	mg/kg	mg, kg
TP 1 (1.4m)	NA	9	NA
TP 2 (0.2m)	NA	1.4	NA
TP 2 (1.1m)	NA	1	NA
TP 2 (1.5m)	NA	1.1	NA
TP 3 (1.6m)	NA	2.3	NA
TP 4 (0.25m)	NA	1.5	NA
TP 4 (1.0m)	NA	1	NA
TP 5 (0.6)	NA	1.5	NA
TP 6 (0.3m)	NA	2.5	NA
TP 6 (0.55m)	NA	1.3	NA
TP 6 (0.8m)	NA	1	NA
TP 6 (1.6m)	NA	3	NA
TP 7 (0.3m)	NA	1	NA
TP 7 (1.0m)	NA	1	NA
TP 8 (0m)	NA	110 0	NA
TP 8 (0.12m)	NA	93 25	NA
TP 8 (0.9m)	NA	2011	NA
TP 8 (1.1m)	NA NA	Ori 2 37	NA
TP 9 (0.7m)	NA S	ed 17	NA
TP 10 (0,8m)	NA DUTY	13	NA
TP 10 (1.8m)	NATTELLE	4.8	NA
TP-12 (1.4-1.9m)	303	93 Hed 17 13 4.8 23 12	85
TP-13 (0.4-0.9m)	of 11 09988	12	20
TP-13 (2.0-3.0m)	388	2	30
TP-15 (0.0-0.75m)	418	2	47
TP-15 (0.0-0.75m) TP-15 (1.5-3.0m) TP-16 (1.1.1.8m)	374	6	125
TP-16 (1.1-1.8m)	57	1	10
TP-22 (0.0-0.6m)	10000	1	210
TP-23 (2.0-2.4m)	101	2	50
TP-24 (0.9-1.2m)	1300	1	10
TP-27 (3.2-3.4m)	1179	31	20
	75	1	10

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

NA - No Analysis requested

Table E: Soil Analytical Results - Metals, Total Sulphur and Sulphide

Sample No.	Arsenic	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc	Sulphur	Sulphide
	mg/kg	mg/kg	mg/kg	mg/kg	mg.kg	ma/kg	mg. kg	mg/kg	malkg	ma ka
TP 1 (1,4m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	20
TP 2 (0.2m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	13
TP 2 (1,1m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	11
TP 2 (1.5m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	35
TP 3 (1.6m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	6
TP 4 (0.25m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	40
TP 4 (1,0m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
TP 5 (0.6)	NA	NA	NA	NA	NA	NA	NA	NA	NA	11
TP 6 (0.3m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	44
TP 6 (0.55m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	7
TP 6 (0.8m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	99
TP 6 (1,6m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	740
TP 7 (0.3m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	5
TP 7 (1.0m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	17
TP 8 (0m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.3
TP 8 (0.12m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	11
TP 8 (0.9m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	26
TP 8 (1.1m)	NA	NA	NA	NA	NA	ŊĄ.	NA	NA	NA	0.50
TP 9 (0.7m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	30
TP 10 (0.8m)	NA	NA	NA	NA	NA S	NA NA	NA	NA	NA	360
TP 10 (1.8m)	NA	NA	NA	NA	OULVIAIN	NA	NA	NA	NA	340
TP-15 (0.0-0.75m)	12	1	12	16 😅	9601	16	109	52	4000	6
TP-15 (1.5-3.0m)	29	1	20	Str PO	1	24	175	73	6500	3
TP-16 (1.1-1.8m)	65	2	29	NA 16 oscillations 16 oscillations	1	146	464	840	8300	1
TP-18 (0.75-1.5m)	2	1	2 15 Per start of the start of	OWIGH	1	8	5	20	0.01	1
TP-19 (0.5-0.9m)	10	1	to inspiral	15	1	12	16	32	400	1
TP-19 (0.9-1,2m)	4	1	90,7	4	1	6	7	15	400	1
TP-22 (1.0-1.5m)	26	2	Sent 034	4	1	6	67	94	151000	19
TP-25 (0.4-0.8m)	18	1 🔦	5ent 14	30	1	18	73	133	2300	18
TP-26a (0.0-0.2m)	31	1 0	16	37	1	21	168	101	4100	5
TP-27 (0.2-0.5m)	21	1	23	59	1	27	332	147	1800	1
TP-27 (3.2-3.4m)	88	1	32	218	1	44	1625	448	8200	11
F1	18	1	14	37	1	21	46	39	4200	3
F3	28	1	8	120	1	14	156	158	17400	1
F5	9	1	3	6	1	3	22	79	12800	1
BH-7 (5.0-5.2m)	18	1	22	27	1	35	77	57	1500	8
BH-11 (7.0-7.3)	7	1	68	44	1	71	54	72	11300	34
*	*									•
Screening Criteria										
(OAPI, 1995, Ref 2)	40	3	1000	130	1	70	2000	300	5000	250

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogram

NA - Analysis not requested

Table F: Soil Analytical Results - BTEX

Sample No.	Benzene µg/kg	Toluene µg/kg	Ethyl Benzene µg/kg	Total Xylene µg/kg
TP-13 (2.5-2.7m)	145	53	33	46
TP-15 (0.6-0.9m)	25390	26990	3282	21973
TP-15 (2.5-2.8 m)	8231	8853	1070	7461
TP-16 east (1.5-1.8m)	31	42	73	433
TP-16 south (1.5-1.8m)	10	10	10	19
TP-18 (0.75-1.5m)	10	10	10 10 10 789 2037 7640 4067 4751	11
TP-19 (0.0-0.5m)	10	10	net 10	15
TP-19 (0.9-1.2m)	1426	3456	789	6145
TP-22 (1.0-1.5m)	4531	2984	2037	12942
TP-23 (1.1-1.4m)	11649	£6839	7640	37550
TP-24 (0.9-1.2m)	25221	36816	4067	20482
F1	25221 387040 58 Only 50 Only 50 Only 50 Only 519	36816	4751	28359
F3	53 WIL	181	53	337
F5	ins do	12	11	62
BH-7	40 7519	764	143	638
BH-11	ς P 98	38	32	89
Screening Criteria Collision (OAPI, 1995, Ref 2)			2.00	
(OAPI, 1995, Ref 2)	1000	130000	50000	25000

### Legend

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

Table F

# Table G (page 1 of 2): Soil Analytical Results - Polycyclic Aromatic Hydrocarbons

Polynuclear Aromatic	Units	TP-1	TP-1	TP-8	TP-9	TP-11	TP-11	TP-12	TP-13	TP-13	TP-14	TP-15	TP-15	TP-17	TP-20	Screening Criteria
Hydrocarbons	+	0.5m	1.4m	1_1m	1.2m	0.3-1.3m	3.3-3.7m	1.4-1.9m	0.4-0.9m	2.0-3.0m	1.4-2.7m	0.0-0.75m	1.5-3 0m	0.0-0.75m	0 0-0 64m	(OAPI, 1995, Rel 2
Naphthalene	mg/kg	100	158	892	39	1	3	6	54	8	25	9	185	47	44	12
Acenaphthylene	mg/kg	160	528	854	1	1	12	2	10	15	5	10	286	2	2	=======================================
Acenaphthene	mg/kg	110	1	1686	1	1	21	3	6	17	8	9	50	2	3	
Fluorene	mg/kg	267	972	2227	23	1	35	5	5	42	16	20	271	7	2	
Phenanthrene	mg/kg	1824	4426	20496	392	6	141	14	32	√5 <sup>0</sup> 160	39	55	691	42	2	
Fluoranthene	mg/kg	650	2177	9039	114	1	72	22	50 the	217	16	47	708	48	17	14
Anthracene	mg/kg	914	2123	11865	101	6	28	3	101	53	8	21	390	10	2	1.0
Pyrene	rng/kg	437	1420	5130	37	7	101	220114 Postsod for tedling	3139	177	11	31	523	37	18	- 0
Benzo(a)anthracene	mg/kg	88	326	1065	17	1	31	258 S	49	99	3	43	2845	95	19	
Chrysene	mg/kg	86	361	1213	10	1	21	Posited 1	60	73	4	19	968	51	12	6
Benzo(b)fluoranthene and							l si	'A Chi								×
Benzo(k)fluoranthene	mg/kg	64	236	1322	9	- 1	.160	34	94	68	4	26	1450	72	16	65
Benzo (a)pyrene	mg/kg	91	322	1133	6	1	19012 Spectiante Spectiante Spectial	47	55	83	4	13	1600	37	9	- Si
Benzo(g,h,i)perylene	rng/kg	24	31	183	2	1 .6	5 713	148	253	188	10	57	9241	236	63	
Dibenz(a,h)Anthracene	mg/kg	1	1	1	1	got !	100 2	15	41	26	1	5	1244	27	13	
indeno(1,2,3-cd)Pyrene	mg/kg	31	81	343	2	1,00	9	91	124	99	9	52	4084	136	50	25
Total PAH	rng/kg	4,847	13,163	57,449	755	×21	516	447	882	1,326	164	418	24,518	851	274	500

