BORD GÁIS

Limerick Gasworks
Dock Road, Limerick

Site Investigation
General Report
Volume 2

October 2001

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All Figures, Appendices and References referred to in the text are located in Volume I of this report.

0.0 EXECUTIVE SUMMARY

Appointment	Parkman Environment were appointed by Bord Gáis Éireann in a letter dated 30th May 2000 to provide Engineering Consultancy Services for the documentation / remediation of the former gasworks sites at Limerick and Waterford. This document comprises Volume 2 (general information) for the Phase II (intrusive investigation) report for the Limerick Gasworks site.
Location	The site lies to the south-east of the Dock Road in the City of Limerick, approximately 100m from the River Shannon; the approximate National Grid Co-ordinates are E 157600 N 157200.
Services	All main services are present in Dock Road, St. Alphonsus Street and O'Curry Street; some gas services enter the site along the north-west boundary of the site and an electricity cable is shown running into the electricity sub-station from O'Curry Street. Private services may also exist on the site.
Geology & Hydrogeology	The site is underlain by various thicknesses of Made Ground, overlying Lower Carboniferous Limestone (Visean Limestone); thin layers of Alluvium deposits have been identified in some locations overlying the bedrock. The Limestone is considered to be a locally important aquifer and due to limited drift cover could be considered vulnerable. The nearest recorded abstraction is 6 km to the south-east of the site.
Site History	A limestone quarry extended over most of the eastern quadrant of the site prior to 1840. The gasworks was established to the north-west of the quarry in the 1830's. Several generations of gasworks producing 'town' gas occupied the site until gas manufacture was converted to oil - gas production in the late 1960's / early 1970's. The arrival of natural gas to Limerick in 1986 made the generating process redundant and most above ground structures were demolished by 1988.
Previous Site Investigations & Results	Two previous site investigations have been carried out on site in 1990 and 1995 comprising a total of 27 trial pits and 12 boreholes. Visual and olfactory evidence of organic contaminations was noted in a large number of exploratory holes, particularly over the south-western part of the site. Tarry staining was identified in the bedrock joints in four boreholes. Groundwater was contaminated with heavy oils and oozing tarry liquid particularly on the western side of the site. The results of leachate testing showed that the potential for leaching was low.
Recent Site Investigation	A total of 17 trial pits and 4 rotary boreholes were excavated between 26 February and 6 March 2001. Samples of soil and water were selected and sent to City Analytical Services plc (CAS) in Coventry, UK for subsequent chemical analysis. Samples were also taken for geotechnical analysis. Gas/water monitoring standpipes with taps were fitted to all 4 boreholes.

Remediation Components	Hydrocarbons are considered to be the major contaminant across the site, with a lesser degree of cyanide contamination adjacent to the former purifiers. Any contaminated groundwater encountered would require treatment prior to discharge to foul sewer. The remediation strategy will include preparation of a QRA, obtaining appropriate licences and permits including a waste management licence and EIS, selection of contractor, physical siteworks including demolition and remediation trials, validation and monitoring. The main available remedial options are bioremediation, soil washing, thermal treatment, solidification/stabilisation/encapsulation and chemical treatment.

1.0 INTRODUCTION

1.1 Terms of Reference

Parkman Environment were appointed by Bord Gáis Éireann in a letter dated 30 May 2000 (ref. No. 00/004) to provide engineering consultancy services for the decontamination/remediation of the former gasworks sites at Limerick and Waterford. These services include the preparation of Phase I (Document Review) and Phase II (Intrusive Investigation) reports. This document comprises Volume 2 (General Report) of the Phase II report for the Limerick gasworks site. Factual data in connection with the intrusive investigation is presented in Volume 1.

Bord Gáis propose to either dispose of the sites in their current condition or alternatively, remediate them ready for development.

The site reviewed in this report is based on the boundaries as defined by Bord Gáis Éireann at the time of the review. Parkman Environment prepared this Report based on the available information obtained during the study period. Every reasonable effort has been made to obtain all relevant information. Sources examined are listed in section 1.2.

This Report has been prepared and written for the exclusive benefit of Bord Gáis for the purpose of providing environmental information relevant to the existing potential environmental liabilities associated with the site in accordance with the Brief. The Report contents should not be used out of that context. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the Report after the date of its submission.

1.2 Methodology

The preparation of the Phase II report involves a review of all current available site information, a review of the information collected during the recent site investigation and discussion of available remediation techniques.

In undertaking the study, the following sources have been consulted: -

Limerick Corporation - Environment, Community & Sport Department
- City Engineer's Department

Environmental Protection Agency
The National Library of Ireland
Geological Survey of Ireland
The Map Library, Trinity College, Dublin
Eircom Ireland
ESB
Bord Gáis Éireann
GVA Donal O'Buachalla (Estate Agents)

Contact details for the above are provided in Appendix A of Volume I of this report. Other references used in completing this report are provided in Section 8.0 of

Volume I of this report.

A walkover survey was undertaken on 13 July 2000 and Mr Michael Shouldice, the Site Manager for Bord Gáis, was interviewed by Parkman.

Site investigation works were carried out between 26 February 2001 and 6 March 2001.

GVA Donal O' Buachalla (Estate Agents) were also consulted with respect to potential future uses for the site.

1.3 Report Format

This Report (volume 2) is sub divided into five sections. Following this Introduction [Section 1], the findings of the Phase I Desk Study are reviewed [Section 2]. The information gathered during the recent site investigation is then presented [Section 3]. Finally, the remediation components are discussed [Section 4]. All of these sections are summarised in tabular form in the Executive Summary [Section 0].

2.0 DESK STUDY ASSESSMENT

2.1 Site Location and Description

Limerick gasworks lies to the south-east of the Dock Road in the City of Limerick, approximately 100m from the River Shannon. The Shannon Bridge lies approximately 400m to the north-east of the site. The approximate National grid co-ordinates of the site are E 157600 N 157200 (see figure 1).

Access to the site is either from Dock Road, which forms the north-western site boundary, or from O'Curry Street forming the north-eastern boundary.

The site is approximately rectangular, 130m x 110m, and covers an area of 1.4 hectares (3.5 acres) including the "house pound" area in the northern corner, adjacent to the junction of Dock Road and O'Curry Street. Part of the site was a former limestone quarry and rock faces are evident in the north-eastern and south-eastern boundaries.

The main area of the site is generally level at about 5.00m OD [Malin Head Datum] but it rises to approximately 8.00m OD towards the site boundaries to the south and east (see figure 2).

The site is used as a depot for Bord Gáis, and includes a two-storey office adjacent to the south-west boundary. Other buildings on-site include a derelict former store building constructed of stone in the eastern corner and various other smaller brick buildings including the former No.'s 3 & 4 Store, the former Naphtha Process Control building (two-storey), ESB sub-station and the former Governor House.

In addition, high stone walls remain around the location of the former gasholder No 2 (T12) whilst the concrete bund walls and slab are present around the former Tank No 1 (T31). An above ground installation [AGI] remains towards the north west corner of the site adjacent to the site access from Dock Road.

The north-eastern boundary along O'Curry Street comprises a 2m high limestone block wall that becomes higher (3.5m) halfway along the boundary towards the south-east. The south-eastern boundary comprises a 6m high limestone block wall that retains the adjacent former Garda training centre, at a level some 2m above the Bord Gáis site level. This wall becomes a 3m high brick retaining wall (which retains limestone fill on the site side) in its south-western end adjacent to residential properties. The south-western boundary comprises a 2.5m high brick wall, which retains fill to 2.5m on the site side. The north-western boundary along Dock Road comprises a 2.5m high limestone block wall.

2.2 Statutory Authorities/Services

Limerick Corporation report that they are not aware of any other substantial sources of contamination within 500m of the gasworks site.

There are no known landfills within 500m of the site.

There are no statutory nuisances within 500m of the site.

Limerick Corporation sewers presently discharge into the River Shannon although a new main drainage scheme is currently being constructed and will subsequently collect all such discharges and route them to a new sewage treatment facility. No other discharges are made into the river. Correspondence with Limerick Corporation is included in Appendix F.

Details of consultees that provided services information in the vicinity of the study area are included in Appendix F.

All main services are provided along the Dock Road, St. Alphonsus Street and O'Curry Street. Electricity cables are shown running into the electricity sub-station from O'Curry Street. Bord Gáis pipelines are shown entering the AGI in the western corner of the site. Low pressure 180mm PE gas pipes also exist in the site along the eastern end of the Dock Road boundary. Private services may also exist on the site.

Figures 3a-e show the layout of services in relation to the site at a scale of 1:1000.

2.3 Geology, Hydrology and Hydrogeology

The Geological Survey of Ireland Sheet 17 Limerick, 1:100,000 Scale (ref. 7), the "Geology of the Shannon Estuary" (ref. 8) and the local geological memoir were consulted and indicated that the bedrock beneath the site comprises the Visean Limestones of the Lower Carboniferous Period. These limestones are 'oolitic' (small (≤1mm diameter) carbonaceous accretionary bodies cemented together, resembling fish eggs) in places, representing a shallow marine carbonaceous shelf depositional environment. These deposits occasionally contain clay 'wayboards' which formed when the limestone was periodically exposed above sea level. The limestone often contains chert nodules (siliceous concretions) and thin interbedded shales. The Visean Limestone is also known as 'Clean Shelf Limestone'. It is over 800m thick and lies conformably on the Waulsartion Limestone, described as a massive unbedded lime mudstone representing a deeper marine depositional environment.

Beneath the site, the beds dip 8° to the north. The site is located on the southern limb of an east-west trending syncline.

The rockhead is close to the surface with little or no drift cover. Should any be present, it is likely to comprise very recent fill [made ground used as backfill in the construction of the gasworks and infilling of the quarry] or Recent alluvium associated with the River Shannon flood plain.

The site is situated on the southern bank of the Shannon River, which flows westwards towards the Atlantic Ocean. The Shannon River will be tidally affected at this point.

The site comprises approximately 60% hard cover and 40% free draining material (with many underground structures that may impinge on the flow of water through the made ground). There is a slight fall in the site level from the south-east (3m OD) to the north-west (5m OD), and so any surface infiltration that does not enter the surface drainage system will tend to flow in the fill materials towards the north-west corner, i.e. towards the River Shannon. The River Shannon water level is typically 3m OD near the site.

Drainage of the site is to the city's sewers, which discharge directly into the river. The 'Site Investigation Report - Limerick Gasworks Site ' (ref 2) records that storm water flooding has occurred in the past along the Dock Road at its junctions with O'Curry Street and Alphonsus Street, i.e. close to the site.

The maximum recorded flood level for the City is reported as 4.25m OD (Malin Head).

The Groundwater Protection Maps for County Limerick (Maps 1-6) (ref. 6) indicate that the Clean Shelf Limestone is a 'Locally Important Aquifer' that is generally Moderately Productive (40-100m^3/d). The aquifer is controlled by fissure flow and well-developed karst features have been observed in the area. The nearest abstraction well is 6 km to the south-east of the site. The oolitic limestones of the Limerick Syncline are known to have relatively high permeabilities. The aquifer is considered 'Vulnerable' due to the lack of impermeable cover.

The majority of the ground water is hard, containing calcium bicarbonate $(Ca(HCO_3)_2)$. Iron and manganese have been found in elevated concentrations west of Limerick. Elevated nitrates have been encountered in some locations due to agricultural activities. Groundwater quality of smaller, shallower sources is generally poorer than the larger, deeper sources.

There are no recorded active wells or boreholes in the vicinity of the site although the historical site plan dated 1977 shows a well 5m to the north west of Gasholder No3 (T11).

It is likely that hydraulic continuity exists between the Made Ground/Alluvial deposits and the bedrock.

The proximity of the site to the tidal inlet of the River Shannon would suggest the potential for groundwater on site to be tidally affected; this would need to be confirmed by on-site monitoring.

2.4 Site History

An extract from the Autumn 1987 Limerick Journal entitled "150 Years of Limerick Gas" (ref.10) provided a background history to the site.

