Dublin City Council

Grand Canal Dock Stormwater Outfall

Geotechnical Report

July 2002

Halcrow Group Limited

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Contents Amendment Record

This report has been issued and amended as follows:

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		Draft for comment	12/7/02	

Contents

1 Introduction

1.1 *General*

In December 2001 the Dublin City Council appointed JB Barry & Partners, assisted by the Halcrow Group, to complete the detailed design of the Grand Canal Dock Stormwater Culvert..

This report is prepared by Halcrow Group Ltd and presents the results of a Geotechnical Study of the subject site, performed for Dublin City Council during the period January to June 2002. This report was written in June 2002 and should be read in the light of any subsequent changes in legislation, statutory requirement or industry practices.

The services provided are outlined below:

- Review of existing material supplied by J B Barry

- Site Inspection and walk-over survey

- Ground investigation together with sampling, monitoring and a programme of laboratory testing.

This report presents the findings of the above investigations to the proposed end use as detailed and described within this document. The various investigations were carried out to allow an interpretation to be formulated as to the geotechnical conditions on the site.

2 Project and Site Description

2.1 *General Project Description*

Dublin City Council propose to remove the stormwater discharge into the Grand Canal Dock by extending the existing stormwater outfall from its present location in the Upper Basin of the Grand Canal Dock to discharge directly into the River Liffey at Sir John Rogerson's Quay.

The route that the new outfall will take runs parallel with the western quay wall from the existing outfall to the north west corner of the lower basin where it swings east along the north quay wall for approximately 70m and then cuts through Hanover Quay, the DDDA site, and Sir John Rogerson's Quay to the River Liffey. The proposed route of the culvert is shown on Drawing No TQ/GCSC/GEO/01.

Further to recent discussions with Irish Waterways, a slight deviation from the above route will also be considered ie. From the Ringsend Road crossing the culvert may be taken into the campshire of Grand Canal Quay and onto the Hanover Quay campshire, thus avoiding construction within the Lower Basin.

2.2 *Site Description*

The Grand Canal Dock, which was constructed in the late 18th century is L-shaped and is divided by a lifting bridge into two water bodies. These water bodies encompass an overall area of 8.7ha comprising;

- Upper Basin above McMahon Bridge – Area 2.4ha

- Lower Basin below McMahon Bridge – Area 6.3ha

There is an average water depth in both basins of approximately 4.9m. The water level within the basin is at +3.4m above ordnance datum. The ground level on the campshire/carriageway surrounding the dock on Grand Canal Quay and Hanover Quay is at a level of between + 4.2 to 4.5m above ordnance datum. The level of the campshire/carriageway at Sir John Rogerson's Quay at the River Liffey is +3.0m above ordnance datum.

The existing land in and around the Grand Canal Dock was originally reclaimed following the construction of a quay wall to the River Liffey. For many years the dominant land use around the dock has been industrial with a number of warehouses, grain silos and stores located at the dockside. As part of a major renovation initiative the Dublin Dockland Developmetn Authority is redeveloping the area. . As part of the DDDA programme the redundant gas production site to the north west of the dock basin,is currently being remediated.

3 Desk Study

3.1 *Information Gathering*

J B Barry and Partners had previously undertaken a feasibility study and preliminary design for the project. In addition JB Barry examined a proposed modification to the outfall route through the DDDA lands between Hanover Quay and Sir John Rogersons Quay. Halcrow's review has therefore been based on the information gathered during these studies and conceptual designs.

The following ground investigation reports or extracts of reports were reviewed:

- Geotechnical Services Ltd (1989) – Dublin Gas Site [ref 1]
- Site Investigations Ltd (1991) – Thomas Garland and Partners (Ringsend Information Centre) [ref 2]
- Irish Geotechnical Services Ltd (1996) – J B Barry (Original route) [ref 3]
- Irish Geotechnical Services Ltd (1999) – Parkman (DDDA Site) [ref 4]
- Irish Geotechnical Services Ltd (2001) – Ellier Developments Ltd (Hanover Quay). [ref 5]

A series of Plans and Geological Profiles have been prepared showing the borehole information obtained during the above investigations along the route of the proposed culvert. These drawings (TQ/GCSC/GEO/02 to 05) are contained within the appendices.

J B Barry and Partners also prepared an Environmental Impact Statement [ref 6] for the routes under consideration. This EIS report and the information gathered in its preparation were also reviewed.