### LEGEND

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogramme

Table G (page 2 of 2): Soil Analytical Results - Polycyclic Aromatic Hydrocarbons

Polynuclear Aromatic	Units	TP-21	TP-22	TP-23	TP-23	TP-25	TP-26a	TP-27	TP-27	F2	Screening Criteria
Hydrocarbons		0.0-0.5m	1.0-1.5m	0.0-0,5m	2.0-2.4m	0.4-0.8	0.0-0.2m	0.2-0.5m	3.2-3.4m		(OAPI, 1995, Ref 2)
			2.								
Naphthalene	mg/kg	27	281	25	21	55	9	1	2	687	
Acenaphthylene	mg/kg	4	123	18	31	153	25	1	22	895	
Acenaphthene	mg/kg	1	57	17	17	45	6	1	8	346	
Fluorene	mg/kg	3	434	41	84	196	31	3	40	1065	320
Phenanthrene	mg/kg	4	1258	183	289	430	103	19	77	1669	-
Anthracene	mg/kg	1	638	41	85	273	40	5	20	83	- 100
Fluoranthene	mg/kg	3	1434	253	273	444	126	27	31	1689	(4)
Pyrene	mg/kg	2	1147	204	241	359	103	20	22	1452	161
Benzo(a)anthracene	mg/kg	3	6011	147	169	307	othe 88	9	14	976	47
Chrysene	mg/kg	2	2102	107	99	186	56	9	15	799	4.1
Benzo(b)fluoranthene and						186 जोर्ज क्य	,				
Benzo(k)fluoranthene	mg/kg	3	1973	123	110		72	9	32	1051	*
Benzo (a)pyrene	mg/kg	1	1808	210	183117	iii 321	121	12	32	2468	:=
Benzo(g,h,i)perylene	mg/kg	10	8813	536	356 30	808	349	24	133	28326	9
Dibenz(a,h)Anthracene	mg/kg	1	1564	78	ecti 40er	107	48	2	8	589	3
Indeno(1,2,3-cd)Pyrene	mg/kg	8	4260	296 💉	110 183,10 3 <b>58</b> ,10 3 <b>58</b> ,10 46,10 8,10 185	368	160	14	76	10351	э.
			UNIVERSAL PROPERTY OF THE PROP	FOT	7%						
Total PAH	mg/kg	71	31903	2278	2190	4241	1338	154	533	52447	500

This Table Summarises the results from both the 1991 O'Connor Suttor Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligram per kilogram

Table H: Soil Analytical Analysis - Mineral Oils, Total Extract and Saturate Quantification by G.C.

Sample No.	Mineral Oils	Total Extract	Isoprenoid	Paraffins	Combined Isoprenoid and Paraffins	Others
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
TP-15 (0.0-0.75m)	10062	22360	368.94	1439,98	1808.92	20551.08
TP-15 (1,5-3,0m)	10567	23148	180.55	689.81	870.36	22277.64
TP-16 (1.1-1.8m)	448	921	24.59	179.69	204.28	716,82
TP-18 (0.0-0.75m)	32	90	2.03	9.09	11,12	78,88
TP-19 (0.5-0.9m)	1445	4768	20.98	119.68	140.66	4627.34
TP-19 (0.9-1.2m)	412	959	8,15	103.28	111,43	847,57
TP-22 (1 0-1 5m)	47582	.111957	4153.6	1206,87	5360.17	95756.83
TP-25 (0.4-0.8m)	19115	34817	1483.3	3203.16	4686.46	30134.11
TP-26a (0.0-0.2m)	3241	8596	44.56 off of	858.45	703,01	7893 71
TP-27 (0.2-0.5m)	1339	4162	on purposition	962.25	1031.15	3130.25
TP-27 (3 2-3 4m)	467	6315	Owner 46 1	589.82	635.92	5679 71
F1	767	111957 34817 8596 4162 6315 6315 2289 On Highly 248885 270463	19.91	52.57	72.48	2164.3
F3	88879	246885	345.64	3431.7	3777.34	234713.57
F5	116029	OTSC 270483	3029.19	10304.64	13333.83	257129.17
BH-7 (5.0-5.2m)	564	642	13.8	166.41	180.21	461,79
BH-11 (7.0-7.3m)	128	2178	4.356	194.5	198.856	1977.19
Screening Criteria (OAPI, 1995, Ref 2)	5000	5000			5000	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kilogram

Table I: Soil Analytical Results - Total Volatiles by Gas Chromotography

Sample No.	Units	Total Volatiles
TP-13 (2.5-2.7m)	µg/kg	3084
TP-15 (0.6-0.9m)	μg/kg	223355
TP-15 (2.5-2.8m)	µg/kg	76342
TP-16 (1.1-1.8m)	µg/kg	4916
TP-16 (1.5-1.8m)	µg/kg	308
TP-18 (0.75-1.5m)	µg.kg	165
TP-19 (0.0-0.5m)  TP-19 (0.9-1.2m)  TP-22 (1.0-1.5m)  TP-24 (0.9-1.2m)  TP-24 (1.1-1.4m) For insignification of the convergence	µg/kg	7 USC. 7046
FP-19 (0.9-1.2m)	ugikg. ald	46254
FP-22 (1.0-1.5m)	authorities of for	74858
P-24 (0.9-1.2m)	on Refeet pg/kg	250914
P-24 (1.1-1.4m) For High	µg/kg	211983
1 sent of co	µg/kg	346343
-3 Cap.	µg/kg	4885
5	µg/kg	875
3H-7 (5.0-5.2m)	µg/kg	4547
3H-11 (7.0-7.3m)	μg/kg	685
creening Criteria		Table
OAPI, 1995, Ref 2)	µg/kg	70000

# Legend

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded. µg/kg - micrograms per kilogram

Table J: Soil Analytical Results (Page 1 of 2) - Results for Soil Leachate Tests

TP15 (1.5-3.0m)	TP22 (1.0-1.5m)
otter 150.5	0.6
other 0.4	0.3
74	0.3
45	2100
	45

Legend
This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation. mg/kg - milligrams per kilogramme of Leachate (DIN 38414)

	TP15 (1.5-3.0m)	TP22 (1.0-1.5m)
Polynuclear Aromatic Hydroarbons	mg/kg DIN Leachate	mg/kg DIN Leachate
Naphthalene	2.11	5.08
Acenaphthylene	2.16	1.63
Acenaphthene	0.46	0.21
Fluorene	1.46	0.85
Phenanthrene	2.19	2.06
Anthracene	0.82	0.50
Fluoranthene	14. 214 P.02	0.77
Pyrene	diot 0.69	0.50
Benzo(a)anthracene	0.17	0.13
Chrysene inspect on the character of the	0.16	0.14
Benzo(b)fluoranthene and		
Benzo(k)fluoranthene of sent	0.19	0.14
Benzo (a)pyrene	0.07	0.05
Phenanthrene  Anthracene  Fluoranthene  Pyrene  Benzo(a)anthracene  Chrysene  Benzo(b)fluoranthene and  Benzo(k)fluoranthene and  Benzo(a)pyrene  Benzo(a)pyrene  Benzo(a)pyrene	0.00	0.03
Dibenz(a,h)Anthracene	0.01	0.01
Indeno(1,2,3-cd)Pyrene	0.02	0.02
Total PAH	11.55	12.11

# Legend

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation. mg/kg- milligrams per kilogramme of DIN Leachate