The article states "In 1826, the London-based United General Gas Company took over the Hibernian Gas Company in Dublin and soon began to spread its operations to the large urban areas throughout the country. It set up businesses in Limerick in the 1830's and became the sole manufacturer of gas in the city. But the service was very poor and the people's patience became so exhausted that in the year 1837 a public protect meeting was convened in the City Courthouse.... shortly afterwards, the newly reformed Corporation purchased premises in Watergate for the manufacture of gas, with the aid of a loan of £24,000. In 1878 following a Parliamentary enquiry and the passing of the Corporation Gas Act, the Local Authority took over the private firm and in 1884 moved from Watergate to the more spacious premises at the Dock Road."

Coal based gas manufacture is reported to have continued on site until the early 1970's and the article also states that "it was only in 1974 that the new catalytic oil-gas plant was finally completed in the city.......in 1986, natural gas was piped to Limerick on a spur line from the main Dublin-Cork pipeline. In early 1987, new natural gas pipelines were laid throughout the city and the change over from 'town' gas was complete. The old manufacturing process has been rendered obsolete and the plant at the Dock Road is nothing more that a relic of industrial archaeology."

2.5 Assessment of Previous Site Investigations

2.5.1 Description of Works Undertaken

Two site investigations have been carried out previously to assess the level of contamination on site (see figure 6 in Phase I report).

The first was carried out in 1990 by Gibb Environmental (environmental sampling) and Irish Geotechnical Services Limited (trial pitting and borehole excavation) under the direction of O'Connor Sutton Cronin and Associates Limited (ref.1). This comprised ten trial pits to between 1.4m and 2.3m deep and six boreholes to between 4m and 7.6m deep, the latter to prove rock.

Twenty-one soil samples were analysed for pH, sulphate, sulphide, cyanide (total & free), phenols, and toluene extractable material, with four also analysed for speciated PAH's and calorific value. Four water samples were analysed for pH, ammonia nitrogen, sulphate, total organic carbon (T.O.C.), total cyanide and total phenols as tar acids. One sample of water and one sludge sample were analysed for speciated PAH's.

The second investigation was carried out by K T Cullen and Company and Glover Site Investigations Limited under the direction of Ove Arup & Partners in 1995 (ref.2) and comprised 17 trial pits to between 0.15 m and 3.7m deep and 6 boreholes to between 5m and 11.8m deep and 5 surface (scraped) samples.

Fifty-five soil samples were analysed for pH, sulphates, total cyanide, toluene extractable material and total phenols. Based on the results obtained, selected samples were then subjected to analysis for dependant options comprising PAH'S, BTEX, free & complex cyanide, thiocyanate and water soluble sulphate.

In addition, selected samples were also analysed in respect of metals, mineral oils and total VOC's and a further two were the subject of a leachability test.

Twenty-three water samples were taken and analysed for a suite comprising total phenols, sulphide, ammoniacal nitrogen, total cyanide, speciated PAH's, pH, temperature and conductivity. Eleven samples were also subjected to a suite of tests including organic and inorganic determinands.

Monitoring was carried out subsequently on two occasions in respect of groundwater levels and gas levels.

The results of both investigations are reported and discussed in Ove Arup's April 1996 Site Investigation Report on Limerick Gasworks Site (ref. 3).

2.5.2 *Details of Ground Conditions*

The following succession of strata was identified from the two previous investigations: -

Table 2.5.2 Summary of ground conditions (1990 and 1995 investigations)

Stratum	Thickness (m)	
	Range	Average
Made Ground	0.2 - 7.3	2.6
Alluvium	0.0 - 4.4	1.8
Limestone	4.2m proven	

The Made Ground was found to be variable in nature and consistency. The exploratory holes describe the made ground as variable but predominately granular.

The Made Ground contains sand, gravels, cobbles, clays, brick rubble, spent oxides, ash, concrete etc. and was often contaminated with tarry liquid and occasionally has a strong phenolic odour. The deepest thicknesses of made ground were associated with either the old quarry or former tanks that extended underground.

The Alluvial deposits were found in at least three excavations (BH11, TP7 and TP27) towards the northern end of the site beneath the Made Ground, and were described as soft to firm brown plastic silty clays. Some materials encountered in other excavations may have also been Alluvial deposits, although it was unclear from the descriptions provided.

The top 0.5m to 1.0m of the bedrock was generally weathered and comprised of gravel to boulder size fragments of angular limestone. Below this level the bedrock comprises strong dark to medium grey coarse grained fresh, bedded Limestone. Total Core Recoveries (TCR) were in the range 14% to 100% with an average of 76%. Rock Quality Designation (RQD) values were also in range 14% to 100% with an average of 64%. The rockhead was often described as "stained with black tar" over a depth of up to 3m.

The bedrock surface was found to be very uneven due to previous quarrying activities and excavation for underground tanks and tank foundations. The natural slope of the bedrock is from approximately 7m OD at the southern boundary to 3m OD at the northern boundary.

Rockhead was encountered at a depth of 8.6m (-1.64m OD) in BH11 near the middle of the site from the 1995 investigation. This identifies a former quarry feature. This is shown on the historical map for 1872, reference Figure 4C included in the Phase I report.

Groundwater was encountered in all of the trial pits and boreholes at depths between 0.3m and 2.8m in the Made Ground. The general direction of groundwater flow was found to be north/north-west towards the River Shannon from a level of approximately 7m OD on the southern side of the site to approximately 4m OD on the northern side of the site (The River Shannon water level is typically 3m OD near the site).

2.5.3 *Details of Analysis*

Initial screening of the site investigation data has been undertaken using the UK ICRCL Threshold Trigger Values (least sensitive end use), for soils (where available), with the Dutch Intervention Values considered for soil contaminants not covered by the ICRCL list. The only exception to this is in the case of PAH where screening assessment criteria has been set at the Acton Trigger Level for the most sensitive end use. Figure 6 in the Phase I report identifies the soil samples where contamination levels have exceeded these initial screening levels.

This screening provides a basic assessment of the areas of site requiring remedial action, although it is recommended that a site specific quantitative risk assessment be carried out to establish remedial action values.

In general, the most significant soil contamination at Limerick gasworks was organic, with evidence of heavy staining by tars and tarry liquid with a phenolic odour being encountered in most of exploratory holes, particularly over the south western part of the site. Tarry staining penetrated into the bedrock joints in BH's 7, 8, 10 and 11. Elevated levels of organic contaminants were encountered in TP's1, 2, 8, 15, 19, 22, 23 and 24, mostly in the vicinity of former tanks. The contamination is most likely due to spillages and leaks from the tanks. Visual evidence of spent oxide ("blue billy") was encountered in the central area of the site (old quarry area), with associated elevated cyanide levels.

Generally there were no significantly elevated metal levels found at the site with the exception of the area around the chimney of the original gasworks (in the vicinity of T12), the elevated levels apparently being associated with ash from burning.

The groundwater encountered in the trial pits on the western side of the site were contaminated with heavy oils and oozing tarry liquid. Floating product with globules of tarry material was detected in three of sixteen trial pits, these are associated with buried structures (e.g. tar tanks). Tarry liquid was discovered to have penetrated downwards into the joints of the bedrock across the central area of the site.

Elevated levels of contaminants in groundwater occurred in generally the same areas as elevated levels of soil contamination, possibly suggesting that the groundwater is not very mobile. Generally, no significantly high metal concentrations were detected in the groundwater, except in trial pits in the area of the old gasworks (near T12).

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

The results of leachate testing showed that the potential for leaching was low, the measured concentrations being less than 0.1% of the original value. The exception was that 28% of the phenol in TP15 was extractable following leaching.

A second set of groundwater samples were taken about six weeks after the initial sampling. There was no significant difference in the results, one possible exception was BH8, where there was a significant increase in the concentration of phenol and a decrease in the concentration of PAH's. These results were associated with a significant decrease in temperature of the sample.

Elevated levels of methane (>1%) were recorded within borehole monitoring installations during a total of seven visits in BH's 7, 8 and 10 although the most significant levels (up to 90%) were recorded in BH12. The levels of methane recorded were generally significantly higher than the explosive limit (5 - 15%). The velocity of the gas flow was measured and found to be negligible. A tube sample of gas was taken from BH12 and analysed using GCMS. Traces of Kinsale Natural Gas was detected, suggesting that the elevated methane levels may have been due to a leak in a nearby gas main.

Levels of carbon dioxide ranged between 1.7 – 3.2% in BH's 7, 8, 10 and 12. Levels of oxygen were reduced significantly in all boreholes and were accompanied by elevated levels of carbon dioxide and methane. No hydrogen sulphide was found in any of the standpipes.

2.6 Development

2.6.1 Development Options

GVA Donal O'Buachalla have indicated in correspondence that the site may be suitable for three potential uses as listed below: -

i. Commercial offices, retail, leisure, car sales etc.

ii. Residential, but excluding townhouses with gardens.

iii. Car park, either a surface or multi-storey.

It is noted that storm water flooding has occurred in the past along the Dock Road at its junctions with O'Curry Street and Alphonsus Street. Limerick Corporation require a minimum floor level of 4.7m OD for any new development. The maximum recorded flood level for the City is reported as 4.25m OD.

It is likely that the No. 5 Stores building in the eastern corner of the site will remain as a part of any proposed development.

2.6.2 Access

Current site access is either via Dock Road, which forms the north-western site boundary, or from O'Curry Street forming the north-eastern boundary. The site access from O'Curry Street was not secured at the time of the site visit and does not appear to be generally locked. The access gate off Dock Road is the main access to the site for Bord Gáis personnel and is kept locked and secure when the site is not in use.

The current site access off Dock Road would be considered most suitable with respect to the proposed uses of the site although the access from O'Curry Street may be appropriate for small vehicles such as cars.

2.6.3 Services

All main services (gas, electricity, telecommunications, water and sewerage) are present in the Dock Road and O'Curry Street. Electricity cables are shown running into the electricity sub-station from O'Curry Street. Bord Gáis pipelines are shown entering the AGI located in the western corner of the site. Low pressure 180mm PE gas pipes also exist in the site along the eastern end of the Dock Road boundary.

In view of the above and further to initial discussions with the statutory utilities, there should be no problems in providing these services at the site. However, detailed discussions will be required to determine the most appropriate connections to existing services, once the precise requirements of the development are known.

2.6.4 Boundary Conditions

Existing site boundaries comprise a 2m high limestone block wall (which becomes higher (3.5m) halfway along the boundary towards the south-east) along the north-eastern boundary along O'Curry Street. The south-eastern boundary comprises a 6m high limestone block wall that retains the adjacent former Garda training centre at a level some 2m above the Bord Gáis site level. This wall becomes a 3m high brick retaining wall (which retains limestone fill on the site side) along its south-western end, adjacent to residential properties. The south-western boundary comprises a 2.5m high brick wall, which retains fill to 2.5m on the site side. The north-western boundary along Dock Road comprises a 2.5m high limestone block wall. The boundaries are considered generally secure at present, although trespassers can gain access over a low wall along O'Curry Street or via the gates on O'Curry Street which do not appear to be generally locked.

A survey of the boundary walls has been carried out by Parkman (report No. 25837/OR/02) on the 6th and 7th March 2001. The report concludes that in places the walls are in a poor state of repair and it is recommended that they are demolished prior to remediation, especially in areas when excavation is required close to the walls.

3.0 SITE INVESTIGATION

3.1 Field and Laboratory Work

The recent site investigation was planned and supervised full-time by Parkman Environment who also scheduled the analysis of soil and water samples. The ground investigation was carried out by Geotech Specialists Limited. A total of 17 trial pits and 4 rotary boreholes were excavated between 26 February and 6 March 2001. Trial pitting was conducted using a JCB 3CX excavator. Rotary holes were drilled using a Soil Mech 215 rig. These exploratory holes were set out to identify the location of underground structures associated with building foundations, various former tanks, and the depth and nature of made ground and the underlying natural strata. The locations of the exploratory holes are shown on Drawing No. 25837/OB/01 (see Volume I).