The locations of the known underground services affected by the proposed works have been obtained from the individual public utilities and will be shown on the detailed design drawings being prepared byJ B Barry and Partners.

A bathymetric survey for both the Upper and Lower Basins was undertaken during April 2002. This information has been submitted to the Dublin City Council seperately from this report.

3.2 Site Inspection and Walkover Survey

A site walkover was undertaken on 13 February 2002. The main aim of this was to determine suitable locations for the additional boreholes required to identify further geotechnical details and clarify apparent anomalies of previous investigations with respect to the re-routeing of the culvert through the DDDA site. Copies of plans received from the public utilities were viewed to enable the proposed boreholes to be located sufficiently far enough away from the services as to avoid disruption or damage. Suitable access routes and other obstructions to the ground investigation works and the final works were considered during the survey.

3.3 Geotechnical Hazards

An examination of the information obtained at the end of this phase of the investigation suggests the following list of geotechnical hazards will need to be accommodated by the proposed scheme:

GEOTECHNICAL HAZARD	**PROBABILITY OF OCCURRENCE**	**AFFECTED STRUCTURE**	**CONSEQUENCE OF OCCURRENCE**	**MITIGATION**
GROUND CONDITIONS – Made Ground				
Obstructions	High	Open Excavations	Delays and costs	Alert Contractor
Chemical/Biological composition	High	Dredging, tunnel and land based cofferdams.	Delays and consequential cost	Alert Contractor

GEOTECHNICAL HAZARD	**PROBABILITY OF OCCURRENCE**	**AFFECTED STRUCTURE**	**CONSEQUENCE OF OCCURRENCE**	**MITIGATION**
Restrictions on off-site disposal	High	All excavated material	Delays and costs	Minimise excavation. Treat material.
GROUND CONDITIONS – Soft Ground				
Unstable cut slopes	High	Open excavations	Staff safety and delays and cost implications	Adopt safe slopes or cofferdams
GROUND CONDITIONS – Stiff Ground.				
Boulders	High	Piling activities	Unable to reach required depth	Avoid piling. Replacement piles instead of displacement piles.
Hard layers	High	Piling activities	Unable to reach required depth	Avoid piling. Replacement piles instead of displacement piles.
BURIED OBSTRUCTIONS				

GEOTECHNICAL HAZARD	**PROBABILITY OF OCCURRENCE**	**AFFECTED STRUCTURE**	**CONSEQUENCE OF OCCURRENCE**	**MITIGATION**
Old foundations	High	Dredging, tunnelling and canal quay wall cofferdams.	Delays and consequential costs	Alert Contractor
Industrial and Domestic waste	High	Dredging, tunnelling and canal quay wall cofferdams.	Delays and consequential costs	Alert Contractor
Sewers	High	Tunnelling	Delays and consequential costs	Alert Contractor
ADJACENT STRUCTURES	1. Railway bridge embankment and outfall. 2. Canal quay wall and offices. 3. Waterways Ireland Visitors Centre. 3.Ringsend Road crossing. 4.Hanover Quay. 5.Sir John Rogerson's Quay.			
Settlement	Low	1, 2, 3, 4, 5		

GEOTECHNICAL HAZARD	**PROBABILITY OF OCCURRENCE**	**AFFECTED STRUCTURE**	**CONSEQUENCE OF OCCURRENCE**	**MITIGATION**
Rotation	Low High	1, 3, 4, 5 2	Structural distress	Establish trigger levels for movement and undertake monitoring during construction.
Horizontal movement	Low High	1, 3, 4, 5 2	Structural distress	Establish trigger levels for movement and undertake monitoring during construction.
SURFACE WATER AND GROUNDWATER				
Flooding from Dock or River Liffey	High	All water based cofferdams	Flooding, Health and Safety issues, cost implications and delays.	Alert contractor
Flooding from groundwater	High	All land based cofferdams	Flooding, Health and Safety issues, cost implications and delays.	Alert contractor
Piping failure	High	Land and water based cofferdams	Flooding, Health and Safety issues, cost implications and delays.	Alert Contractor
SERVICES				

GEOTECHNICAL HAZARD	**PROBABILITY OF OCCURRENCE**	**AFFECTED STRUCTURE**	**CONSEQUENCE OF OCCURRENCE**	**MITIGATION**
Gas	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Electricity	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Telephone	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Foul and surface water sewers	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Water	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Fibre Optic Cables	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
Street Lighting	High	Tunnelling and cofferdam	Delays and consequences	Alert Contractor
LEGAL HAZARDS				
Acceptable noise and vibration levels.	High	General works area	Complaints from public	Council to set noise and vibration levels.
Siltation and pollution of surface water.	High	Dredging	Increased siltation of river	Keep lock gates closed during works