Table K: Groundwater Field Analysis Results - pH, Conductivity and Temperature

Sample No.	pН		Conduct	ivity (µS)	Temperature (°c)		
Test	First	Second	First	Second	First	Second	
TP-2	9.75	NA	NA	NA	NA	NA	
Gas holder water							
chamber 2	8.95	NA	NA	NA	NA	NA	
TP-9	8.35	NA	NA	NA	NA	NA	
Gas holder water							
chamber 1	8.75	NA	NA	NA	NA	NA	
TP- 11	NFA	NS	NFA	NS	NFA	NS	
TP - 12	8.43	NS	662	NS	12	NS	
TP - 13	7.41	NS	1633	NS	13	NS	
TP - 14	7.2	NS	1845	NS	14	NS	
TP - 15	NFA	NS	NFA	NS	NFA	NS	
TP - 16	7.19	NS	1021	NS	NFA	NS	
TP - 17	NFA	NS	NFA	NS	NFA	NS	
TP - 18	7.47	NS	NFA	NS	12.4	NS	
TP - 19	8.5	NS	487	NS	14	NS	
TP - 20	6.9	NS	1472	NS	12	NS	
TP - 21	7.1	NS	868	net NS	12	NS	
TP - 22	NFA	NS	NFA	other NS NS	NFA	NS	
TP - 23	7.8	NS	949 11	NS	13	NS	
TP - 24	NFA	NS	Carrie O	NS	NFA	NS	
TP - 26(A)	NFA	NS 🏑	NFA NFA	NS	NFA	NS	
TP - 26(B)	NFA	NS NS PUT	NFA	NS	NFA	NS	
BH-7	NFA	NE Anet	NFA	NFA	NFA	NFA	
BH-8	7.07	S 6.85	2189	2280	17.05	13,5	
BH-9	7.9	.65	1767	1737	14.9	14	
BH-10	NFA	6.95 1.107.65 NFA 7.48 NS	NFA	NFA	NFA	NFA	
BH-11	7.74	7.48	1508	1544	14.1	13.5	
BH-12(S)	7012	NS	1539	NS	14.4	NS	
BH-12(D)	€ <sup>07</sup> .52	7.5	1487	1730	15	14	
Screening Criteria							
(OAPI, 1995, Ref 2)	<5	<5	1500°	1500°	22	22	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

First Analysis for phase II SI on 10/8/95

Second Analysis for phase II SI on 26/9/95

## Values which exceed the Screening Criteria are shown shaded.

\* - EC Directive 75/440/EC Concerning drinking water quality

° C = degrees celcius

µS/cm= micro siemens per centimetre.

NFA - Field analysis not available due to heavy contamination

NA - No Analysis requested

NS - Not Sampled, Trial pit backfilled after excavation.

Table L: Groundwater Analytical Results - Total Phenols, Amm. Nitrogen, and Total Cyanide

Sample No.	Total F	henols	Amm. i	Vitrogen	Total Cyanide		
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Test	First	Second	First	Second	First	Second	
BH-7	NDP	NDP	58.30	NDP	NDP	NDP	
BH-8	137.00	595,60	99.30	97.50	0.46	0.60	
ВН-9	97.50	80.80	108.80	142.50	0.38	0.13	
BH-10	NA	NDP	410.80	540.00	NDP	NDP	
BH-11	2.33	3.15	71.50	80.00	0.05	0.05	
BH-12 (S)	0.42	NA	35.80	NA	0.05	NA	
BH-12 (D)	1.57	1.45	75.90	72.50	0.05	0.05	
TP-11	NA	NA I	NA	NA	NA	NA	
TP-12	0.02	NA	6.00	NA	9.60	NA	
TP-13	0.53	NA	4.30	NA	2.40	NA NA	
TP-14	10.23	NA	18.90	NA	0.90	NA	
TP-15	828.00	NA	297.00	NA	0.07	NA	
TP-16	1.99	NA	13.20	NA	0.07	NA NA	
TP-17	4.13	NA	37.00	NA	0.01	NA	
TP-18	22.73	NA	75.00	NA	0.04	NA	
TP-18(RS)	23.10	NA	76.10	NAS.	0.24	NA	
TP-19	1.91	NA	6.20	NA NA	0.05	NA	
TP-20	3.00	NA	8.90	NA	0.02	NA	
TP-21	0.06	NA	4,10	NA	0.02	NA	
TP-22	4.85	NA	53.50	NA	0.22	NA	
TP-23	0.95	NA 🕺	16.40	NA	2.90	NA	
TP-24	55.45	NA QU	49.00	NA	43.20	NA	
TP-25	NA	I WANT	NA	NA	NA	NA	
TP-26 (a)	NA .		NA	NA	NA	NA	
TP-26 (b)	NAco	NA NA	NA	NA	NA	NA	
TP-27	0.02	NA 👂	2.70	NA	7.30	NA	
TP-2	45.00	NA NA	NA	NA	NA	NA	
Gas holder water	onsento	4	4	@( )	•	9	
chamber 2	Name of the Control o	NA	NA	NA	NA	NA	
TP-9	10.00	NA	NA	NA	NA	NA	
Gas holder water	-	•	200	227	520	32	
chamber 1	0.10	NA	NA	NA	NA	NA	
Screening Criteria							
(OAPI, 1995, Ref 2)	2	2	3	3	1.5	1.5	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

First Analysis for phase II SI on 10/8/95

Second Analysis for phase II SI on 26/9/95

Values which exceed the Screening Criteria are shown shaded.

mg/kg - milligrams per kılogramme

TEM - Total Extractable Matter

NA - No analysis reqired

RS - Resample

Table M (1 of 4)

Table M (Page 1 of 4): Groundwater Analytical Results - Polycyclic Aromatic Hydrocarbons

	TP-12	TP-13	TP-14	TP-15	TP-18	TP-16	TP-19	TP-23	TP-27	Screening Criteria
	µg/l	μg/l	µg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	(OAPI, 1995, Ref 2)
Naphthalene	0.34	0.339	39.742	9982	954	7265	50	3.297	0.05	70
Acenaphthylene	0.09	27.007	21.204	3172	617	1641	125	153.122	1087	<b>■</b> 2
Acenaphthene	0.104	24.603	607.123	725	106	1183	60	66.516	0.05	P
Fluorene	0.088	63.8	343.658	2508	246	1707	179	123.104	0.089	
Phenanthrene	0.221	45.918	103.277	3937	171	2388	359	134.891	0.153	5
Anthracene	0.058	16,213	48.484	2437	69	1037	92	34,391	0.161	5
Fluoranthene	0.157	21,136	63.425	3329	26	2575	138	29.375	0.572	1
Pyrene	0.162	29.816	35.338	282	18	218	90	17.361	0.868	
Benzo(a)anthracene	0.05	0.484	2.899	2410	10	1564	50	6.192	0.177	0.5
Chrysene	0.05	0.672	2.444	1778	104.	1043	50	3,953	0.352	0.05
Benzo(b)fluoranthene and					onicit	W. 100.51				
Benzo(k)fluoranthene	0.05	0.05	0.257	4787	10 y oses only or o	2927	50	1.194	0.05	
Benzo (a)pyrene	0.05	0,11	0.43	7355	oses which	4581	50	1,891	0.05	0.05
Benzo(g,h,i)perylene	0.05	0.05	0.05	17925	10	7058	50	0.05	0.05	0.05
Dibenz(a,h)Anthracene	0.05	0.05	0.05	43827	10	1627	50	0.05	0.05	3
Indeno(1,2,3-cd)Pyrene	0.05	0,05	0.05	9309	10	4221	50	0.05	0.05	0.05
Total PAH	1.218	230.096	1,268	74317	2206	42998	1042	575.288	3.46	

LEGEND

This Table Summarises the results from both the 1991 Octonor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

µg/l = microgram per litre

Table M (Page 2 of 4): Groundwater Analytical Results - Polycyclic Aromatic Hydrocarbons

		BH-7	BH-7	BH-8	BH-8	BH-9	BH-9	BH-10	BH-10	Screening Criteria
	Units	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	(OAPI, 1995, Ref 2
Naphthalene	µg/l	14373	12109	5102	3535	1554	3851	11020	23174	70
Acenaphthylene	µg/l	10180	4834	1417	362	442	453	6564	10006	
Acenaphthene	μg/l	3054	1718	186	50	44	50	1357	1700	2:
Fluorene	µg/l	11635	6466	644	65	120	101	6489	6599	20
Phenanthrene	μg/l	12284	6715	1368	61	116	84	6661	9235	5
Anthracene	μg/l	7264	4177	491	50	33	50	5715	5988	5
Fluoranthene	µg/I	9420	5274	863	50	18	50	7132	8917	1
Pyrene	μg/l	7819	3864	556	50	11	50	6190	7196	5
Benzo(a)anthracene	μg/l	9851	7078	295	50	1050.	50	4076	7172	0.5
Chrysene	μg/l	5646	2893	149	50	othad	50	1863	3281	0.05
Benzo(b)fluoranthene and	1			11 JEE 2000 VEHICLE VANDE	14. 0	800			CONTENT   CONT	
Benzo(k)fluoranthene	μg/l	5331	4336	206	200 10 W	10	50	10	4432	
Benzo (a)pyrene	µg/l	4244	6166	157	0505 50 701 of 050 500 500 500 500 500 500 500 500 50	10	50	10	6624	0.05
Benzo(g,h,i)perylene	µg/l	18880	3995	592 💉	GUI 50	10	50	10	3824	0.05
Dibenz(a,h)Anthracene	µg/i	991	1653	3011 01	50	10	50	10	1347	
Indeno(1,2,3-cd)Pyrene	µg/l	2777	11291	S 80°	50	10	50	10	11393	0.05
Total PAH	µg/l	123749	82540	12137	4023	2337	4489	72289	110889	

LEGEND

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 O'College Legendre 1 and the 1995 OAPI/KT Cullen Investigation.