Samples of soil and water were selected and sent to City Analytical Services plc (CAS) in Coventry, UK for subsequent analysis. Analyses were carried out in accordance with British Gas Property "Guidance for Assessing the Potential Contamination on Gasworks Sites" Version 2.4. The results of contamination analyses are included in Appendix A; trial pit and borehole logs are presented in Appendix B, and photographs taken during the investigation are included in Appendix G. Bulk samples were taken for geotechnical analysis. The results of the geotechnical testing carried out are included in Appendix D. All appendices referred to above are contained in Volume I.

Gas monitoring standpipes with taps were fitted to all 4 boreholes. These took the form of slotted pipes surrounded with gravel, sealed at the surface with bentonite clay and covered with vandal proof covers.

Monitoring of water levels within all installations (including boreholes from previous investigations that still remain) has been undertaken on two occasions so far, on 2 April and 8 May 2001.

On-site monitoring of gas by a GA-90 infrared detector from the recent installations has been undertaken on two occasions so far, on 2 April and 8 May 2001.

Groundwater samples were also taken from the gas/water monitoring installations. Samples were sent to CAS plc for analysis.

Details of the water and gas monitoring are included in Appendix C.

Samples were obtained from two local quarries and sent to CAS for analysis. The samples were taken to provide information on potential sources of backfill during any future remedial works. The results of the chemical analysis are included in Appendix A.

3.2 General Ground Conditions

The following section describes the ground conditions identified by the recent site investigation carried out by Parkman Environment.

The general sequence of ground conditions comprises made ground overlying river deposits of silt and limestone bedrock.

The made ground was found to predominantly comprise granular material of sand and gravel/cobbles of limestone, brick, and concrete with some clay and pieces of clinker, glass and metal. Gravel to cobble sized pieces of iron oxide and some spent oxide was identified near the former purifiers. Hydrocarbon contamination was recorded in approximately 70% of the trial pits excavated. The depth of made ground varied between 0.04m and greater than 3.6m below ground level (mbgl) in the trial pit excavations although it is noted that some of them were excavated within former tanks. Made ground was recorded to a depth of 7.15mbgl in BH34, which is located in the area of the former quarry. It is noted that BH34 was drilled using rotary open hole techniques; here soil and rock descriptions rely on 'chippings' being retrieved to the surface during drilling which results in difficulties in determining precise depths for interfaces between different strata.

The deposits of natural soft grey clay and sandy silt were observed in three of the trial pits (TP's 33, 34 and 35), located within the central and eastern areas of the site. The top of this layer was encountered at depths between 1.8 and 2.8mbgl. The full thickness of this layer was not identified although it was proven to a thickness of 0.9m in TP33.

The surface of the limestone bedrock was identified by each of the rotary boreholes and four of the trial pits. The bedrock surface was found to be very uneven due to previous quarrying activities and excavation for underground tanks and tank foundations. The depth to the bedrock surface varied from outcropping at the surface at BH33 to 7.15 mbgl for BH34. In general the rock surface was found to be dipping to the north at levels of approximately 7m OD at the southern boundary and approximately 3m OD at the northern boundary. Previous investigations identified that the rock was 'stained with black tar' over a depth of up to 3m (see section 2.5.2).

Table 3.2A Summary of ground conditions (2001 investigation)

Stratum	Thickness (m)	
	Range	Average
Made Ground	0.0 - 7.15	2.3
Alluvium	0.0 - 0.9	0.53
Limestone	8.45m proven	

During the site investigation a number of structures were targeted. The following table details the targets and findings of each exploratory hole.

Table 3.2B Exploratory Hole Targets

Exploratory Hole	Target	Site Findings
TP31	General Coverage	Hydrocarbon odour 0.15-2.9mbgl
TP32	General Coverage	Stained/hydrocarbon odour 0.1-0.5mbgl
TP33	Investigate Former No.5 Store	Some lime present 0.3-1.8mbgl
TP34	General Coverage	Slight hydrocarbon odour 0.75-1.3m
TP35	Leaks/Spills From Tank T11	Strong tarry odour inside tank, black tarry water standing at 1.5mbgl Relatively clean outside the tank
TP36	Retort Area, Leaks/Spills from Tank T12	Slight hydrocarbon odour from groundwater
TP37	Leaks/Spills from Tanks T12, T13, T14, T15	Slight hydrocarbon odour from groundwater
TP38	Former Purifiers	0.2m thick reinforced concrete at surface
TP39	Leaks/Spills from Tanks T20, T21 and T22	Blue staining 0.4-0.6mbgl Oily sheen/tarry odour from groundwater
TP40	General Coverage	Slight tarry odour 1.9-2.5mbgl Generally clean
TP41	Leaks/Spills from Tanks T16, T17, T18, T19, T23	Hydrocarbon odour from groundwater TP ended at 0.9m due to location of gasmain
TP42	Leaks/Spills from Tanks T26, T28	Rockhead at 0.5m with traces of tar
TP43	Leaks/Spills from Tank T28	Rockhead at 0.5m with traces of tar within fissures
TP44	General Coverage	Pit cancelled due to services location and proximity to occupied offices
TP45	General Coverage	Pit cancelled due to services location and proximity to occupied offices
TP46	Infilled Pit	Pit cancelled due to services location and proximity to occupied offices
TP47	Tank T11	Tarry fill to 3.5m within tank
TP48	Tank T28	Tarry fill to 3.6m within tank, including oozing liquid tar
TP49	Leaks/Spills From T11	Outside of tank wall located
TP50	General Coverage	Pit cancelled due to density of vegetation/lack of space
TP51	General Coverage	Very tarry odour 0.4-1.35mbgl Very tarry water
BH31	General Ground Conditions/Analysis of Water Within Rock	Limestone bedrock surface at 1.85mbgl
BH32	General Ground Conditions/Analysis of Water Within Rock	Limestone bedrock surface at 1.65mbgl

Exploratory Hole	Target	Site Findings
BH33	General Ground Conditions/Analysis of Water Within Rock	Limestone bedrock surface at 0mbgl
BH34	General Ground Conditions/Analysis of Water Within Rock	Limestone bedrock surface at 7.15mbgl

3.3 Groundwater Conditions

A total of 20 exploratory holes encountered groundwater during the investigation. Perched water was encountered in several excavations within tanks or above concrete bases/cohesive layers. The natural groundwater was located at approximately 5.5-6.5m OD in the south and south eastern areas of the site. The levels decrease to 3-3.5m OD to the north and west of the site in the direction of the River Shannon. The table below details the groundwater levels and observations within excavations.

Groundwater levels were subsequently measured in monitoring installations constructed within boreholes and their results are considered to be more reliable as water levels have time to reach a steady state condition. These results are included and discussed in Section 3.7.2. An initial analysis of the groundwater levels suggests a hydraulic gradient in the region of 1 in 26 in a north westerly direction, and that there is hydraulic continuity between the bedrock and overburden materials.

Table 3.3 Groundwater Conditions

Exploratory Hole	Ground Level m OD	Depth to Water Strike m OD *	Observations
TP31	5.16	3.16	-
TP32	7.13	3.63	Minor seepage
TP33	7.99	5.49	-
TP34	6.71	4.66	Hydrocarbon sheen
TP35	8.30	5.30	Brown water
TP36	5.85	3.65	Hydrocarbon odour
TP37	5.88	4.88	Hydrocarbon sheen
TP38	7.07	5.52	Brown water
TP39	7.97	5.37	-
TP41	6.01	5.11	Hydrocarbon odour
TP42	7.17	6.77	Hydrocarbon sheen, some tar
TP47	8.18	5.43	Black water
TP48	7.09	4.09	Black water, hydrocarbon odour/sheen
TP49 (outside well)	7.71	5.31	Hydrocarbon odour/sheen

Exploratory Hole	Ground Level m OD	Depth to Water Strike m OD *	Observations
TP49 (inside well)	7.71	7.01	Tarry odour
TP51	6.34	5.09	Very tarry odour, hydrocarbon sheen
BH31	6.30	4.45	-
BH32	5.12	3.37	-
BH33	7.33	-	-
BH34	7.85	0.60	-

*During excavation of exploratory hole m OD- metres above Ordnance Datum

3.4 Basis of Environmental data Assessments

The chemical test results have been compared against applicable 'generic guidelines'. Ireland has no formal guidance to this extent, but Dutch Guidelines are frequently used within the country and these have been adopted (where available) for our assessment. It must be remembered, however, that the Dutch Guidance has been derived from extremely conservative assumptions, which apply to all uses of all sites in the Netherlands, and these assumptions are based on a 'standard Dutch soil' i.e. 10% organic matter and 25% clay. The Dutch approach for which the 'Intervention Values' were derived was based upon the principal of 'multifunctionality' i.e. a site clean to the values could be used for any purpose. This has now proven to be unsustainable on economic grounds as a national strategy. The UK ICRCL guideline levels are sometimes quoted which are based on specific end use; these comprise 'Threshold' and 'Action' trigger values given in ICRCL 59/83 'Guidance on the Assessment and Redevelopment of Contaminated Land' 2nd Edition. The Netherlands, in common with many other countries including the UK, is leaning towards a site specific risk assessment approach.

In this case, chemical test results for soil samples are compared against Dutch Intervention Levels or, where they are not available, ICRCL levels for the intended end use of hard cover.

Chemical test results for water samples are compared against Dutch Intervention Levels or, where they are not available, Maximum Allowable Concentrations for drinking water in the UK quoted in the Water Supply (Water Quality) Regulations 1989.

Leachate test results are compared against a factor of ten times the Maximum Allowable Concentrations quoted in the UK drinking water standards. These guideline values have been used for comparison purposes only; it has been assumed that leachate will be diluted by a factor of ten before reaching a receptor.

Finally, it is reiterated that the proposed guideline values are to be used for comparison purposes only; it is anticipated that the site would be subject to a quantitative risk assessment (QRA) which would derive site specific clean-up criteria. The methodology for undertaking a QRA should be agreed with the

Environmental Protection Agency prior to carrying out the assessment.

With respect to assessing sulphate concentration in soils and water, reference is made to BRE Digest 363 which advises on the durability of concrete in the ground.

CIRIA 149 (Protecting Development from Methane) suggests that the highest measured gas parameter should be used as a determining factor in recommending gas precautionary measures. CIRIA 149 presents six 'characteristic situations' dependent on the levels of methane, carbon dioxide and emission rates encountered. The report also stipulates requirements (e.g. well constructed ground slab, low-permeability gas membrane, etc.) with respect to any proposed development where methane and carbon dioxide levels exceed 0.1% and 1.5% by volume in air respectively. It is noted that Irish legislation has stricter guidelines on carbon dioxide levels than the UK (0.5% as opposed to 1.5%) and it is usual to increase the characteristic situation by one for construction activities in Ireland where elevated levels of carbon dioxide are found (see Section 3.7.1).

3.5 Discussion of Contamination Results

In order to assess the levels of contaminants found within the site, the soil analysis results have been compared against the guidance levels outlined in Section 3.4. Locations where determinands exceed guidance levels identified in Section 3.4 are indicated on Drawing no. 25837/OB/02. As part of the site investigation, water and leachate samples from across the site were also analysed for contamination; locations where determinands exceed guidance levels identified in Section 3.4 are indicated on Drawing no. 25837/OB/03 and Drawing no. 25837/OB/04 respectively. All laboratory test results associated with the investigation are included in Appendix A (Volume 1).