<u>**GEOTECHNICAL HAZARD**</u>	<u>**PROBABILITY OF OCCURRENCE**</u>	<u>**AFFECTED STRUCTURE**</u>	<u>**CONSEQUENCE OF OCCURRENCE**</u>	<u>**MITIGATION**</u>
Maintenance of groundwater elevations	High	Cofferdam at Sir John Rogerson's Quay and Hanover Quay.	Monitoring of water during construction	Alert contractor
Protection of sensitive archaeological artefacts.	High	Quay walls	Instability	Establish trigger levels for movement and undertake monitoring during construction.

4 Ground Investigation

4.1 Ground Investigation

It was noted from the review of the available previous ground investigation information that further boreholes would be required to identify the following:

- Ground conditions at Sir John Rogerson's Quay and Hanover Quay on new route of culvert (outside of the DDDA site)
- Soil parameters behind quay walls and within basin to assist stability modelling
- Degree of contamination within basin's silt deposits
- Confirmation of rockhead level.

A further nine boreholes were scheduled, the positions of which are shown on drawing TQ/GCSC/GEO/01.

4.2 Fieldwork

Geotech Specialists Limited were appointed to carry out the investigation which they undertook between 20 March and 30 April 2002. Boreholes BH1, 2, 3, 5 and 8 were located on land while BH4, 6, 7 and 9 were taken from a barge over water. Each borehole was advanced by cable percussion to the depths noted in Table 1. Boreholes 1, 3 and 8 were continued by rotary open holing and coring.

During the cable percussion drilling, representative bulk samples were obtained from each strata encountered. In fine grained material, undisturbed samples were also obtained.

Borehole logs and full test results are included in the Geotech Final Report (No.172045).

BOREHOLE	C/P (m)	ROTARY Open Hole (m)	ROTARY Cored (m)
BH1	15.0	-	-
BH R1	-	0 – 20.6	20.6 – 23.6
BH2	11.0	-	-
BH3	9.6	-	-
BH R3	-	0 – 19.24	19.24 – 22.24
BH4	4.7	-	-
BH5	8.5	-	-
BH6	5.2	-	-
BH7	5.4	-	-
BH8	7.5	0 – 14.4	-
BH R8	-	16.1 – 17.0	14.4 – 16.1
BH9	4.3	-	-

Table 1: Borehole Depths

Standpipe piezometers were installed in BH1, 2, 3, 5 and 8 to allow long term monitoring of the ground water levels. The depth of the response zone for each piezometer is given in Table 2 along with readings taken shortly after installation during the sitework period. Water samples were also retrieved during drilling to allow testing.

BOREHOLE	RESPONSE ZONE Depth (m bgl)	WATER LEVEL Depth (m bgl)
BH R1	2.0 – 6.0m	2.04m
BH 2	3.0 – 7.3m	2.52m
BH R3	2.0 – 6.0m	2.63m
BH 5	3.0 – 6.0m	2.00m
BH R8	2.0 – 6.0m	4.60m

Table 2: Standpipe Piezometer Response Zones

Standard penetration tests were also carried out in each borehole at regular intervals using either a split barrel sampler (S) or a solid cone (C).

4.3 Laboratory Testing

Halcrow scheduled a suite of laboratory tests for the soils, soil contamination, leachability tests and groundwater samples. The classification tests were undertaken by Geotech at their laboratory in Cork. The shear strength and consolidation testing was undertaken by Exploration Associates in England The contamination tests were undertaken by T S Bretby, again in England.

(NOTE: The above paragraph is only relevant if there are still significant data gaps that are directly related to the Geotech errors, in which case we should instruct them to repeat the investigations to rectify their error.

5 Engineering Discussion

5.1 *Desk Study*

A large quantity of background information had been obtained by J B Barry during the preparation of their feasibility study, preliminary design and Environmental Impact Statement. This information provided the basis for the desk study.

From the review of the previous ground investigations carried out along or adjacent to the route of the proposed culvert, it was considered that further investigation was required.

5.2 *Fieldwork and Laboratory Testing*

The additional boreholes were required to determine the ground conditions at Sir John Rogerson's and Hanover Quay, the soil parameters behind the Quay wall, the degree of contamination within the basin and to confirm the level of rockhead.