# Values which exceed the Screening Criteria are shown shaded.

<sup>\*</sup> For BH-7 Sample analysed as "oil", units are milligrams per Kilogram μg/l - microgram per litre

		BH-11	BH-11	BH-12(S)	BH-12(S)	BH-12(D)	BH-12(D)	Screening Criteria
	Units	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	(OAPI, 1995, Ref 2
Naphthalene	µg/l	27	100	15	NA	10	50	70
Acenaphthylene	μg/l	160	/8	10	NA	24	50	2
Acenaphthene	μg/l	107	51	10	NA	43	50	
Fluorene	μg/l	133	57	10	NA	29	50	
Phenanthrene	µg/l	123	99	13	NA	10	50	5
Anthracene	µg/l	21	50	10	NA	10	50	5
Fluoranthene	µg/l	19	50	12	NA	22	50	1
Pyrene	µg/I	11	50	15	NA 🚜	12	50	
Benzo(a)anthracene	μg/l	10	50	10	NA 158 NAST 158	10	50	0.5
Chrysene	µg/l	10	50	10	₩Ã I	10	50	0.05
Benzo(b)fluoranthene and	µg/l			ally	any			
Benzo(k)fluoranthene	μg/l	10	50	10 350	NA	10	50	140
Benzo (a)pyrene	µg/l	10	50	120 jaren	NA	10	50	0.05
Benzo(g,h,i)perylene	μg/l	10	50	10, 60g	NA	10	50	0.05
Dibenz(a,h)Anthracene	µg/l	10	50 tio	net 10	NA	10	50	/⊛
Indeno(1,2,3-cd)Pyrene	µg/l	10	50 50 citor	THE TO TH	NA	10	50	0.05
Total PAH	µg/l	602	386	55		131	750	350

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

# Values which exceed the Screening Criteria are shown shaded.

\* For BH-7 Sample analysed as "oil", units are milligrams per Kilogram

µg/l - microgram per litre

NA - No Analysis Requested

Table M (Page 4 of 4): Groundwater Analytical Results - Polycyclic Aromatic Hydrocarbons

		Tankbase west quadrant	Naphtha Tank	Screening Criteria
	Units	Water	Sludge	(OAPI, 1995, Ref 2)
Naphthalene	µg/l	1508	10	70
Acenaphthylene	μg/t	711	1	
Acenaphthene	μg/l	867	4	(€
Fluorene	µg/l	1243	3	( €:
Phenanthrene	μg/l	14500	51	5 5
Anthracene	μg/l	1	ī	5
Fluoranthene	µg/l	1	1	1
Pyrene	μg/l	3848	se. 1	(*)
Benzo(a)anthracene	μg/I	1	1	0.5
Chrysene	μg/l	1 A Oliv	ï	0.05
Benzo(b)fluoranthene and	µg/l	Only and		
Benzo(k)fluoranthene	µg/l	1 3848  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1	<b>⊘</b> €9
Benzo (a)pyrene	µg/I	nk Politice	ï	0.05
Benzo(g,h,i)perylene	μg/l	on Pired	29	0.05
Dibenz(a,h)Anthracene	µg/l	ection mer	Ĭ	:::::::::::::::::::::::::::::::::::::::
Indeno(1,2,3-cd)Pyrene	µg/l	- 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1	2	0.05
Total PAH	µg/l	COT 1100 22.69	108.00	

LEGEND

This Table Summarises the results from bottle 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation. College Which exceed the Screening College and Colle

Values which exceed the Screening Criteria are shown shaded.

µg/l - microgram per litre

NA - No Analysis Requested

	BOD		COD		Sulphi	de	Sulpha	te
Sample No.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/9
BH-7	9141	10249	1126168	168440	•	0.04	NFA	1339
BH-8	177	169	4000	4260	0.25	0.25	469	356
BH-9	89	349	988	1332	0.12	0.08	187	324
BH-10	1412	1164	617648	424065	0.19	1.02	292	452
BH-11	105	91	3104	556	0.07	0.44	249	393
BH-12 (S)	127	NA	1476	NA	0.05	NA	394	NA
BH-12 (D)	47	386	300	728	0.05	0.08	169	346
TP-13	18	NA	31	NA	ther 0.01	NA	NA	NA
TP-15	1330	NA	16320	on Aint	0.01	NA	900	NA
TP-16	560	NA	2120	hited NA	0.01	NA	250	NA
TP-18	NA	NA	Decitor President	NA	0.07	NA	252	NA
TP-19	50	NA 🞺	Tight 105	NA	0.01	NA	138	NA
TP-2	N.	A Consent of C	31 NA  16326 ON A ANA  2120 ON A ANA  NA  NA  NA  NA		NA		740.00	
GH Water		Couse						
Chamber 1	N	A	N.A		NA		415.00	
TP-9	NA		NA		NA		3600.00	
GH Water								
Chamber 2	N,	A	NA		NA		31.00	
Screening Criteria								
(OAPI, 1995, Ref 2)	3	•	30		0	.3	150*	

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

# Values which exceed the Screening Criteria are shown shaded.

\* - EC Directive 75/440/EC Concerning drinking water quality

mg/l - milligrams oxygen per litre

NFA - Field analysis not available due to heavy contamination

NA - Analysis not requested

#### Table O: Groundwater Analytical Results-Metals: Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead, Selenium, Zinc

Sample	Units	Ars	enic	Cadn	ilum	Chron	nium	Copp	er	Mercu	iry	Nicke	el	Lead	d	Selen	ium	Zinc	
	6	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95
TP-15	mg/l	0.40	NA	0.06	NA	0.05	NA	0.15	NA	0.05	NA	0.07	NA	0.11	NA	0.1	NA	0.09	NA
TP-16	mg/l	0.08	NA	0.05	NA	0.05	NA	0,05	NA	0,05	NA	0 05	NA	0.23	NA	0, 1	NA	0.09	NA
TP-18	mg/l	0.13	NA	0.05	NA	0,05	NA	0,05	NA	0,05	NA	0.05	NA	0.05	NA	0, 1	NA	0 05	NA
TP-19	mg/l	0.05	NA	0 05	NA	0.05	NA	0.05	NA	0.05	NA	0.05	NA	0.05	NA	0 1	NA	0.05	NA
Вн-7	mg/l	1	0,1	1	0.05		0.05	<b>1.</b>	0.05	1.00	o osuse	1	0.09	1.00	0,05	1.0	0.1	3	0.65
ВН-8	rng/l	1,54	0.05	0.05	0.05	0.05	0.05	0,05	0,05	0,00	0.05	0.05	0.05	0.05	0,05	0.1	0 1	0.05	0.05
BH-9	mg/l	0.18	0.05	0.05	0.05	0.05	0.05	0.05	0.05	ري و <u>ار 1</u> 05	0.05	0.05	0.05	0,05	0.05	0.1	0 1	0.05	0.05
BH-10	mg/l	0,05	0_05	0.05	0.05	0.05	0.13	0,05	voil et te	VIII 0 05	0.05	0.05	0.12	0.05	0.46	0.1	0_100	0 05	0.36
BH-11	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0 05 ec	John Street	0.05	0 05	0 05	0.05	0.05	0.05	0 1	NA	0.05	0.05
BH-12(D)	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05%	0 05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.05	0.05
BH-12(S)	mg/l	0.05	NA	0.05	NA	0.05	NA	5 00 05	NA	0.05	NA	0.05	NA	0.05	NA	0.1	NA	0.05	NA
Screening Criteria (OAPI, 1995, Rel 2)		0 06	0.06	0.006	0.006	0.03	C0103	0.075	0.075	0.0003	0.0003	0.075	0.075	0 075	0 075			0.8	

#### LEGEND

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation Values which exceed the Screening Criteria are shown shaded.