Analysis of the soil samples generally indicated the presence of contamination in the form of tars and oils; the most common determinands at elevated concentrations being PAH, TPH, phenols, cyanide, benzene, toluene and xylene. This type of contamination was found at elevated levels at locations across the site. The heaviest tar contamination was found within, or in the vicinity of, historic structures such as former tar tanks and gasholder wells. Contamination with heavy metals was not significant across the site although two elevated levels of lead were identified. Less common contaminants detected at elevated concentrations were sulphur and sulphate. Analysis of the leachate samples prepared from the soil samples indicate the most leachable compound to be cyanide (between 0.03 and 71% of the original values), with lesser amounts of phenols (between 0.8 and 65% of the original values) and ammonium (between 3 and 20% of the original values). The remaining analytes had a very low leaching potential, with measured concentrations being less than 0.1% of the original values.

Analysis of groundwater sampled during the investigation identified that the most common contaminants in groundwater were PAH, benzene, xylene, cresol, phenol, sulphate and cyanide. Elevated levels of arsenic, chromium, nickel and lead were encountered in a number of locations. The heaviest tar contamination was found within, or in the vicinity of historic structures such as former tar tanks and gasholder wells. It is noted that these results may be more elevated than those taken from borehole installations after steady state conditions have been allowed to establish. Analysis of groundwater sampled from borehole installations is discussed in Section 3.7.2.

Samples were taken from two local quarries to obtain information with regard to potential sources of fill. Subsequent chemical analysis found the samples to be clean in comparison with the proposed guidelines.

The following tables show the range of contaminants in samples compared to the relevant action levels for soils, water and leachate.

Table 3.5A Comparison of chemical test results for soil samples against proposed guidelines

Contaminant	On site range (mg/kg air dried soil)	Dutch Intervention Level (except where stated) (mg/kg)	Samples Where Proposed Guidelines have been exceeded (concentration mg/kg)
Arsenic	0.32 - 26	55	0
Boron (water soluble)	0.041 - 0.64	3***	0
Cadmium	0.16 - 0.5	12	0
Chromium	1.1 - 36	380	0
Copper	0.34 - 94	190	0
Mercury	0.025 - 1.4	10	0
Nickel	0.73 - 32	210	0
Lead	0.84 - 1100	530	TP34 1.2m (1100), TP48 2.5m (1100)
Selenium	0.047 - 0.81	6*	0
Zinc	1.2 - 160	720	0
Total Phenols	<0.5 - 3700	45	TP35 1.0m (620), TP39 0.5m (90), TP47 1.0m (400), TP48 1.5m (370), TP48 2.5m (1800), TP49WELL 0.5m (180), TP51 0.3m (3700)
Sulphur (Elemental)	54 - 20000	5000**	TP49WELL 0.5m (20000)
Sulphate (Total) as SO_4	5.5 - 4100	2000*	TP33 0.6m (3100), TP35 2.0m (4100)
PH	6.3 - 12	NL*	-
Total Cyanide	0.27 - 15000	70	Tp33 0.6m (120), TP33 1.5m (410), TP34 1.2m (120), TP35 2.0m (180), TP39 0.5m (15000), TP39 1.5m (200), TP39 2.8m (120), TP49 0.3m (150), TP49 1.5m (400), TP49 (640)
TPH (Total)	38 - 140000	800▲	TP34 2.0m (1200), TP35 1.0m (16000), TP39 2.8m (1700), TP47 1.0m (16000), TP48 2.5m (120000), TP49WELL 0.5m (26000), TP51 0.3m (140000), TP51 1.0m (1500)
Total PAH	<10 - 27000	40	BH32 0.5m (330), TP31 0.6m (66), TP31 1.1m (42), TP31 2.2m (65), TP32 0.2m (3800), TP33 0.6m (180), TP34 0.3m (65), TP34 1.2m (620), TP34 2.0m (140), TP35 1.0m (6900), TP35 2.0m (200), TP35 3.0m (52), TP38 0.5m (500), TP38 1.5m (99), TP39 0.5m (3100), TP39 1.5m (68), TP39 2.8m (910), TP40 2.2m (56), TP41 0.8m (51), TP47 1.0m (2700), TP47 2.0m (130), TP48 1.5m (1200), TP48 2.5m (27000), TP49 0.3m (92), TP49 1.5m (190), TP49 2.6m (180), TP49WELL 0.5m (1000), TP51 0.3m (1500), TP51 1.0m (430)

Contaminant	On site range (mg/kg air dried soil)	Dutch Intervention Level (except where stated) (mg/kg)	Samples Where Proposed Guidelines have been exceeded (concentration mg/kg)
Benzene	<0.1 - 200	1	TP35 1.0m (62), TP47 1.0m (23), TP48 1.5m (11), TP48 2.5m (200), TP49WELL 0.5m (15), TP51 0.3m (150), TP51 1.0m (1.9)
Toluene	<0.1 - 240	130	TP48 2.5m (240), TP51 0.3m (200)
Xylene's	<0.1 - 450	25	TP35 1.0m (260), TP47 1.0m (130), TP48 1.5m (50), TP48 2.5m (450), TP49WELL 0.5m (37), TP51 0.3m (410)
Loss on Ignition (%)	0.05 - 45	25#	TP39 0.5m (28), TP48 2.5m (37), TP51 0.3m (45)

Key
- * ICRCL Threshold Trigger Level for Parks, Playing Fields, Open Space
- ** ICRCL Threshold Trigger Level for All Proposed Uses
- *** ICRCL Threshold Trigger Level for any uses where plants are to be grown
- NL No Limit
- ▲ Dutch Guidelines (from Moen et al, 1986)
- # Common Practice Site Trigger Level

Table 3.5B Comparison of chemical test results for water sampled during the investigation against proposed guidelines

Contaminant	On site range (mg/l)	Dutch Intervention Level (except where stated) (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)
Arsenic	<0.01 - 0.42	0.06	TP47 2.75m (0.09), TP49 WELLW (0.42)
Cadmium	<0.005 - 0.0054	0.006	0
Chromium	<0.01 - 0.08	0.03	BH10 2.0m (0.08), TP35 1.5m (0.06), TP47 2.75m (0.05)
Copper	<0.01 -0.03	0.075	0
Mercury	<0.001 - 0.002	0.0003	TP49 WELLW (0.002)
Nickel	<0.01 - 0.28	0.075	TP35 1.5m (0.13), TP36 2.2m (0.28), TP47 2.75m (0.1)
Lead	<0.01 - 0.9	0.075	TP34 2.05m (0.19), TP35 1.5m (0.9), TP35 3.0m (0.12)
Selenium	<0.002 - 0.027	0.01*	TP47 2.75m (0.027)
Zinc	<0.01 - 0.78	0.8	0
Total Cyanide	<0.2 - 540	3	TP35 1.5m (270), TP38 1.55m (5.5), TP39 2.6m (4.7), TP49 2.4m (540), TP49 WELLW (15)
Conductivity (µS/cm)	380-5100	1500*	BH10 2.0m(2300), TP34 2.05(1700), TP35 3.0m (2400), TP39 2.6m (1600), TP47 2.75m(5100), TP51 1.25m (1800)
Cresols	<0.0005-1200	0.2	BH7 1.0m(11), BH10 2.0m(130), TP35 3.0m(380), TP36 2.2m(15), TP39 2.6m(3.6), TP47 2.75m(550), TP48 3.5m(170), TP49 2.4m(4.5), TP49 WELLW (1200), TP51 1.25m(18)
Catechol	<0.0005-33	1.25	BH10 2.0m(7.9), TP35 1.5m(13), TP47 2.75m(27), TP48 3.5m(31), TP49 WELLW(33), TP51 1.25m(3.5)
Phenol	<0.0005-440	2	BH7 1.0m(3.3), BH10 2.0m(110), TP35 1.5m(190), TP47 2.75(360), TP48 3.5m(87), TP49 2.4m(2.6), TP49 WELLW(440), TP51 1.25m(9.8)
Sulphate	8.2 - 1300	250*	BH7 1.0m (1000), BH10 2.0m (280), TP33 2.5m (480), TP34 2.05m (400), TP35 1.5m (1100), TP35 3.0m (1000), TP38 1.55m (840), TP39 2.6m (390), TP47 2.75m (1300), TP48 3.5m (340), TP49 2.4m (740), TP49 WELLW (690)

Contaminant	On site range (mg/l)	Dutch Intervention Level (except where stated) (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)
Ammonium	0.64 - 1500	3	BH7 1.0m (32), BH10 2.0m (1500), TP33 2.5m (9.6), TP34 2.05m (23), TP35 1.5m (13), TP35 3.0m (9.6), TP36 2.2m (7.5), TP39 2.6m (3.9), TP47 2.75m (490), TP48 3.5m (140), TP49 WELLW (690), TP51 1.25m (15)
Iron	0.07 - 70	0.2*	BH7 1.0m (5.7), BH10 2.0m (40), TP33 2.5m (21), TP34 2.05m (16), TP35 1.5m (70), TP35 3.0m (64), TP36 2.2m (0.29), TP38 1.55m (2.0), TP39 2.6m (21), TP47 2.75m (68), TP48 3.5m (12), TP49 2.4m (1.3), TP49 WELLW (29), TP51 1.25m (0.45)
TPH	<0.1 - 440	0.15▲	BH7 1.0m (7.2), BH10 2.0m (14), TP34 2.05m (5.1), TP35 1.5m (22), TP35 3.0m (0.25), TP36 2.2m (77), TP37 1.0m (1.8), TP39 2.6m (7.2), TP42 0.4m (4.7), TP47 2.75m (27), TP48 3.5m (16), TP49 2.4m (1.3), TP49 WELLW (440), TP51 1.25m (86)
PH	6.7 - 12	<5.5* >9.5*	BH7 1.0m (11), TP35 1.5m (9.9), TP48 3.5m (9.8), TP49 WELLW (11), TP51 1.25m (12)
Total PAH	0.00095 - 1.7	0.08175	BH7 1.0m (0.37), BH10 2.0m (0.37), TP34 2.05m (0.09), TP35 1.5m (0.38), TP36 2.2m (0.33), TP37 1.0m (0.12), TP38 1.55m (0.25), TP39 2.6m (0.87), TP42 0.4m (0.12), TP47 2.75m (0.35), TP48 3.5m (0.35), TP49 2.4m (0.12), TP49 WELLW (1.7), TP51 1.25m (0.71)
Benzene	<0.01-30	0.03	BH7 1m(1.6), BH10 2m(1.7), TP34 2.05m(1.6), TP35 1.5m(1), TP36 2.2m(0.49), TP37 1.0m (0.31), TP39 2.6m(1.1), TP42 0.4m (0.33), TP47 2.75m (18), TP48 3.5m(7.3), TP49 2.4m(0.065), TP49 WELLW (30), TP52 1.25m (1.6)
Toluene	<0.01-7.8	1	BH10 2m (7.5), TP35 1.5m(4.4), TP47
Ethylbenzene	<0.01-0.32	0.15	BH10 2m(0.32), TP35 1.5m(0.21), TP47 2.75m(0.21), TP48 3.5m(0.19), TP49 WELLW(0.3), TP51 1.25m(0.24

Contaminant	On site range (mg/l)	Dutch Intervention Level (except where stated) (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)
Xylene's	<0.01-3.8	0.07	BH7 1m(0.3), BH10 2m(3.8), TP34 2.05(0.23), TP35 1.5m(2.1), TP36 2.2m(0.14), TP37 1m(0.22), TP39 2.6m(0.42), TP42 0.4m(0.41), TP47 2.75m(2.5), TP48 3.5m(2.1), TP49 WELLW (3), TP51 1.25m(2.2)

Key

* UK Water Supply (Water Quality) Regulations 1989

▲ Dutch Guidelines (from Moen et al, 1986)

NOTE Some of the water samples (BH7 & BH10) relate to boreholes excavated in the previous investigation (see Section 2.5).