The ground conditions encountered are discussed separately for distinct sections of the culvert in the following pages, including Sir John Rogerson's and Hanover Quay. The geotechnical parameters obtained from the laboratory test results and derived from reference material, where required, have been included in appendix B.

Bedrock was encountered in BHs 1 and 3 at depths below ground level of 20.6 and 19.24m respectively. Borehole 8 was taken to a depth of 17m without encountering bedrock. At these depths, bedrock is unlikely to impact on the works.

The contamination encountered during the investigation is discussed later.

5.3 *Quay Wall (Upper Basin)*

The stability of the existing wall, before, during and after the construction of the culvert, has been modelled using FLAC, the results of which are included as Appendix B.

Three cases have been considered (Case A, B and C) for the construction of the culvert along the length of the quay wall. These are shown on drawings TQ/GCSC/GEO/07, 08 and 09 and are discussed on the following pages.

- *Case A*

In this case, the dock basin is dredged to the required level from a barge and precast culvert sections or twin pipelines are placed into position.. The modelling has indicated that the culvert must be placed 10m away from the existing quay wall in order that the dredging does not undermine the stability of the wall.

The main difficulty associated with this construction method is ensuring that a suitable level base has been created for the culvert sections to be placed onto. This is required to minimise any differential movement between the precast sections or pipe joints and prevent any leakage through the joints.

The 10m offset from the wall means that the culvert footprint will be between 10-15m offset from the wall. This coincides with the spacing between the foundation piles of the Visitor Centre entrance structure (7.8m offset) and the piles of the main structure (18.0m minimum offset).

This would be the most favourable solution if the above can be overcome.

- *Case B*

A sheet piled cofferdam wall is constructed parallel to the quay wall to allow the basin in-between to be drained. This will then allow the bed to be excavated to the required level and a precast or cast insitu culvert to be constructed.

There are numerous risks associated with this option. Upon draining the basin, the factor of safety for the stability of the quay wall is reduced. Again, the culvert requires to be located approximately 10m from the quay wall in order that the excavation does not undermine the stability of the wall. The sheet piled wall has to be able to support in excess of 4m of water and would therefore require to be braced against the quay wall. The sheet piles must also be sufficiently embedded into a low permeability material to prevent piping failure within the base of the excavation. There is also a risk that the piling will not be able to be advance to the required depth due to the amount of cobbles and boulders within the glacial till. This is discussed in more detail later.

Due to the numerous associated risks, this method is considered the least favourable option.

- *Case C*

A twin walled sheet piled cofferdam is constructed parallel to the quay wall to allow the basin internally to be drained. This will then allow the bed to be excavated to the required level and a precast or cast insitu culvert to be constructed.

This method reduces the risks associated when the quay wall is exposed. However, the sheet piling will be installed closer to the wall and this increase the risk of destabilising the wall by vibration from the piling. Again, the sheet piles must achieve the required depth and be sufficiently embedded within a low permeability material to prevent piping failure.

This is likely to be the most expensive solution.

5.4 Ringsend Road Crossing

The Ringsend Road/MacMahon Bridge crossing separates the Upper and Lower basins. Therefore, the culvert will require to connect through the existing quay/road embankment. It is proposed to create chambers within each basin either side of the road/bridge to allow the connection to be made by a tunnelled piped culvert. These chambers would also act as a transition between the box culverts within the docks and the piped section under the road. A longitudinal section for the crossing is shown on drawing TQ/GCSC/GEO/06.

- Cofferdams

To create the transition chambers/working shafts, it is recommended that cofferdams are constructed to provide a suitable working area. The bathymetric survey indicates that silt has accumulated to a level of approximately between 0 and +1.5m where the cofferdams are to be constructed. Excavation will be required to a level of -2.4m. The material to be excavated will comprise approx 2m of soft silts and a further 1.5m of dense sandy gravel.

Fine grained glacial till (boulder clay) is noted underlying the gravels and should provide an adequate seal for the driven piles. Difficulties with regard to the piling operations are discussed separately within the report.

- Transition Chamber

The formation level for both chambers is provisionally taken as -2.4m which will be within medium dense to dense sandy gravel (coarse grained glacial till). This material will provide a suitable formation.

The levels of contamination recorded within the basin silts are discussed separately.

- Tunnel

It was originally considered that, to meet hydraulic requirements, the culvert at the crossing would be 3.2m diameter. However, this would require to be constructed with segmental units, which may be costly in comparison to precast pipes. By introducing two 2.4m m diameter pipes, which meets the hydraulic requirement, there will be more cover to ground level and services which will be advantageous with regard to minimising settlement., and there may also be a reduction in cost.