mg/t - milligrams per litre

NA - Analysis not requested

Parameter	Unit	BH-7	7	BH-8		BH-9		BH-1	0	BH-1	1	BH-12(	S)	BH-12	(D)	Screening Criteria
		10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	10/08/95	26/09/95	EC Directive /5/440/EC
Aluminium	mg/I as AI	2	0 14	0.14	0.50	0.08	0.90	0 17	10.40	0 06	0.05	0.05	NA	0 05	0.05	0 2
Calcium	mg/l as Ca	127	2955	1037	520	133	83 10	46 60	159	284	222	505	NA	473.00	127.00	200 00
Iron	mg/l as Fe	53	28.80	1.97	1.69	0.39	1.53	2.22	51,10	0.90	0.57	0.47	NA	3.18	0.38	0 20
Magnesium	mg/l as Mg	6	1.14	20 90	22 50	15 30	14 70	5.86	12 30	28 50	31.70	28.40	NA	25 20	25 90	50 00
Manganese	mg/l as Mn	1	0.05	5.17	12	0,07	0.11	0 05	2.27	1.24	0.74	0.79	NA	0.16	0,23	0.05
Colour (True)	Hazen Unils		NFA	430	138	89	85	8/0 00	NPA	42	35	31	NA	28 00	28 00	3
Total Hardness	mg/l as CaCO3	NFA	1953	731	886	214	258	48.00	119	3/0	541	540	NA	268 00	351 00	
Furbidity	NTU		NFA.	6000	800	750	725	4250 00	HFA	1650	700	2850	NA	3250 00	10/5 00	3
Non-Carbonate Hardness	mg/l as CaCO3	NFA	NFA	77.10	99 60	5/	55,40	्यहें हैं। य	NFA	122	123	123	NA	96.00	96 80	
Potassium	mg/l as K	±1	76.40	17.20	16.50	14.50	13.98°	11eg 60	19,40	9 40	9 80	10 70	NA	20.70	14.10	12 00
Sodium	mg/Las Na	*	258	87	131	44	on Pireo	88 00	207	4-1	46	52	NA	68 00	189.00	150 00
Organic Carbon	mg/l as C	47	57,30		171	14.60 14 	ON 212	593	668	20	46		NA	4	189 00	Ē.
Chloride	mg/l as Cl	NFA	1268	383	282	Of 2500	172	168 00	18/	61	62	56	NA	65 00	77 00	250 00
Vilnte	mg/I as NO2	NFA	0.19	0.18			0 02	2.80	0.17	0.08	0.02	0.10	NA	0,10	0 02	0.03
Nitrále	mg/l as NO3	NFA	1 20	2 10	Corsont	2 40	10 10	6.00	1.90	2	10,90	2 40	NA	2 00	6 90	50 00
Fotal Alkalinity	mg/i as CaCO3	NFA	NFA	NFA	1390	NFA	1180	NFA	NFA	NFA	1130	NFA	NA .	NFA	32/0 00	

#### Legend

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Culten Investigation

Values which exceed the Screening Criteria are shown shaded.

rng I - milligrammes per litre

NFA - Field analysis not available due to heavy contamination

NA - No Analysis requested

Table P (2 of 2): Groundwater Analytical Results - Inorganics

Parameter	Unit	TP-15	TP-16	TP-18	TP-19	TP-2	TP-9		Holder	Screening Criteria
								Water Chamber 1	Water Chamber 2	EC Directive 75/440/E
Aluminium	mg/l as Al	1.65	0.47	0.19	0,66	NA	NA	NA	NA	0.2
Calcium	mg/l as Ca	1127.00	218,10	251.00	109.20	NA	NA	NA	NA	200.00
Iron	mg/l as Fe	17.25	3,74	0.58	1,19	NA	NA	NA	NA	0.20
Magnesium	mg/l as Mg	5.05	10.76	20.30	7.99	NA	NA	NA	NA	50.00
Manganese	rng/I as Mn	0.30	0.65	1.22	0.31	NA	NA	NA	NA	0.05
Colour (True)	Hazen Units	1180.00	49 00	84.00	47.00	NA	NA	NA	NA	E
Total Hardness	mg/I as CaCO3	2705.60	2705,60	331,00	284.80	NA 15°	NA	NA	NA	722
Turbidity	N.T.U.	1100.00	280.00	9	75.00	any ona	NA	NA	NA	: <b>:</b> :
Non-Carbonate Hardness	mg/I as CaCO3	NDP	36 10		75.00 25.30 AC THUS HIS THE 12.00	NA	NA	NA	NA	.59
Potassium	mg/l as K	33.50	8.70	34	In Purgagit	NA	NA	NA	NA	12 00
Sodium	mg/l as Na	185.60	17.30	ه چون	Wine 12.00	NA	NA	. NA	NA	150 00
Organic Carbon	mg/l as C	2	<u> </u>	For inspect		1000 00	90,00	13.00	10 00	(*)
Chloride	mg/i as Ci	900,00	17.00	" of cos,	16,00	NA	NA	NA	NA	250 00
Nitrite	mg/l as NO2	0.01	0,01	ent of copyright	0.01	NA	NA	NA	NA NA	0.03
Nitrate	mg/I as NO3	2.00	2.00	94	8,00	NA	NA	NA	NA	50,00
Total Alkalinity	mg/I as CaCO3	2415.00	2415.00	*	280.00	NA	NA	NA	NA	9K

#### <u>Legend</u>

This Table Summarises the results from both the 1991 O'Connor Sutton Cronin/Gibb Environmental investigation and the 1995 OAPI/KT Cullen Investigation.

Values which exceed the Screening Criteria are shown shaded.

mg/l - milligrammes per litre

NFA - Field analysis not available due to heavy contamination

NA - No Analysis requested

Table Q (1 of 2): Summary of Soil Analytical Results

Compound/Element	Units	Results table	No. of Results	Min. Conc	Max Conc.	Arithmetic Mean	Standard Deviation	Median	Screening Criteria (OAPI, 1995, Ref 2
 οΗ	рН	Table C	72	2.55	10.86	0.01			
Water Soluble Sulphate	g/l	Table C	11	0.09		8,21	1.11	8.24	<5
Acid Soluble Sulphate	mg/Kg	Table C	72		1.13	0.53	0.36	0.54	1.00
Total Cyanide	mg/Kg	Table C	72	0.01	102000	9750	21740	800	2000
Total Phenols		Table C		1	10000	402	1641	20,50	250
TEM	mg/Kg		72	0.01	634	44.49	112	4.25	5
I CIVI	mg/Kg	Table C	72	68	632577	43510	100386	7219	5000
Complex Cyanides	mg/Kg	Table D	11	57	10000	2205	3692	000	
Free Cyanide	mg/Kg	Table D	32		10000 NI 10			388	250
Thiocyanate	mg/Kg	Table D	11	10 5	210	12.04	24.85	2	25
	mg/rg	Table D		alt Pail	210	56.09	59.58	30	50
Arsenic	mg/Kg	Table E	16	ion 2 redu	88	24.13	21.97	18	40
Cadmium	mg/Kg	Table E	16	pecto wife	2	1,13	0.33	1	3
Chromium	mg/Kg	Table E	16		68	19.13	16.05	15	1000
Copper	mg/Kg	Table E	16	4	244	55.75	71.94	29	130
Mercury	mg/Kg	Table E	16	1	1	1.00	0.00	1	1 1
Nickel	mg/Kg	Table E	1601	3	146	29.50	34.32	20	70
_ead	mg/Kg	Table E	CON 6	5	1625	212	384.22	75	2000
Zinc	mg/Kg	Table E	16	15	840	148	204.23	76	300
Sulphur	mg/Kg	Table E	16	0.01	151000	14638	35538	4150	5000
Sulphide	mg/Kg	Table E	37	0.30	740	52.21	139	11	250
Benzene	µg/Kg	Table F	16	10	38704	7252	11628	332	100
Toluene	μg/Kg	Table F	16	10	36816	8044	12330	473	130000
Ethyl Benzene	μg/Kg	Table F	16	10	7640	1501	2210	108	50000
Total Xylene	μg/Kg	Table F	16	11	37550	8535	11760	536	25000

Table Q (2 of 2): Summary of Soil Analytical Results

Compound/Element	Units	Results table	No. of Results	Min. Conc.	Max Conc.	Arithmetic	Standard Deviation	Median	Screening Criteria
						Mean			(OAPI, 1995, Ref 2
Naphthalene	mg/Kg	Table G	23	1	892	116	220	27	
Acenaphthylene	mg/Kg	Table G	23	1	895	137	257	15	
Acenaphthene	mg/Kg	Table G	23	1	1686	105	345	8	2
luorene	mg/Kg	Table G	23	1	2227	252	509	35	-
Phenanthrene	mg/Kg	Table G	23	2	20496	1407	4185	141	-
Anthracene	mg/Kg	Table G	23	1	9039	625	1853	50	1
luoranthene	mg/Kg	Table G	23	2	11865	<u>~</u> 861	2418	53	-
Pyrene	mg/Kg	Table G	23	2	5130 🎺	502	1078	101	
Benzo(a)anthracene	mg/Kg	Table G	23	11	6011	540	1317	88	-8
Chrysene	mg/Kg	Table G	23	1	011 2/102	273	509	56	
Benzo(b)fluoranthene and				S	S. O. T.				
Benzo(k)fluoranthene	mg/Kg	Table G	23	1 OUT	1973	303	547	68	
Benzo (a)pyrene	mg/Kg	Table G	23	iditerio	2468	373	670	55	F
Benzo(g,h,i)perylene	mg/Kg	Table G	23	EDEC PAIR	28326	2165	6111	148	12:
Dibenz(a,h)Anthracene	mg/Kg	Table G	23	Killight	1564	166	403	13	150
ndeno(1,2,3-cd)Pyrene	mg/Kg	Table G	23	त्र <sup>भ</sup> 1	10351	906	2318	91	)B.
Total PAH	mg/Kg	Table G	23 &	21	57449	8730	16350	882	500
			asento						
Mineral Oils	mg/Kg	Table H	1601	32	116029	18817	34054	1392	5000
Total Extract	mg/Kg	Table H	16	90	270463	46281	84698	5542	5000
soprenoid	mg/Kg	Table H	16	2	4154	613	1197	45	
Parattins	mg/Kg	Table H	16	9	10305	1445	2501	624	
Total Parafins & Isoprenoid	mg/Kg	Table H	16	11	13334	2961	3357	669	5000
Others	mg/Kg	Table H	16	79	257129	43009	80133	5154	5#S
Fotal Volatiles	μg/Kg	Table I	16	165	346343	78535	109759	5981	