Table 3.5C Comparison of chemical test results for leachate samples against proposed guidelines

Contaminant	On site range (mg/l)	Proposed Guideline Level (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)
Arsenic	<0.01	0.5▲	0
Cadmium	<0.005	0.05▲	0
Chromium	<0.01	0.5▲	0
Copper	<0.01	30▲	0
Mercury	<0.001	0.01▲	0
Nickel	<0.01	0.5▲	0
Lead	<0.01	0.5▲	0
Selenium	<0.002 - 0.003	0.1▲	0
Zinc	<0.01 - 0.02	50▲	0
Iron	<0.01 - 2.7	2▲	TP39 0.5m (2.7)
Ammonium	<0.64 - 14	5▲	TP48 2.5m (14)
Total Cyanide	0.3 - 3.8	0.5▲	TP31 2.2m (0.9), TP32 0.2m (0.8), TP32 3.4m (0.9), TP34 0.3m (0.6), TP34 2.0m (0.7), TP35 2.0m (1.3), TP37 1.1m (0.6), TP39 0.5m (3.8), TP39 2.8m (2.5), TP47 1.0m (1.4), TP47 3.0m (0.8), TP48 2.5m (0.6), TP51 0.3m (0.6), TP51 1.0m (1)
Phenol	<0.0005-46	0.005▲	TP39 0.5m (0.02), TP47 1m(20), TP47 3m(4.6), TP48 2.5m(46), TP51 0.3m(20), TP51 1m(1.2)
PH	7.1 - 11	<5.5 >9.5▲	TP37 1.1m (9.6), TP51 0.3m (9.6), TP51 1.0m (11)
Total PAH	0.00028 - 0.69	0.002▲	TP32 0.2m (0.026), TP36 2.3m (0.0027), TP39 0.5m (0.0062), TP39 2.8m (0.037), TP47 1.0m (0.69), TP47 3.0m (0.075), TP48 2.5m (0.6), TP51 0.3m (0.27), TP51 1.0m (0.034)

Key

▲ 10 x Maximum Allowable Concentration from UK Water Supply (Water Quality) Regulations 1989

3.6 Discussion of Geotechnical Results

3.6.1 Particle Size Distribution

Five particle size analyses were scheduled on samples of made ground. Two of the samples, both from TP35, were considered to be too highly contaminated by the testing laboratory for analysis. The remaining three samples (BH32 (0-0.5m), TP36 (0.5), TP41 (0.5m)) were tested. Two of the samples (BH32 and TP36) were classified as sandy gravels. The remaining sample from TP41, a puddle clay lining to a tank, was classified as a sandy gravelly clay.

3.6.2 Permeability Tests

We are intending to carry out in-situ permeability tests during one of the forthcoming monitoring events, results of which will be presented in the final issue of this report.

3.7 Interpretation of Readings from Gas/Water Installations

3.7.1 Soil Gas Monitoring

The soil gas installations have been monitored on two occasions to date using a GA90 infrared detector. The results are tabulated below and included in Appendix C of Volume 1B.

Table 3.7.1 Soil gas monitoring results

Sampling Date	02/04/01			08/05/01					
Gas Results	**CH_4 %**	**CO_2%**	**O_2%**	**CH_4 %**	**CO_2%**	**O_2%**	**CH_4 %**	**CO_2%**	**O_2%**
BH31	0	0.2	19.8	0	0	20.6			
BH32	0	0	15.9	0	0	20.5			
BH33	0.3	0.1	18.3	0	0	20.7			
BH34	0	0	20.3	0	0	20.6			
BH11	-	-	-	0	0.2	20.2			

In accordance with CIRIA 149 'Protecting Development from Methane' (see Section 3.4), Characteristic Situation 2 would be applicable as the highest concentration of methane detected is above 0.1%. Characteristic Situation 2 recommends the following precautionary means for all types of structures: -

- Ventilation of confined spaces
- Well constructed ground slab
- Low permeability gas membrane
- Minimum penetration of ground slab by services

It is noted that the results of further soil gas monitoring may change to recommended precautionary measures in relation to building construction.

3.7.2 *Water Monitoring*

Water levels within monitoring installations have been monitored on one occasion to date. The results are tabulated below.

Table 3.7.2A Water levels

	Water Depth (m OD)		
Sampling Date:	**02/04/01**	**08/05/01**	
BH31	4.395	5.045	
BH32	3.777	3.697	
BH33	6.526	6.956	
BH34	7.845	4.995	
BH11*	-	-	

*Note - this borehole relates to a previous investigation (see Section 2.5.1).

Water was sampled from all borehole monitoring wells on 11 April 2001, 16 May 2001 and 28 June 2001. The samples were sent to City Analytical Services in the UK for chemical analysis. Before the water was sampled, the monitoring wells were purged of three times their volume to allow steady-state conditions more representative of the general groundwater conditions. The test results are included in Appendix C of Volume 1B. The results generally indicate that the water samples from boreholes 33 and 7 (from the recent investigation and a previous investigation respectively) were contaminated with hydrocarbons. Elevated lead and sulphate concentrations were detected in water samples from across the site. The following table indicates the locations where concentrations of contaminants in water samples exceed Dutch Intervention Levels.

Table 3.7.2B Comparison of chemical test results for water sampled from borehole installations against proposed guidelines

Contaminant	On site range (mg/l)	Dutch Intervention Level (except where stated) (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)		
			11 April 2001	16 May 2001	28 June 2001
Arsenic	<0.01-0.03	0.06	0	0	0
Cadmium	<0.005-0.027	0.006	0	BH10 (0.018), BH31 (0.009)	BH11 (0.027), BH32 (0.0073)
Chromium	<0.01-0.04	0.03	0	BH10 (0.04)	0
Copper	<0.01-0.05	0.075	0	0	0
Mercury	<0.001	0.0003	0	0	0
Nickel	<0.01-0.09	0.075	0	BH31 (0.09)	0
Lead	<0.01-0.38	0.07	BH31 (0.19), BH32 (0.11), BH34 (0.09)	BH10 (0.16), BH11 (0.08), BH31 (0.2), BH33 (0.13)	BH10 (0.2), BH11 (0.21), BH32 (0.12), BH33 (0.38)
Selenium	<0.002-0.01	0.01*	0	0	0

Contaminant	On site range (mg/l)	Dutch Intervention Level (except where stated) (mg/l)	Samples Where Proposed Guidelines have been exceeded (concentration mg/l)		
			11 April 2001	16 May 2001	28 June 2001
Zinc	<0.1-2.2	0.8	0	BH10 (2.2)	0
Total Cyanide	0.2-9.9	3	BH7 (4.4)	BH7 (9.9)	0
Cresols	0.0005-31	0.2	BH33 (31), BH7 (12)	0	BH7 (2.1), BH10 (28), BH11 (1.1), BH33 (18)
Catechol	0.0005-0.51	1.25	0	0	0
Phenol	0.0005-20	2	BH33 (20), BH7 (3.9)	0	BH10 (10), BH33 (13)
Sulphate	29-1600	250*	BH31(550), BH33(510), BH7(1100)	BH7 (980), BH11 (410), BH31 (360), BH34 (580)	BH7 (1600), BH11 (410), BH31 (300)
PH	6.7-9.8	<5.5 >9.5*	BH7 (9.8)	0	BH7 (9.7)
Total PAH	0.0011-3.6	0.08175	BH33 (0.75), BH7 (0.4)	BH7 (3.6), BH10 (2.8), BH32 (0.088), BH33 (0.17), BH34 (0.13)	BH7 (1.3), BH10 (0.34), BH11 (1.1), BH33 (1.1)
Benzene	0.01-16	0.03	BH33 (16), BH7 (2.7)	BH7 (1.6), BH10 (7.5), BH11 (0.51), BH33 (13)	BH7 (1.7), BH33 (7.2)
Toluene	0.01-5.5	1	BH33 (5.5)	BH10 (4.5), BH33 (4.3)	BH10 (3.8), BH33 (3.2)
Ethylbenzene	0.01-0.3	0.15	BH33 (0.25)	BH10 (0.23), BH11 (0.19), BH33 (0.19)	BH10 (0.3), BH11 (0.18)
Xylene's	0.01-3.6	0.07	BH33 (3), BH7 (1.1)	BH7 (1), BH10 (3), BH11 (1.3), BH32 (0.15), BH33 (2.3), BH34 (0.074)	BH7 (0.85), BH10 (3.6), BH11 (1.2), BH32 (0.31), BH33 (2.1)
TPH	0.1-66	0.15	BH32 (0.44), BH33 (9), BH34 (0.54), BH7 (13)	BH7 (66), BH10 (15), BH11 (1.9), BH31 (0.16), BH32 (9.3), BH33 (14), BH34 (0.87)	BH7 (8.2), BH10 (26), BH11 (4.8), BH31 (0.35), BH32 (1.1), BH33 (9.1)

Key

* Water Supply (Water Quality) Regulations 1989

3.7.3 *Monitoring over 13 Hour period*

Monitoring of water levels in boreholes is to be carried out every hour over a 13 hour period in the near future to determine tidal influences on the site.

4.0 REMEDIATION COMPONENTS

4.1 General

This section describes the main aspects to be considered in respect to any proposed remediation scheme. An outline remediation strategy and options for treatment of contaminated soils are also presented.

4.2 Demolition

It is anticipated that all above ground structures are to be demolished as part of any remediation scheme, perhaps with the exception of the large building in the eastern corner of the site identified as 'No. 5 Stores' on Drawing no. 25837/OB/01. This may be retained as a feature in the proposed development.

It is also anticipated that the majority of floor slabs, foundations, underground tanks etc, will require removal as part of the reclamation works. The review of historical plans and information gathered during the ground investigation works indicated that a large amount of underground obstructions, tanks, redundant services, etc. are present. Only after demolition of the existing buildings can details of floor slabs for removal be ascertained in these areas.

Demolition of several boundary and internal walls, which generally comprise brick or limestone masonry, will also be required as part of the remediation works.

Experience of other similar gasworks has found that 'hard dig' accounts for a volume equivalent to a thickness of 0.5 - 1.0m across the whole site.

4.3 Hydrocarbons

The presence of hydrocarbons is a considerable issue in relation to the potential remediation of the site. Several underground tar tanks or similar have been identified with high total PAH, total phenol, TPH and BTEX (benzene, toluene, ethylbenzene and xylene). Currently organics of the following physical conditions are anticipated, in unknown volumes:

- Made ground/demolition material contaminated by hydrocarbons (PAH's, phenols, BTEX, etc.)
- Free product floating in the ground water in the area of T12 (gas oil/lighter fractions of PAH's)
- Liquid, semi liquid and viscous tar

4.4 Heavy Metals/Cyanides

Contamination in the form of heavy metals was not significant across the site, although elevated levels of cyanide were located in the area of the former purifiers. Heavy metals are not generally suitable for thermal treatment although cyanide can be degraded by this process. On-site solidification or stabilisation can be effective for these materials, although such treatments would be subject to consultation with the relevant authorities and the surrender of a waste licence, which may be complicated.

4.5 Groundwater

Any proposed remediation scheme should ensure removal of the primary sources of groundwater contamination. Contaminated waters arising during the works would be treated on-site with the resulting cleaned water recycled within the site or disposed of through foul sewers. It is considered that source removal of contaminants should be a satisfactory solution in terms of groundwater, within the general groundwater context of the site.

4.6 Planning, Licences and Permits

4.6.1 Waste Management Licence

It is our understanding that any processing of contaminated materials on-site will require a Waste Management Licence from the Environmental Protection Agency (EPA). Discussions should be held with the Agency at an early stage in the scheme to establish the conditions that are likely to be imposed in connection with the remediation scheme.

Contaminated materials being transported from site would be subject to duty of care transference procedures. In particular, any waste being transferred overseas would be subject to Transfrontier Shipment of Waste Notification in accordance with EU legislation.

4.6.2 Planning

Planning permission would be required in relation to any development. It is also our understanding that a two-stage Environmental Impact Statement (EIS) would be required. The first stage would relate to the remediation works, with the second covering aspects with respect to specific development proposals.

4.6.3 Water

A temporary waste water discharge consent will be required for the works and any trials. Consented discharges to foul sewer will need to meet criteria acceptable to Limerick Corporation.