The connection between the shafts is over a distance of 25m and at either end requires cutting through the existing quay wall/bridge wing wall. Considering this and the likelihood that further structure/obstructions could be encountered on the tunnel drive, it is considered that the use of a TBM is not suitable. Therefore, the twin pipes can be installed by pipejacking with an open shield and excavated by hand mining., or as segmental lined tunnels hand driven within a shield. The pipejacked option is the recommended.

The ground investigation indicated that the material encountered on the drive will consist of made ground (sand/gravel/clay/ash) in the upper section of the pipe with dense gravels in the lower portion. Due to the variability of the material, the possibly water flows from the Docks, and in order to protect the services both above and beneath the level of the drive, it is recommended that ground treatment is carried out to strengthen the soils and support the excavated face. The most suitable method is considered to be grouting in advance of the drive. However, the precise method of ground treatment will be established following discussions with a specialist contractor.

Contact should be made with the affected service authorities with regard to these works to determine the level of protection required to cables/pipes during the construction activities.

5.5 *Quay Wall (Lower Basin)*

Refer to the previous notes for the Upper Basin with the added consideration that there are no super structures on the campshire and the excavation depth is less.

5.6 *Hanover Quay*

The proposed culvert from the lower basin will break through the quay wall and cut across Hanover Quay connecting through the DDDA remediation cut-off wall and into the culvert in the DDDA site. Between the quay wall and the cut-off wall, the culvert will be constructed within a cofferdam, which will cross Hanover Quay. The connection through the quay wall will again be constructed from a cofferdam constructed within the lower basin. A longitudinal section for the connection is shown on drawing TQ/GCSC/GEO/06.

- Land Based Cofferdam

Excavation is required to a level of approximately -2.5m. The material encountered at this level will be fine grained glacial till and will provide an adequate formation level for the culvert. The fine grained till extends to a depth of -4.77m at which level coarse grained material is encountered. During the drilling of the borehole, groundwater was encountered within this lower material. When encountered, the level of the groundwater was noted to rise to a level of +1.7m within a 20 minute period, indicating that there may be some flow out of the dock into the campshire Therefore, during the construction of the culvert, wells may require to be drilled to allow the water to be drained and provide pressure relief to the base of the excavation.

The excavated material comprises predominantly made ground and sand and gravels. Contaminated material was noted within this material and is discussed separately elsewhere.

At present, the culvert route passes beneath light industrial units/sheds which are being to be demolished. The nature of the foundations for these structures is not known at present, therefore allowance should be made for encountering and/or excavating artificial hard obstructions. During the works, it will also be necessary to close this section of Hanover Quay to vehicular access. There are limited undderground services within Hanover Quay.

- Cofferdam within Basin at breakout to Hanover Quay

The bathymetric survey indicates that silt levels within the basin are at an approximate level of between –0.4 to –1.9m. Excavation will be required to a level of –2.5m. The material encountered at this level will be fine grained glacial till which will provide a suitable founding material.

Historic records indicate that there may be a brick toe support to the base of the Hanover Quay Wall. This is to be investigated further by the contractor of the Phase 1 culvert constuction works.

5.7 Site John Rogerson's Quay

The culvert passes through the remediation cut-off wall at the DDDA site into the road and campshire at Sir John Rogerson's Quay where an outlet structure is constructed to allow discharge into the River Liffey. A cofferdam will be created between the cut-off wall and the Liffey wall to allow the culvert to be installed. The final outlet through the Liffey wall will be constructed from a further cofferdam installed within the River Liffey. A longitudinal section is shown on drawing TQ/GCSC/GEO/06.

- Land Based Cofferdam

The formation level for the culvert at the river outlet is at approximately –5.7m. At this level, soft organic silt deposits were encountered which will not provide a suitable founding medium. Excavation should therefore be extended into the coarse grained glacial till, which underlies the softer material, and backfilled with suitable granular material. These aspects will need to be incorporated into the tender documents.

Details of the excavation required during the DDDA contract, at the cut-off wall, should be incorporated into the design for these works.

Details of the construction of the existing and previous harbour walls are available and have been incorporated onto the drawings. However, text suggests that the two smaller walls, which were offset from the present wall, were dismantled and re-used during its construction.

During the works, vehicular access will not be available on this section of Sir John Rogerson's Quay.