Table R (1 of 2): Summary of Groundwater Analytical Results

Compound/Element	Units	Results table	No. of Results	Min. Conc.	Max Conc.	Arithmetic Mean	Standard Deviation	Median	Screening Criteria (OAPI, 1995, Ref 2
all	ol I	Toble K	00	0.05	0.74	7.70			
pH Constructivity	pH	Table K	22	6.85	9.75	7,76	0.73	7.51	<5
Conductivity	μS	Table K	17	487	2280	1454	487	1539	1500
Temperature	°C	Table K	17	12	17.05	13.70	1.26	14	22
Total Phenols	mg/l	Table L	28	0.02	828	69.05	184	3.08	2
Amm, Nitrogen	mg/l	Table L	27	2.70	540	91,16	125	58.30	3
Total Cyanide	mg/l	Table L	24	0.01	43	2.87	8.73	0.10	1,50
Naphthalene	l/gu	Table M	25	0.05	23174	<b>3792</b>	5877	100	70
Acenaphthylene	µg/l	Table M	24	0.09	10180 💉	1756	2984	402	-
Acenaphthene	μg/l	Table M	24	0.05	3054	503	766	63.26	-
Fluorene	µg/I	Table M	24	0.09	O1,8635	1617	2969	128	(4)
Phenanthrene	μg/l	Table M	25	0.15	14500	2341	4110	116	5
Anthracene	µg/l	Table M	25	0.060117	7264	1106	2149	50	5
Fluoranthene	μg/l	Table M	25	0,96,05	9420	1523	2881	50	1
Pyrene	μg/l	Table M	24	200.00	7819	1349	2436	50	
Benzo(a)anthracene	μg/l	Table M	25	0.05	9851	1310	2688	10	1
Chrysene	μg/l	Table M	25	0.05	5646	679	1375	10	0.05
Benzo(b)fluoranthene and			્રું						
Benzo(k)fluoranthene	μg/l	Table M	24 cent	0.05	5331	931	1798	10	
Benzo (a)pyrene	µg/l	Table M	EDIT	0.05	7355	1178	2369	10	0.05
Benzo(g,h,i)perylene	μg/l	Table M	25	0.05	18880	2105	5090	10	0.05
Dibenz(a,h)Anthracene	μg/l	Table M	24	0.05	4382	431	978	10	:5
Indeno(1,2,3-cd)Pyrene	μg/l	Table M	25	0.05	11393	1575	3507	10	0.05
Total PAH	І/дц	Table M	25	1.22	123749	21488	37776	1042	2
BOD	mg/l	Table N	17	18	10249	1498	3032	177	3
COD	mg/l	Table N	17	31	1126168	139508	299745	2120	30
Sulphide	mg/l	Table N	17	0.01	1.02	0.16	0.24	0.07	0.30
Sulphate	mg/l	Table N	20	31	3600	565	753	351	150

Table R (2 of 2): Summary of Groundwater Analytical Results

Compound/Element	Units	Results table	No. of Results	Min. Conc.	Max Conc.	Arithmetic Mean	Standard Deviation	Median	Screening Criteria (OAPI, 1995, Ref 2
									10/11/1, 1000, 11012
Arsenic	mg/l	Table O	17	0.05	1.54	0.23	0.40	0.05	0.06
Cadmium	mg/l	Table O	17	0.05	1	0.11	0.22	0.05	0.006
Chromium	mg/l	Table O	17	0.05	1	0.11	0,22	0.05	0.03
Copper	mg/l	Table O	17	0.05	1	0.11	0.22	0 05	0.075
Mercury	mg/l	Table O	17	0.05	1	0.11	0.22	0.05	0.000
Nickel	mg/l	Table O	17	0.05	1	0.11	0.22	0.05	0.075
_ead	mg/l	Table O	17	0.05	11	0.14	0.24	0.05	0.075
Selenium	mg/l	Table O	16	0.10	1	<sup>©</sup> 0.16	0.22	0.10	l e
Zinc	mg/l	Table O	17	0.05	3 net	0.30	0.70	0.05	0.80
					14. VA Op.				
Aluminium	mg/l as Al	Table P	17	0.05	011 40 40	1.03	2.41	0.17	0.20
Calcium	mg/l as CA	Table P	17	46.60	2955	497.47	688	222	200
ron	mg/l as Fe	Table P	17	0.3800	53	9.76	16.79	1.89	0.20
Magnesium	mg/l as Mg	Table P	17	10941	31.70	16.62	9.29	15.30	50
Manganese	mg/l as Mn	Table P	. 17	20° Q 95	12	1.55	2.88	0.65	0.05
Colour (True)	Hazen Units	Table P	14	11 dh 28	1180	224	347	66.50	
Total Hardness	mg/l as CaCo3	Table P	16	48	2705.60	769	849	361	
Turbidity	N.T.U.	Table P	13	75	6000	1808	1702	1075	
Non-Carbonate Hardness	mg/l as CaCo3	Table P	125011	19.80	123	77.59	36.52	86.55	72/
Potassium	mg/l as K	Table P	CP5	5.20	75.40	18.51	16.57	14.10	12
Sodium	mg/l as Na	Table P	15	12	258	97.99	74.59	68	150
Organic Carbon	mg/l as C	Table P	10	10	1000	306	347	140	**
Chloride	mg/l as Cl	Table P	15	16	1268	264	344	168	250
Vitrite	mg/l as NO2	Table P	15	0.01	2.80	0.26	0.68	0.08	0.03
Vitrate	mg/l as NO3	Table P	15	1.20	10.90	4.33	3.16	2.40	50
Total Alkalinity	mg/l as CaCO3	Table P	7	280	3270	1726	940	1390	-



BH7G: EVIDENCE OF STAINING(OILY SHEEN) ON ROCK CHIPPINGS @ BEDROCK.



BH7 W: VISUAL EVIDENCE OF HEAVY CONTAMINATION FROM BH7.



PLATE 1 BGE - LIMERICK D1078/03



BH8G: HEAVY TARS FROM BOREHOLE



BH8G: HEAVY OIL & TAR FROM BOREHOLE

ARUP

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PLATE 2 BGE - LIMERICK D1078/03



BH10: GROUND WATER CONTAMINATION.



BH10G: HEAVY OILS & TARS AROUND THE CASING.

ARUP

Ove Arup & Partners Ireland ©

PLATE 3 BGE - LIMERICK D1078/03



Consent of copyright owner required for any

BH 11: GROUND WATER CONTAMINATION.

ARUP

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PLATE 4 BGE - LIMERICK D1078/03





STEAM CLEANING OF EQUIPMENT AFTER EACH BORE HOLE.