4.6.4 Odour, Dust, Noise and Vibration

Strict measures to control odour, dust, noise and vibration will be required if planning permission and a waste licence are to be obtained from Limerick Corporation and the EPA respectively. In particular, it is our opinion that the EPA will require that odour control measures are sufficient to prevent nuisance to local residents.

Finally, it is noted that ambient levels of odour, dust, noise and vibration should be monitored prior to works commencing. This would be a requirement of the waste licensing and planning permission processes.

4.6.5 Asbestos

A full specification for the removal of asbestos encountered will be required as part of the demolition process.

4.6.6 Health and Safety

All site operations must comply with relevant legislation including Safety, Health and Welfare at Work regulations 1995. It is anticipated that the remediation contractor would act as Project Supervisor (Construction) in accordance with this legislation.

4.7 Remediation / Reclamation Strategy

4.7.1 General

The remediation/reclamation strategy would comprise the following components: -

- Prepare Quantitative Risk Assessment (QRA); methodology should be agreed with the EPA prior to undertaking the assessment.
- Agreement of site clean-up criteria derived by QRA with Regulatory Authorities.
- Obtain appropriate licenses and permits.
- Discussions with Limerick Corporation and EPA to confirm the requirements for a Waste Management Licence, Environmental Impact Statement and Planning Permission.
- Ensure adequate site security (site should also be vacated by existing Bord Gais staff).
- Trials to assess suitability of alternative remediation techniques.
- Selection of experienced remediation contractor.
- Demolition of structures, removal of foundations, underground tasks, floor slabs etc.
- Construction of any physical barriers required (e.g. cut - off trenches etc.).
- Removal/treatment of liquid, semi-liquid and viscous tar from within underground tanks, pipelines, etc.
- Removal/treatment of soil contaminated with PAH's, phenols, cyanides, sulphur

and heavy metals in addition to potentially combustible material (where required).

- Treatment of contaminated groundwater encountered during excavation works.
- Validation before, during and after remedial actions.
- Longer term monitoring (if required).

The selection of the most appropriate remediation method or combination of methods will depend on the assessment of a wide range of site-specific factors. These include: -

- Location of the site (site access, value, adjacent property etc.).
- Nature of ground conditions (soils, dip of strata etc.).
- Nature and extent of contamination (soils, water, leachate).
- Hydrogeological regime.
- Proposed use(s) of the site.
- Suitability of remediation techniques.
- Time available for remediation.
- Liabilities (statutory and non-statutory).
- Cost of remediation works.

The various remedial techniques available must therefore be considered in terms of attaining an overall remedial solution. No suitably licensed landfills are available for soils contaminated to the levels identified on-site and therefore landfilling of material in Ireland is not an available option. The UK Waste Plan and EU legislation on the Transfrontier Shipment of Waste also prevents contaminated material being transferred to landfill in Northern Ireland, Great Britain or elsewhere in Europe.

In view of this, the main available options are discussed in the following sections.

4.7.2 Bioremediation

This option has been used in the U.S.A. on gaswork type-sites, although timescales for bio-treatment are quoted generally in terms of 9 months to several years. The anticipated concentrations of organic contaminants denote that traditional in-situ or landfarming techniques would probably take in excess of a year for the anticipated volumes. Some of the soil at the Limerick site may not be suitable due to the presence of 'heavy' fraction PAH's which are unlikely to be broken down by the process. A number of proprietary methods employing "aggressive" blending techniques with the addition of water, materials and organisms such as fungi and bacteria may be viable. This process is generally more cost effective than thermal processes, although it is unlikely that the viability of such a process could be determined without trials. It could be considered in conjunction with another treatment as part of a waste minimisation strategy. The anticipated timescales would be a major factor in deciding whether or not this approach should be pursued.

4.7.3 *Soil Washing*

This process involves the segregation of the soil into predominantly granular materials, based upon grain size and density properties, resulting in "clean" coarse materials and a clay fraction ("filter cake") into which most of the contamination is generally concentrated. There are a number of optimisation techniques that can be used as a part of the soil washing process including solvent washing where organic contaminants are removed to liquid phase for disposal or treatment. The "filter cake" residue would require further treatment or disposal. It is anticipated that this would comprise approximately 15-20% of the initial volume if the treatment of the predominantly granular proportion of the Made Ground was undertaken. However, due to the likely high concentrations of contaminants including cyanide, sulphur etc, it may prove difficult to find a secondary treatment for this material which can reduce contamination levels to acceptable limits.

Low temperature thermal desorption plants are available as both mobile and fixed in the U.K, Holland and Germany and may represent one secondary treatment option. However this process may struggle to process fine-grained materials with a high moisture content and high 'heavy fraction' organics. Both the Department of the Environment, Transport and the Regions and the Environment Agency's Transfrontier Shipment Division in the U.K. confirm that contaminated material would only be allowed to enter the country if it was to be incinerated. This presently occurs when clinical waste from hospitals in Ireland enters the U.K. Contaminated material would be only allowed into Holland if the contamination levels of treated materials fall below "Category 2 Building Material" levels (defined as material that is considered to be suitable for use as a sub-base in road construction in Holland). It is possible that the "filter cake" may contain high concentrations of heavy metals, treatment of which is unlikely to reduce contamination to acceptable levels.

It is known that some fixed soil washing plants in Europe have licences to dispose of limited volumes of the 'filter cake' into lined lagoons. Leachate is collected from the lagoons over long periods and treated prior to discharge into foul sewer systems.

4.7.4 *Thermal Treatment*

Low temperature desorption or incineration can treat a wide variety of contaminants, although sulphur and heavy metals are not treated.

Treatment on-site would be more cost effective than shipping the waste overseas.

Dutch-based mobile plants will operate to emission standards approximately 1/10th of those common to the EU. Planning permission and Waste Management Licence are likely to be required by the Regulatory Authority, and it is possible that on-site treatment could be rejected if there was sufficient local opposition to such proposals. It is possible that the resulting residues could be used on site. Discussions with specialist contractors and trials would be required to ascertain whether or not this option was viable.

Incineration cannot be considered on cost grounds for the large-scale treatment of soils, although some of the liquid/semi-liquid tars and free product could be considered for this process if a recycling facility was not identified for treating these materials.

4.7.5 *Solidification, Stabilisation and Encapsulation*

Cement, lime and other similar treatments are not considered suitable due to the contaminants present, difficulty with obtaining warranties, and political implications. It is anticipated that there would be problems with long term liabilities, planning, suitability to any proposed development, and EPA waste licence requirements if material was encapsulated in-site.

4.7.6 *Chemical Treatments*

All such methods need to be considered and controlled carefully due to the sensitivity of the river to chemically enhanced groundwater. Chemical compounds containing powerful oxidising agents are commercially available which can rapidly degrade hydrocarbon contaminated soils and may be worth further consideration. Soil vapour extraction techniques would not be suitable for the range of contaminants identified on site.

A simple summary of remedial options is given in the table overleaf: -

Table 4.7.5 Remedial Options Available

Technique	Comments	Decision
Bioremediation	**Against:** May not be suitable due to spectrum of contaminants present (including heavy fraction organic), timescales **For:** Possible treatment of lighter fraction hydrocarbons	Trial required
Soil Washing	**Against:** Problem with disposal of contaminated fine residue, not suitable for high organic concentrations **For:** Versatile, wide range of contaminants, cost	Possible option Trial required
Low Temperature Desorption	**Against:** Cost, possible rejection of residues for landfill abroad, shipping, licence of mobile plant **For:** Wide range of contaminants treatable, mobile plant on site	Possible option Trial required
Incineration	**Against:** Cost, shipping **For:** Wide range of contaminants treatable	Possible option for treatment of contaminated residues, liquid, semi-liquid and viscous tars
Cement and Lime Stabilisation	**Against:** Not suitable for range of contaminants, long term durability and warranty, EPA licence requirements **For:** Cost	Rejected
Repository/Encapsulation	**Against:** Planning, long term liability, space, EPA licence requirements **For:** Cost	Only considered on cost basis as an option Not recommended
Chemical Treatment	**Against:** Cost, political aspects, groundwater **For:** Possible treatment on site	May be suitable for selected materials Trial required
Soil Vapour Extraction	**Against:** Not suitable for range of contaminants **For:** Cost	Rejected

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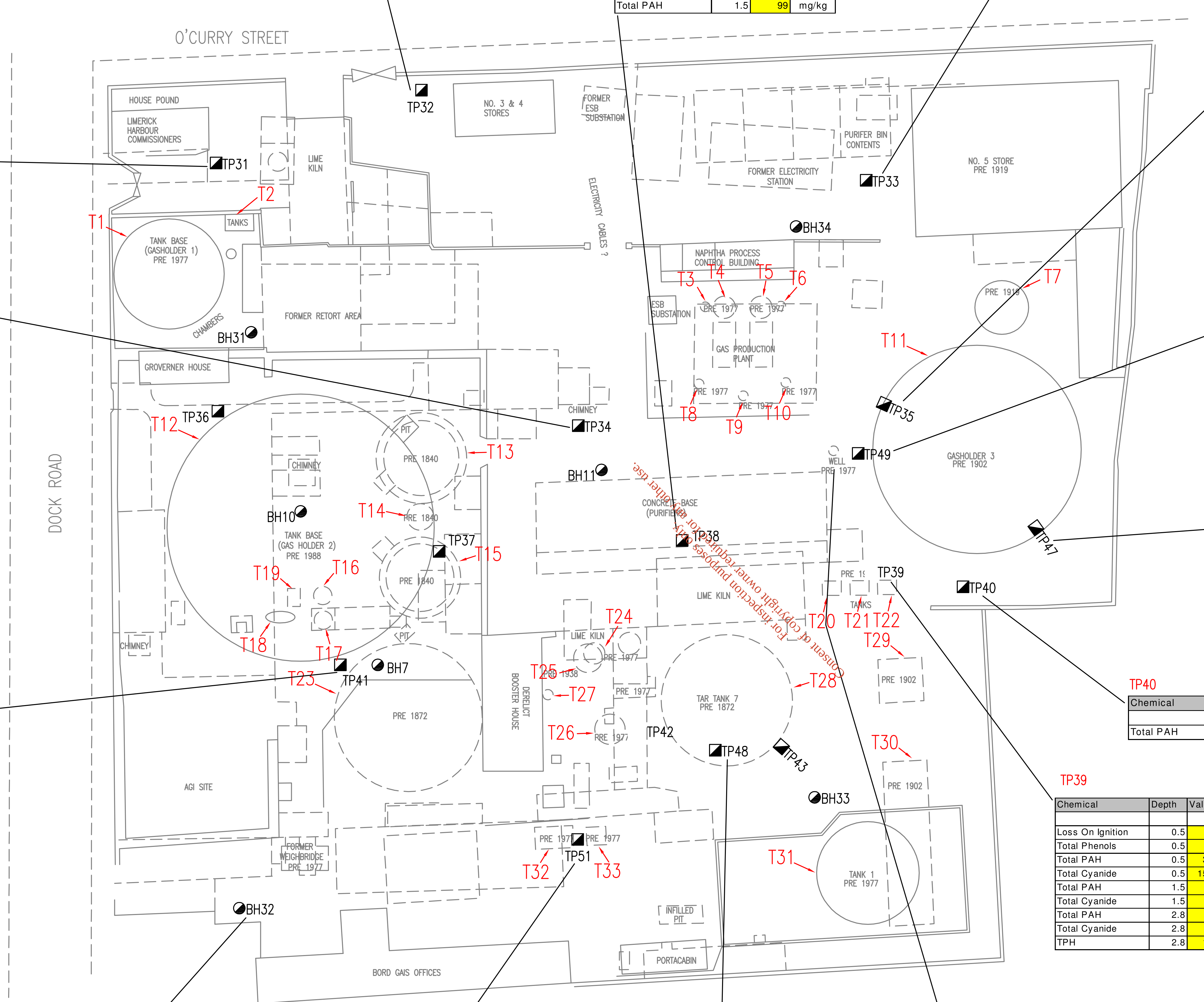
DRAWINGS