There are many services within the campshire and carriageway, most noticeably a high pressure gas main. As they all run across the excavated line, these will need to be supported across the width of the excavation. However, the individual authorities must be contacted to agree suitable systems of support or diversions for the apparatus.

- River Liffey Cofferdam

The river bed levels assumed on the longitudinal section are taken from a previous investigation which was located at the end of ForbesStreet. Prior to works commencing on site, these levels should be confirmed by the appointed contractor. At present, the bed levels within the River Liffey have been assumed to be around –8.0 and –10.0m in the vicinity of the proposed cofferdam.

5.8 *Alternative Route*

To maximise development and future usage options and minimise permanent impact of the culvert workswithin the Lower Basin, an alternative route for the culvert would be to take it into the campshire along Grand Canal Quay directly behind the quay wall. The culvert would break through the wall after the Ringsend Road crossing and continue along the campshire to Hanover Quay. It would then turn east along the campshire or carriageway to the connection with the DDDA site.

The section along the campshire of Grand Canal Quay forms Site 4 of the remediation contract presently being undertaken on the DDDA site. This site was remediated to -1.0m OD with a few cyanide soil hotspots remediated down to -2.5m OD. Any further contamination will be identified by systematical sampling of material excavated during the culvert construction works.

There is approximately 12m between the quay wall and the carriageway of Grand Canal Quay and therefore there will be restricted space for plant during the construction of the culvert. It is likely that some disruption to traffic will result and partial road closures may be required. The location of the services within the carriageway would also have to be considered.

5.9 *Piling Activities*

Cofferdams will require to be constructed to provide suitable working areas within the Dock Basin and behind the quay walls. It is anticipated that these cofferdams, which form the contractor's temporary works, will be constructed by driving Larssen steel sheet piles.

There are likely to be a number of difficulties associated with the piling works. These difficulties are as follows:

- Ground conditions

Throughout the site, the underlying fine and coarse grained glacial tills are noted to contain a high percentage of cobbles and boulders. During the driving of the sheet piles, these cobbles and boulders may be sufficient enough to preventthe pile from reaching the required depth within the stiff/dense matrix of the till.

Due to the granular nature of much of the underlying coarse grained glacial till, this material may prove to be highly permeable and will not provide an adequate cut-off when creating a cofferdam. This could lead to piping failure in the base of the excavations when dewatered. Therefore, the piles are required to be taken into the fine grained glacial till which is less permeable to a sufficient depth as to provide an adequate cut-off. This may be difficult to achieve due to the cobbles and boulders mentioned above.

- Incorporating existing structures

The cofferdams within the Dock Basin and the River Liffey are required to create a dry working environment. However, wherethe piles will require to butt-up against existing quay walls to create an adequate seal against an often irregular shaped structure. The piles may also require to transfer loading to these walls whose condition at present is uncertain and will require detailed survey and monitoring

- Noise and Vibration

Driving piles will inevitably cause a certain degree of noise and vibration and consultation will be required with property owners and the local authority at an early stage.

The main concerns are the existing structures directly affected by the works, namely the quay wall, and the offices and residential house (No 40A) on Grand Canal Quay. The vibration generated during the piling may affect the stability of these structures and therefore their condition must be known prior to any works commencing. Discussions with all owners should take place at an early stage to accommodate any requirements which may be negotiated and agreed..

These properties will also provide a physical obstacle to the works and will necessitate much of the works being undertaken from a barge.

5.10 *Contamination*

(NOTE: Section should report samples versus Dutch Intervention and Target Levels, ie. start with the issue before discussing the action required. A secondary issue is the fact that the Dublin disposal option waste standards are onerous and therefore there will be a need for alternative disposal of non-inept surplus excavation or waste.

With regard to the land based boreholes, contamination was found in BHs 1 and 2 at Sir John Rogerson's Quay and BH 3 at Hanover Quay. At these locations, both the Total Petroleum Hydrocarbon (TPH) and the Polycyclic Aromatic Hydrocarbon (PAH) levels were exceeded. Additionally, a highly elevated value of lead was recorded in BH 2.

Similar results were obtained from the water based boreholes within the Dock. The TPH and PAH values were all exceeded in BHs 6, 7 and 9. Elevated lead was further noted in BHs 6 and 9 and mercury in BH 6. The limit values were not exceeded in the samples tested in BH 4. The contamination noted within the water based boreholes was all within the upper silt deposits, which are at a depth of approximately 1 to 2m below bed level, and is therefore likely to be excavated to achieve formation level for the culvert. Similarly the contamination from the land-based boreholes was noted at levels above formation within the cofferdams and again will require to be excavated. As the limit values for acceptance as inert waste have been exceeded then other sources for disposal will require to be considered.