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PLATE 5
BGE - LIMERICK
D1078/03 GEN

**GENERAL** 

### **APPENDIX V**

## Historical Drawings, Maps and Aerial Photographs

			Produced By	Description
1840 - 1842	Limerick 20 B 15	1:10560	Ordnance Survey	Topographical Map
1841	M23/03	1:500	O'Connor Sutton Cronin	Histor : Site Plan
1870	M23/03	1:500	O'Connor Suttor Cronin	Hist: 2 Site Plan
1897 - 1903	Limerick 20 B 17	1:10560	Ordnance Survey	Topo raphical Map
1902 - 1905	Limerick 19 C 3	1:10560	Ordnance Survey	Topographical Map
1907	M2B/03	1:500	O'Cannor Sutton Cronin	Historic Site Plan
1919	M2B/03	1:500	O'Sonnor Sutton Cronin	Historic Site Plan
1938	M2B/03	1:500	Connor Sutton Cronin	Historic Site Plan
1937 - 1939	Limerick 20-F-11	1:1250	Ordnance Survey	Topographical Sheet
1941	Limerick 5/14	1:250	rdnance Survey	Topographical Sheet
1954	V177/67, 68, 69	1:10250 approx.	Geological Survey	Aerial Photographs
1977	M23/02	1:500 200 300	O'Connor Sutton Cronin	Historic Site Plan
1978	4743-2	1:10250 approx.5 1:500 1:10005 110	Ordnance Survey	Topographical Sheet
1982	OS2-0796	1:10000 approx.	Geological Survey	Aerial Photograph
1988	M23/04	100	O'Connor Sutton Cronin	Pre-Demolition Layout Plan
1991	M23/02A	1:200	O'Connor Sutton Cronin	Site Survey Plan
		ant		



10 Westington Road Dublin 4 Ter J1-6683112 Fax 01-6683169 \_-MERICK CORK

D1078/3 SK1

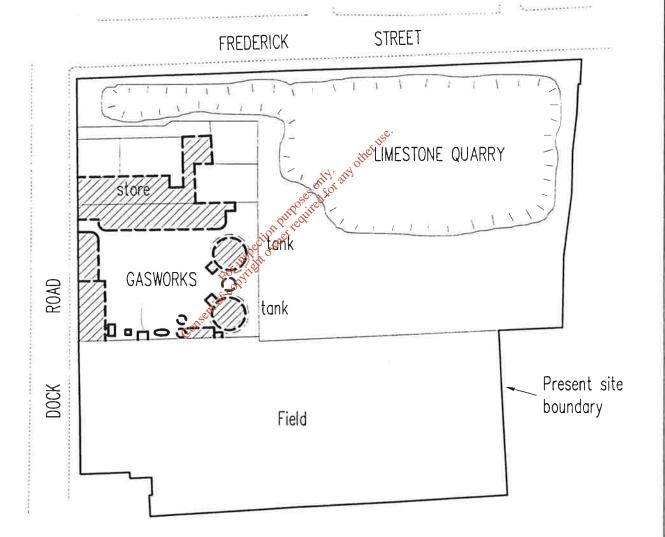
BGE REGIONAL GAS WORKS STUDY

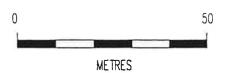
LIMERICK GASWORKS 1841

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LIMERICK GASWORKS 1870

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DUBLIN CORK LIMERICK

D1078/3

SK2

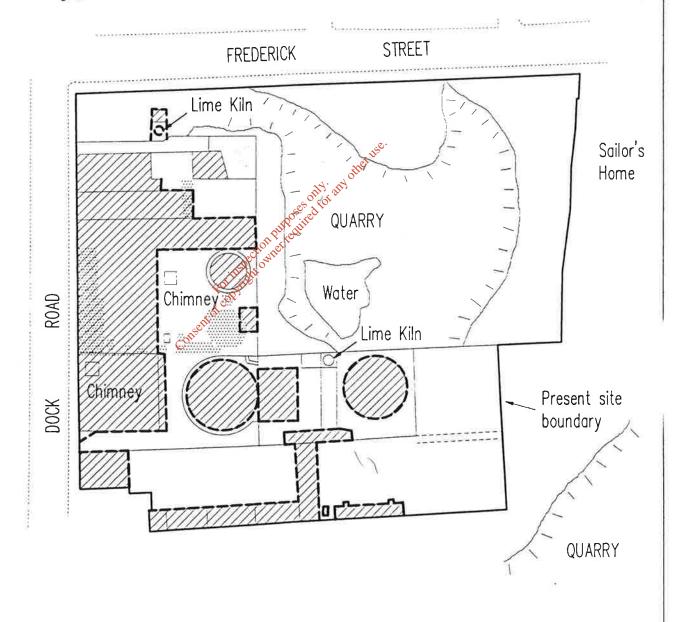
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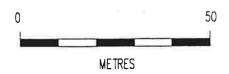
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SK3

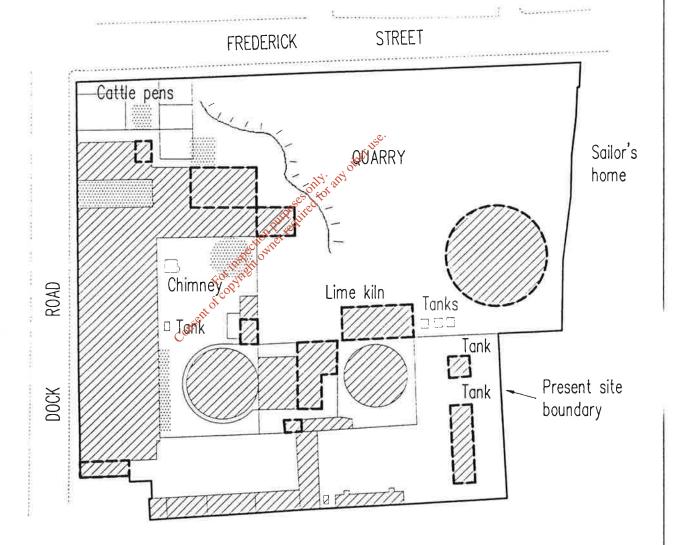
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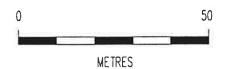
LIMERICK GASWORKS 1907

BGE REGIONAL GAS WORKS STUDY

PN 30te 24/11/94 Cha. MMi 30ssed K







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D1078/3	SK4

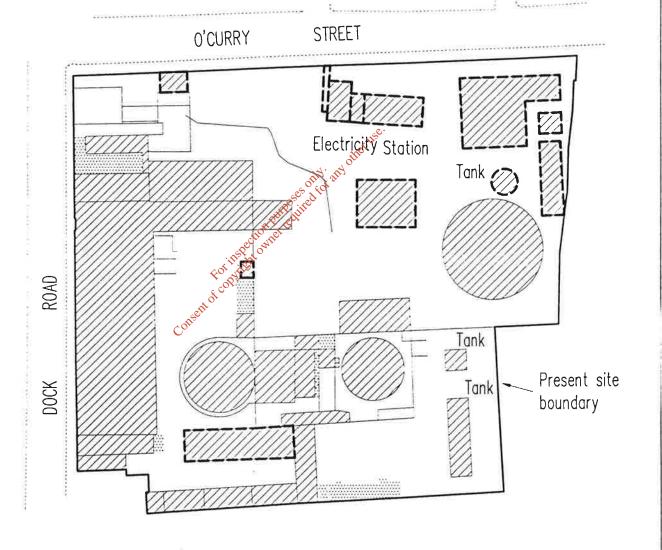
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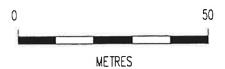
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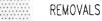






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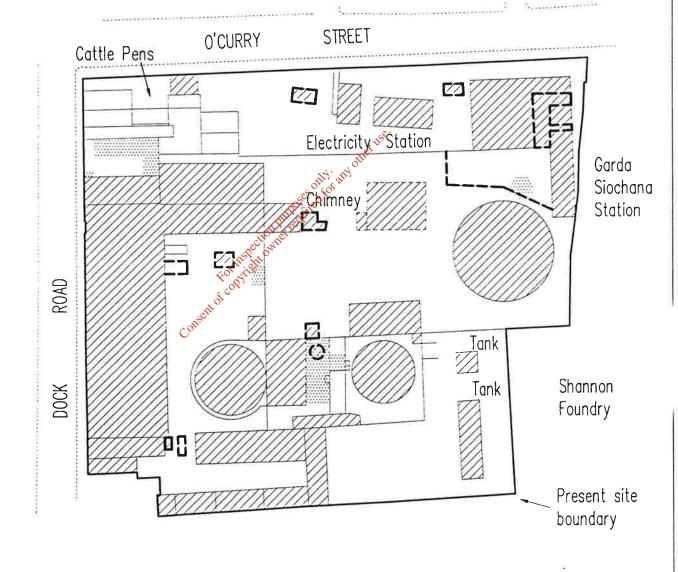
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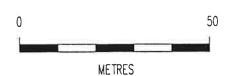
LIMERICK GASWORKS 1938