TP31

Chemical	Depth	Value	Units
Total PAH	0.6	66	mg/kg
Total PAH	1.1	42	mg/kg
Total PAH	2.2	65	mg/kg

TP34

Chemical	Depth	Value	Units
Total PAH	0.3	65	mg/kg
Total PAH	1.2	620	mg/kg
Total Cyanide	1.2	120	mg/kg
Pb	1.2	1100	mg/kg
Total PAH	2.0	140	mg/kg
TPH	2.0	1200	mg/kg

TP41

Chemical	Depth	Value	Units
Total PAH	0.8	51	mg/kg

TP32

Chemical	Depth	Value	Units
Total PAH	0.2	3800	mg/kg

TP38

Chemical	Depth	Value	Units
Total PAH	0.5	500	mg/kg
Total PAH	1.5	99	mg/kg

TP33

Chemical	Depth	Value	Units
Total PAH	0.6	180	mg/kg
Total Cyanide	0.6	120	mg/kg
SO_4	0.6	3100	mg/kg
Total Cyanide	1.5	410	mg/kg

TP35

Chemical	Depth	Value	Units
Total Phenols	1.0	620	mg/kg
Total PAH	1.0	6900	mg/kg
Benzene	1.0	62	mg/kg
Xylenes	1.0	260	mg/kg
TPH	1.0	16000	mg/kg
Total PAH	2.0	200	mg/kg
Total Cyanide	2.0	180	mg/kg
SO_4	2.0	4100	mg/kg
Total PAH	3.0	52	mg/kg

TP49

Chemical	Depth	Value	Units
Total PAH	0.3	92	mg/kg
Total Cyanide	0.3	150	mg/kg
Total PAH	1.5	190	mg/kg
Total Cyanide	1.5	400	mg/kg
Total PAH	2.6	180	mg/kg
Total Cyanide	2.6	640	mg/kg

TP47

Chemical	Depth	Value	Units
Total Phenols	1.0	400	mg/kg
Total PAH	1.0	2700	mg/kg
Benzene	1.0	23	mg/kg
Xylenes	1.0	130	mg/kg
TPH	1.0	16000	mg/kg
Total PAH	2.0	130	mg/kg

TP40

Chemical	Depth	Value	Units
Total PAH	2.2	56	mg/kg

TP39

Chemical	Depth	Value	Units
Loss On Ignition	0.5	28	%
Total Phenols	0.5	90	mg/kg
Total PAH	0.5	3100	mg/kg
Total Cyanide	0.5	15000	mg/kg
Total PAH	1.5	68	mg/kg
Total Cyanide	1.5	200	mg/kg
Total PAH	2.8	910	mg/kg
Total Cyanide	2.8	120	mg/kg
TPH	2.8	1700	mg/kg

BH32

Chemical	Depth	Value	Units
Total PAH	0.5	330	mg/kg

TP51

Chemical	Depth	Value	Units
Loss On Ignition	0.3	45	%
Total Phenols	0.3	3700	mg/kg
Total PAH	0.3	1500	mg/kg
Benzene	0.3	150	mg/kg
Toluene	0.3	200	mg/kg
Xylenes	0.3	410	mg/kg
TPH	0.3	140000	mg/kg
Total PAH	1.0	430	mg/kg
Benzene	1.0	1.9	mg/kg
TPH	1.0	1500	mg/kg

TP48

Chemical	Depth	Value	Units
Total Phenols	1.5	370	mg/kg
Total PAH	1.5	1200	mg/kg
Benzene	1.5	11	mg/kg
Xylenes	1.5	50	mg/kg
Loss On Ignition	2.5	37	%
Total Phenols	2.5	1800	mg/kg
Total PAH	2.5	27000	mg/kg
Pb	2.5	1100	mg/kg
Benzene	2.5	200	mg/kg
Toluene	2.5	240	mg/kg
Xylenes	2.5	450	mg/kg
TPH	2.5	120000	mg/kg

TP49 Well

Chemical	Depth	Value	Units
Total Phenols	0.5	180	mg/kg
Total PAH	0.5	1000	mg/kg
Sulphur	0.5	20000	mg/kg
Benzene	0.5	15	mg/kg
xylenes	0.5	37	mg/kg
TPH	0.5	26000	mg/kg

Key

[ ] Approximate Location of Former Structure

Trial Pit

Borehole

Total PAH – Total Polyaromatic Hydrocarbons
Pb – Lead
TPH – Total Petroleum Hydrocarbons
SO_4 – Sulphate

Notes

Soil results are compared against Dutch Guidelines, Intervention Valves (1994) where available on Threshold or Action Trigger levels in ICRCL 59/83 2nd Edition 1987 (UK Guidlines).

Version	Amendment	Originated by and date	Checked by and date	Approved by and date
A	First Issue	15.10.01	D.H. 15.10.01	T.B. 15.10.01

PARKMAN

Certificate no. FS 15024

Client: Bord Gais Eireann

Project: Limerick Gasworks

Drawing Title: Elevated Contamination Levels – Soils

Purpose: Information

Draft / Issue ●

Scale: 1:500 (A2)

Issuing Office: Cheshire

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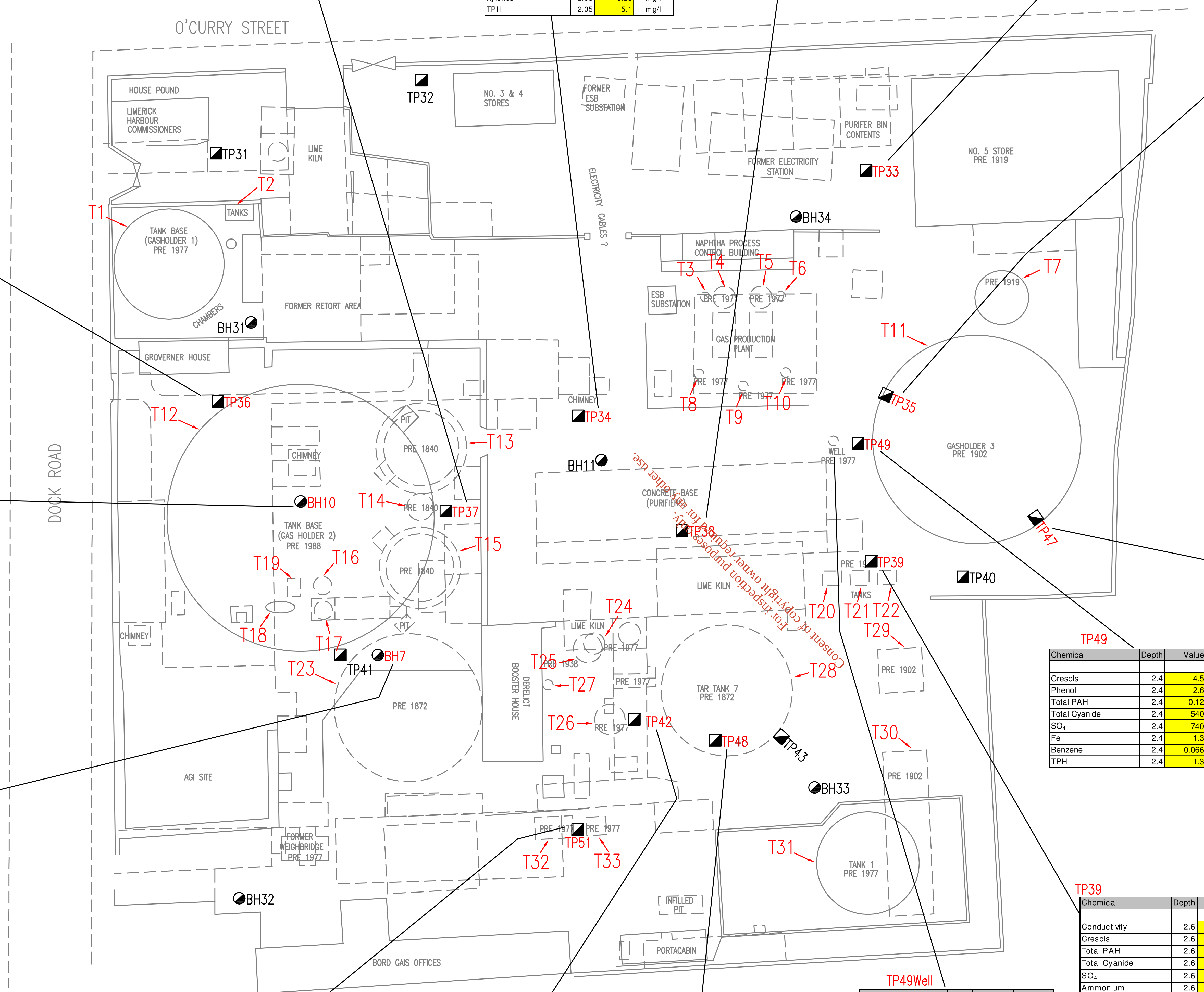


TP33

Chemical	Depth	Value	Units
SO_4	2.5	480	mg/l
Ammonium	2.5	9.6	mg/l
Fe	2.5	21	mg/l

TP37

Chemical	Depth	Value	Units
Total PAH	1.0	0.12	mg/l
Benzene	1.0	0.31	mg/l
Xylenes	1.0	0.22	mg/l
TPH	1.0	1.8	mg/l

TP34

Chemical	Depth	Value	Units
Conductivity	2.05	1700	µS/cm
Total PAH	2.05	0.09	mg/l
SO_4	2.05	400	mg/l
Ammonium	2.05	23	mg/l
Pb	2.05	0.19	mg/l
Fe	2.05	16	mg/l
Benzene	2.05	1.6	mg/l
Xylenes	2.05	0.23	mg/l
TPH	2.05	5.1	mg/l

TP38

Chemical	Depth	Value	Units
Total PAH	1.55	0.25	mg/l
SO_4	1.55	840	mg/l
Fe	1.55	2	mg/l

TP36

Chemical	Depth	Value	Units
Cresols	2.2	15000	mg/l
Total PAH	2.2	0.33	mg/l
Ammonium	2.2	7.5	mg/l
Ni	2.2	0.28	mg/l
Fe	2.2	0.29	mg/l
Benzene	2.2	0.49	mg/l
Xylenes	2.2	0.14	mg/l
TPH	2.2	77	mg/l

TP35

Chemical	Depth	Value	Units
pH	1.5	9.9	
Cresols	1.5	380	mg/l
Catechol	1.5	13	mg/l
Phenol	1.5	190	mg/l
Total PAH	1.5	0.38	mg/l
Total Cyanide	1.5	270	mg/l
SO_4	1.5	1100	mg/l
Ammonium	1.5	13	mg/l
Cr	1.5	0.06	mg/l
Pb	1.5	0.9	mg/l
Ni	1.5	0.13	mg/l
Fe	1.5	70	mg/l
Benzene	1.5	13	mg/l
Toluene	1.5	4.4	mg/l
Ethylbenzene	1.5	0.21	mg/l
Xylenes	1.5	2.1	mg/l
TPH	1.5	22	mg/l
Conductivity	3	2400	µS/cm
SO_4	3	1000	mg/l
Ammonium	3	9.6	mg/l
Pb	3	0.12	mg/l
Fe	3	64	mg/l
TPH	3	0.25	mg/l

BH10

Chemical	Depth	Value	Units
Conductivity	2.0	2300	µS/cm
Cresols	2.0	130	mg/l
Catechol	2.0	7.9	mg/l
Phenol	2.0	110	mg/l
Total PAH	2.0	0.37	mg/l
SO_4	2.0	280	mg/l
Ammonium	2.0	1500	mg/l
Cr	2.0	0.08	mg/l
Fe	2.0	40	mg/l
Benzene	2.0	17	mg/l
Toluene	2.0	7.5	mg/l
Ethylbenzene	2.0	0.32	mg/l
Xylenes	2.0	3.8	mg/l
TPH	2.0	14	mg/l