The Environment Protection Agency (EPA) has set limit values for pollutant content for inert waste landfills in the Dublin area. A summary table containing only the determinands, which exceed these limit values from the samples tested, during the recent ground investigation, is included in Appendix B.

6 Conclusions

6.1 *Strata*

The strata likely to be encountered during land based excavations will generally comprise the following;

Made Ground

Soft clay/silt

Coarse grained glacial till

Fine grained glacial till

The strata likely to be encountered during excavations within the dock basin generally comprise the following;

Silt (basin deposits)

Coarse grained glacial till

Fine grained glacial till

The depth to bedrock has been confirmed across the site and is unlikely to be encountered during excavations or piling activities.

6.2 *Formation Level*

Both the fine grained and coarse grained glacial till will provide an adequate formation level for the proposed culvert. Soft clays and silts are likely to be encountered towards Sir John Rogerson's Quay and will not provide suitable founding material.

6.3 *Cofferdams*

It is likely that the contractor will adopt steel sheet piled cofferdams to create the required transition chambers and working areas. The driving of the piles is likely to be problematical as the underlying deposits contain a high percentage of cobbles and boulders. Sufficient depth into a low permeable material must be achieved by the piles in order to prevent piping failure within the base of the excavation. The noise and vibration generated during the piling works is also likely to cause a high degree of disturbance to local residents and existing properties/structures respectively.

6.4 *Excavated Material*

The material to be excavated within the land-based cofferdams and the basin of the Grand Canal has been contaminated through previous land-uses. Only a few hot spots are likely to exceed Dutch Intervention Standards and therefore requrie treatment and licensded disposal.

Based on Limit Values applied by Inert Waste Landfills in the Dublin area, it is likely that the material to be excavated will not be classified as "inert waste". Therefore where surplus excavation exceeds even the Austrian Limits disposal mayl need to be outside of the Dublin area.. This is due to elevated concentrations of Total Petroleum Hydrocarbons (TPHs), Polycyclic Aromatic Hydrocarbons (PAHs) and lead.

6.5 *Quay Wall*

Three methods of construction were considered for the culvert along the base of the quay wall within the upper and lower basins. Two options required the construction of a sheet piled wall or cofferdam with subsequent draining of the basin. Both these options presented numerous risks associated with the stability of the quay wall and the feasibility of constructing a safe working environment within the drained area. The least risk option was to dredge the basin along the route of the culvert and to place precast units or pipes from a barge.

6.6 *Ringsend Road Crossing*

The connection through the Ringsend Road Crossing has to avoid a number of services at carriageway level and also pass over an existing sewer. A twin 2.5m diameter pipe, installed by pipejacking methods and hand mined utilising an open shield, is considered the most appropriate solution. It is also likely that the ground to be tunnelled through will require to be grouted to stabilise the face and reduce water ingress.

6.7 *Groundwater*

The groundwater levels recorded during the ground investigation suggest that the groundwater level generally lies at between 2 and 2.5m below ground level. However, the groundwater level in BH 8 was recorded at 4.6m below ground level.

During the drilling operations, groundwater was encountered in the coarse grained glacial tills at a depth of 9.1m. During a twenty minute period, the water level was noted to rise to approximately 3m below ground level. Consideration should therefore be given to providing pressure relief to the base of the excavations during the works.

6.8 Services

The excavations for the cofferdams will affect a number of existing services within the carriageway/campshire at Ringsend Road, Sir John Rogerson's and Hanover Quay. It is likely that these services will be able to be diverted prior to the works commencing or suspended within the excavations during construction.

7 Recommendations

7.1 Strata

The soil parameters given in Appendix B should be adopted for the geotechnical design.

7.2 Formation Level

Where encountered at formation level, the soft clays and silts should be excavated and replaced with suitably compacted granular material.

7.3 Quay Wall

The favoured option , for the construction of the culvert along the base of the quay wall in both basins, would be to dredge the basin and place precast units on a suitably prepared formation.

7.4 Excavated Material

The contract documents will detail a sampling requirement to identify the degree of contamination of all excavated material. The level of contamination will determine the appropriate method of re-use, treatment or disposal. .