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LIMERICK GASWORKS 1977

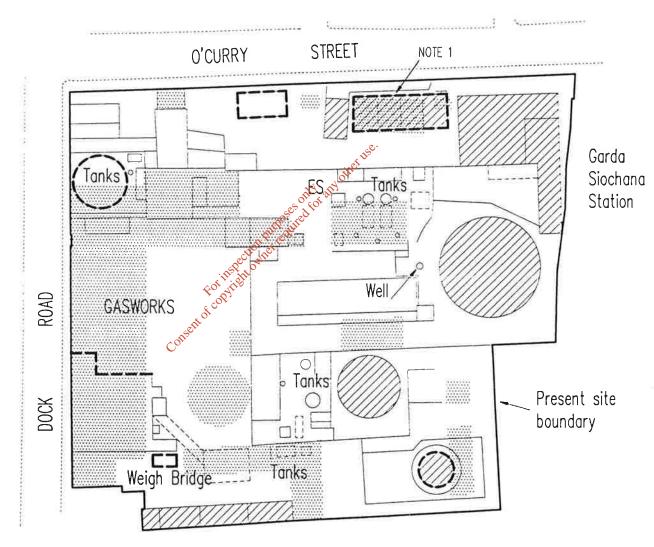
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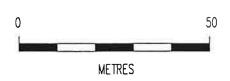
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Cod MMC Passed 7





NOTE 1. DOUBT ABOUT DATE OF REMOVAL AND RECONSTRUCTION OF STATION



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SK10

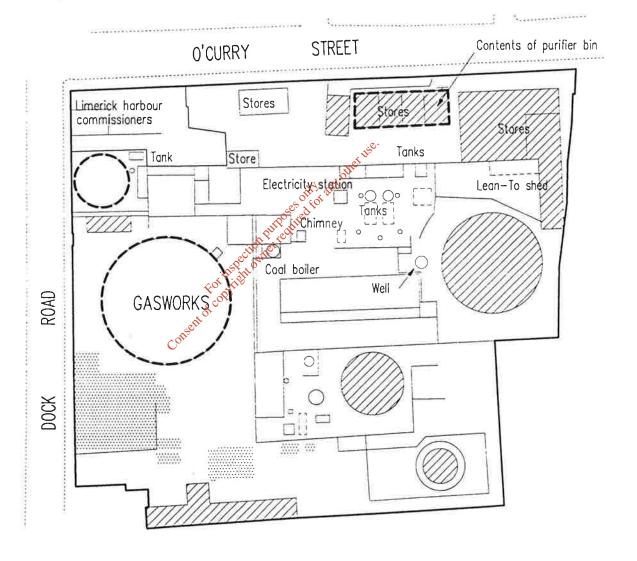
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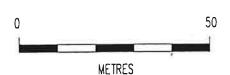
LIMERICK GASWORKS 1988

BGE REGIONAL GAS WORKS STUDY

Orn. PN 30te 23/11/94 Chd. MML 30ssed R







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LEGEND

REMOVALS







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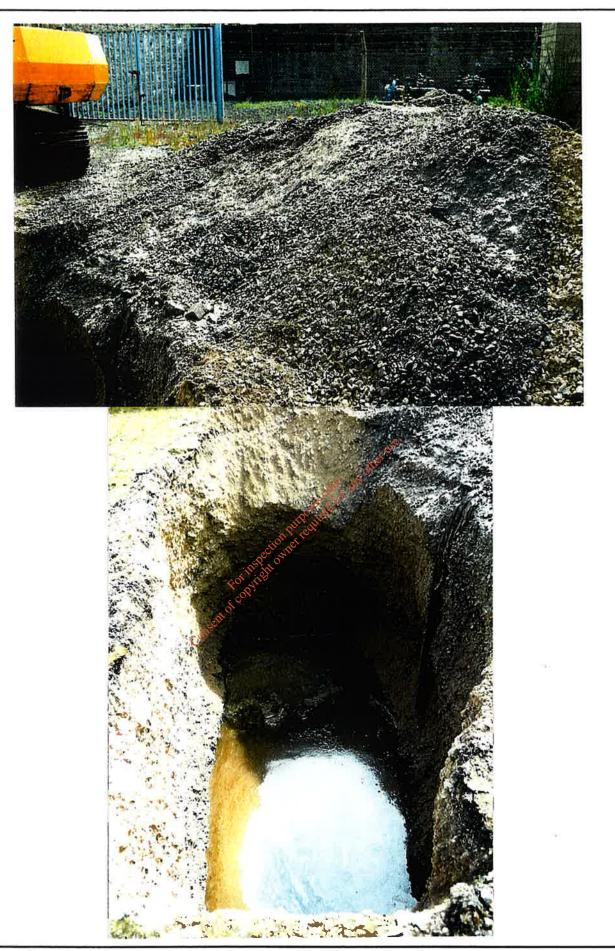
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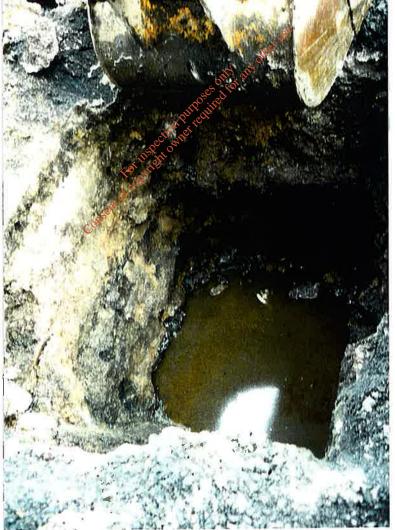
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ROCK CORES BGE - LIMERICK D1078/03



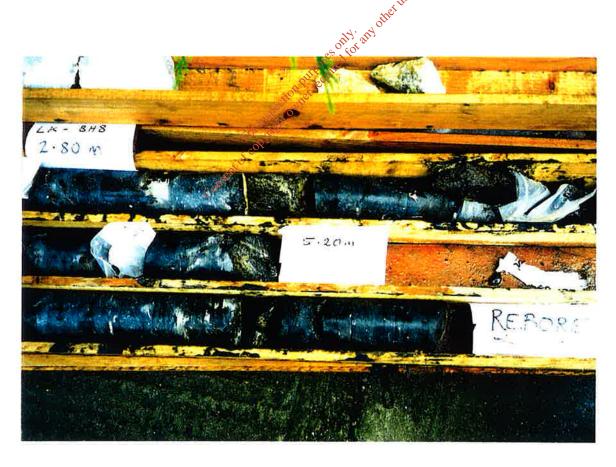
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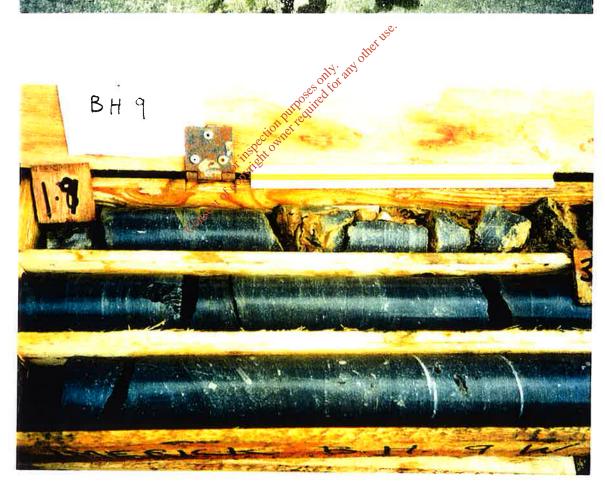




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ALLUVIAL CLAYS/SILTS @ 6.5m BGE - LIMERICK

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D 1078/3

### BGE Limerick/Waterford **Chemical Testing Suites**

#### SOIL TESTING

Suite S1 Total Cyanide Sulphate Toluene Extractable Matter (TEM) Total Phenols pΗ

S2

Arsenic

Lead

Cadmium

Chromium

Mercury

Nickel

S1x (Applies if total cyanide exceeds 500 mg/kg)
Free Cyanide
Complex Cyanide
Thyiocyanate

S1y (Applies if total sulphate exceeds 0.24%)
Water Soluble Sulphate

S1z (Applies if TEM exceeds 1.5
16 Priority PAH's
BTEX BTEX

S3

Mineral Oils

Mineral Oil Speciation by GCMS

S<sub>5</sub>

Total VOC's

**S6** 

Leachate Test

MML/PCH 13 July 1995

D 1078/3

#### BGE Limerick/Waterford Chemical Testing Suites

#### WATER TESTING

Suite W1

In-situ Tests (pH, Conductivity, DO, Temperature, Redox Potential)

Total Phenols

Ammoniacal Nitrogen

Sulphide

Free Cyanide

16 Priority PAH's

W2

In-situ Tests (pH, Conductivity, DO, Temperature, Redox Potential)

BOD

COD

Sulphate

Sulphide

Arsenic

Cadmium

Chromium

Lead

Mercury

Selenium

Copper

Nickel

Zinc

W3

Colour

Turbidity

Total Hardness

Total Alkalinity

Non-Carbonate Hardness

Chloride

Non-purgeable organic carbon

Calcium

Magnesium

Sodium

Potassium

Iron

Manganese

Aluminium

Nitrate

Nitrite

MML/PCH 13 July 1995

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