TP47

Chemical	Depth	Value	Units
Conductivity	2.75	5100	µS/cm
Cresols	2.75	550	mg/l
Catechol	2.75	27	mg/l
Phenol	2.75	360	mg/l
Total PAH	2.75	350000	mg/l
SO_4	2.75	1300	mg/l
Ammonium	2.75	490	mg/l
As	2.75	0.09	mg/l
Cr	2.75	0.05	mg/l
Selenium	2.75	0.027	mg/l
Ni	2.75	0.1	mg/l
Fe	2.75	68	mg/l
Benzene	2.75	18	mg/l
Toluene	2.75	5.2	mg/l
Ethylbenzene	2.75	0.21	mg/l
Xylenes	2.75	2.5	mg/l
TPH	2.75	27	mg/l

TP49

Chemical	Depth	Value	Units
Cresols	2.4	4.5	mg/l
Phenol	2.4	2.6	mg/l
Total PAH	2.4	0.12	mg/l
Total Cyanide	2.4	540	mg/l
SO_4	2.4	740	mg/l
Fe	2.4	1.3	mg/l
Benzene	2.4	0.066	mg/l
TPH	2.4	1.3	mg/l

BH7

Chemical	Depth	Value	Units
pH	1.0	11	
Cresols	1.0	1.1	mg/l
Phenol	1.0	3.3	mg/l
Total PAH	1.0	0.37	mg/l
SO_4	1.0	1000	mg/l
Ammonium	1.0	32	mg/l
Fe	1.0	5.7	mg/l
Benzene	1.0	1.6	mg/l
Xylenes	1.0	0.3	mg/l
TPH	1.0	7.2	mg/l

TP39

Chemical	Depth	Value	Units
Conductivity	2.6	1600	µS/cm
Cresols	2.6	3.6	mg/l
Total PAH	2.6	0.87	mg/l
Total Cyanide	2.6	4.7	mg/l
SO_4	2.6	390	mg/l
Ammonium	2.6	3.9	mg/l
Fe	2.6	21	mg/l
Benzene	2.6	1.1	mg/l
Xylenes	2.6	0.42	mg/l
TPH	2.6	7.2	mg/l

TP49Well

Chemical	Depth	Value	Units
pH		11	
Cresols		1200	mg/l
Catechol		33	mg/l
Phenol		440	mg/l
Total PAH		1.7	mg/l
Total Cyanide		15	mg/l
SO_4		690	mg/l
Ammonium		220	mg/l
As		0.42	mg/l
Hg		0.002	mg/l
Fe		29	mg/l
Benzene		30	mg/l
Toluene		7.8	mg/l
Ethylbenzene		0.3	mg/l
Xylenes		3	mg/l
TPH		440	mg/l

TP48

Chemical	Depth	Value	Units
pH	3.5	9.8	
Conductivity	3.5	4200	µS/cm
Cresols	3.5	170	mg/l
Catechol	3.5	31	mg/l
Phenol	3.5	87	mg/l
Total PAH	3.5	0.35	mg/l
SO_4	3.5	340	mg/l
Ammonium	3.5	140	mg/l
Fe	3.5	12	mg/l
Benzene	3.5	7.3	mg/l
Toluene	3.5	3.1	mg/l
Ethylbenzene	3.5	0.19	mg/l
Xylenes	3.5	2.1	mg/l
TPH	3.5	16	mg/l

TP42

Chemical	Depth	Value	Units
Total PAH	0.4	0.12	mg/l
Benzene	0.4	0.33	mg/l
Xylenes	0.4	0.41	mg/l
TPH	0.4	4.7	mg/l

TP51

Chemical	Depth	Value	Units
pH	1.25	12	
Conductivity	1.25	1800	µS/cm
Cresols	1.25	18	mg/l
Catechol	1.25	3.5	mg/l
Phenol	1.25	9.8	mg/l
Total PAH	1.25	0.71	mg/l
Ammonium	1.25	15	mg/l
Fe	1.25	0.45	mg/l
Benzene	1.25	1.6	mg/l
Toluene	1.25	1.8	mg/l
Ethylbenzene	1.25	0.24	mg/l
Xylenes	1.25	2.2	mg/l
TPH	1.25	86	mg/l

Key

- Approximate Location of Former Structure
- TP33 Trial Pit
- BH11 Borehole
- TP37 / BH10 Exploratory hole locations indicating postion where water samples were taken during the site investigation

Total PAH – Total Polyaromatic Hydrocarbons
As – Arsenic
Cr – Chromium
Pb – Lead
Hg – Mercury
Ni – Nickel
Zn – Zinc
Fe – Iron
TPH – Total Petroleum Hydrocarbons
SO_4 – Sulphate
mg/l – Milligrams per litre

Notes

Water results are compared against Dutch Guidelines, Intervention Valves (1994) where possible or maximum allowable concentrations given in the Water Supply (Water Quality) Regulations 1989 (UK Legislation).

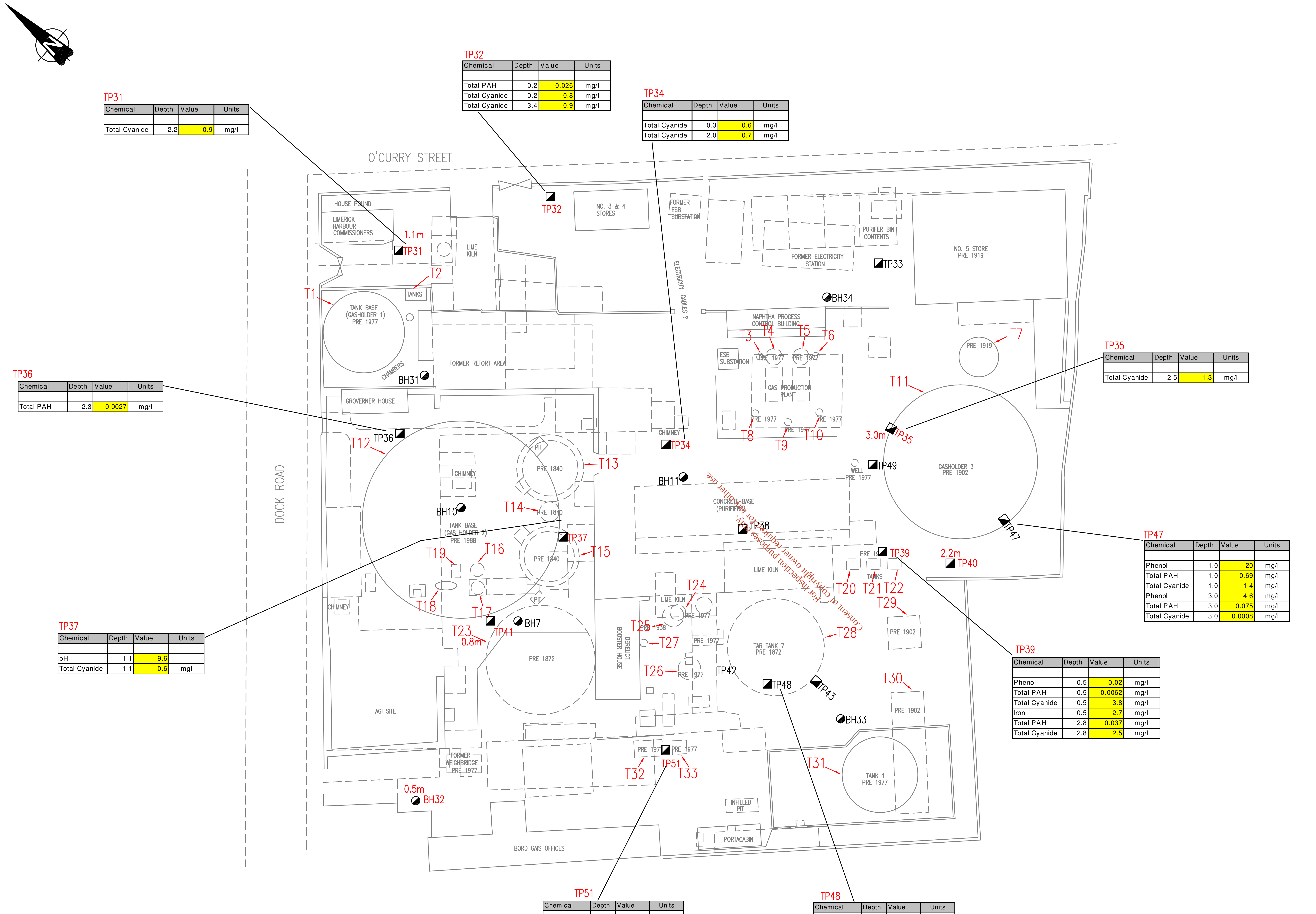
Version	Amendment	Originated by and date	Checked by and date	Approved by and date
A	First Issue	15.10.01	D.H. 15.10.01	T.B. 15.10.01

PARKMAN

BSI Registered Firm

Certificate no. FS 15024

Client: Bord Gais Eireann
Project: Limerick Gasworks
Drawing Title: Elevated Contamination Levels – Water
Purpose: Information
Draft
Issue ●
Scale: 1:500 (A2)
Issuing Office: Cheshire
Telephone: 0151 356 1666
Drawing Number: 25837/0B/03
Version: A



TP31			
Chemical	Depth	Value	Units
Total Cyanide	2.2	0.9	mg/l

TP32			
Chemical	Depth	Value	Units
Total PAH	0.2	0.026	mg/l
Total Cyanide	0.2	0.8	mg/l
Total Cyanide	3.4	0.9	mg/l

TP34			
Chemical	Depth	Value	Units
Total Cyanide	0.3	0.6	mg/l
Total Cyanide	2.0	0.7	mg/l

TP36			
Chemical	Depth	Value	Units
Total PAH	2.3	0.0027	mg/l

TP35			
Chemical	Depth	Value	Units
Total Cyanide	2.5	1.3	mg/l

TP47			
Chemical	Depth	Value	Units
Phenol	1.0	20	mg/l
Total PAH	1.0	0.69	mg/l
Total Cyanide	1.0	1.4	mg/l
Phenol	3.0	4.6	mg/l
Total PAH	3.0	0.075	mg/l
Total Cyanide	3.0	0.0008	mg/l

TP37			
Chemical	Depth	Value	Units
pH	1.1	9.6	
Total Cyanide	1.1	0.6	mgl

TP39			
Chemical	Depth	Value	Units
Phenol	0.5	0.02	mg/l
Total PAH	0.5	0.0062	mg/l
Total Cyanide	0.5	3.8	mg/l
Iron	0.5	2.7	mg/l
Total PAH	2.8	0.037	mg/l
Total Cyanide	2.8	2.5	mg/l

TP51			
Chemical	Depth	Value	Units
pH	0.3	9.6	
Phenol	0.3	20	mg/l
Total PAH	0.3	0.27	mg/l
Total Cyanide	0.3	0.6	mg/l
pH	1.0	11	
Phenol	1.0	1.2	mg/l
Total PAH	1.0	0.034	mg/l
Total Cyanide	1.0	1	mg/l

TP48			
Chemical	Depth	Value	Units
Phenol	2.5	4.6	mg/l
Total PAH	2.5	0.6	mg/l
Total Cyanide	2.5	0.6	mg/l
Ammonium	2.5	14	mg/l

Key

Approximate Location of Former Structure

TP33 Trial Pit

BH11 Borehole

TP37 / BH18 Exploratory hole locations indicating position where leachate samples were taken during the site investigation

0.7m, 2.2m Depths from which leachate samples were taken.

Total PAH – Total Polyaromatic Hydrocarbons

mg/l – Milligrams per litre

Notes

Leachate results were compared against 10 x Maximum Allowable Concentrations given in the water supply (Water Quality) Regulations 1989 (UK Legislation).

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Purpose: Information

Draft / Issue ●

Scale: 1:500 (A2)

Issuing Office: Cheshire

Telephone: 0151 356 1666

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