7.5 Existing Structures

As the driving of piles will generate vibration, the quay wall and any other structure directly affected by the works, should have a structural inspection undertaken prior to the works to identify its present condition. Monitoring of these structures, taking due regard to movement trigger levels, should be carried out during construction.

7.6 Sir John Rogerson's and Hanover Quay

Details of the material excavated during the construction of the culvert through the DDDA site should be obtained along with the construction details of the tie-in with the cut-off wall.

7.7 Groundwater

Monitoring of the groundwater levels within the piezometers, which were installed during the recent ground investigation, should be continued to determine any fluctuations and tidal influence. Care should be taken during this operation as the groundwater is likely to contain contaminants and therefore appropriate clothing and cleaning materials should be used.

7.8 Services

Consultation with the public utilities should be started to confirm the exact location of their apparatus and obtain agreement for the diversion or support of the apparatus during the construction works.

APPENDICES

Appendix A

References

1. Geotechnical Services Ltd (1989) – Dublin Gas Site

2. Site Investigations Ltd (1991) – Thomas Garland and Partners (Ringsend Information Centre)

3. Irish Geotechnical Services Ltd (1996) – J B Barry (Original route)

4. Irish Geotechnical Services Ltd (1999) – Parkman (DDDA Site)

5. Irish Geotechnical Services Ltd (2001) – Ellier Developments Ltd (Hanover Quay).

6. Environmental Impact Statement – J B Barry.

Appendix B

Geotechnical Design Parameters

FLAC Modelling Report

Contamination Results

Project	Grand Canal Dock Stormwater Culvert, Dublin.	**Date**	12 May 2003
Note	FLAC Analysis of Upper Dock Quay Wall	**Ref**	TQ/GCSC/11
Author	David Raeside / Suhol Bu		

1 Introduction

It is proposed to install a stormwater culvert alongside the Quay Wall within the Upper Dock of the Grand Canal Dock in Dublin. A typical section showing the submerged twin pipe arrangement is shown on drawing TQ/GCSC/010. Numerical Analysis of the Quay Wall has been undertaken to establish the global and internal stability of the wall for the following load cases at offsets of 8m and 10m from the wall.

Load Case 1 – Building 1. Surcharge and Lateral loading.

Load Case 2 – Building 1. Surcharge only.

Load Case 3 – Building 2.

Reference should be made to the Geotechnical Report and the previous FLAC analysis issued on 28 June and 2 October 2002.

2 FLAC Analysis

Numerical Analysis was undertaken using a software package called FLAC. FLAC is a two dimensional explicit finite difference program for engineering mechanics computation. This software models ground conditions based on the Mohr-Coulomb model and has assumed that the quay wall behaves as an elastic material. The following general assumptions have been made in the analysis:

- The loading arrangement, applied by the existing buildings on the quay wall, was determined by J B Barry.
- The effects of the counterforts on stability of the quay wall are negligible.
- The excavation for the culvert will be overdredged by 0.5m.
- The water level on both sides of the quay wall is 3.4mOD.
- The design bed level for the quay wall is -1.48 m OD as indicated on historical drawings.
- The toe pile is intact. However, stability of the quay wall has also been examined without the toe pile in place.
- The quay wall is a masonry structure. The masonry blocks in the wall are not grouted together and rely purely on friction for stability. Five shear planes at intervals along the height of the quay wall were set up in the FLAC model to encourage the interaction between the masonry blocks.
- There is no disturbance, other that that modelled, from construction activities.

3 Global and Internal Stability of the Quay Wall Prior to Culvert Installation

The stability of the quay wall was analysed for the upper section without the toe pile. This analysis shows that the quay wall is stable with the factors of safety as shown in the table below. Critical State Parameters have been used in the analysis and a factor of safety greater than 1 is required for stability.

Load Case	**Factor of Safety**	
	10m Offset	8m Offset
1	1.36	1.36
2		
3	1.26	1.19

4 Conclusions

From stability analyses of the Upper Dock Quay Wall the following conclusions can be made:

- The quay wall in its existing condition is stable.
- The lowest factor of safety for the stability of the quay wall occurs at an offset of 8m when load case 3 is applied.
- Following installation of the culvert the quay wall is stable.

5 Recommendations

In light of the results from this analysis the following recommendations are made:

- The present condition of the quay wall and the integrity of the toe pile should be determined prior to the construction works.
- A robust monitoring arrangement should be installed along the quay wall to determine if movement occurs during the construction works and to allow suitable action to be taken to protect the campshire and adjoining structures.

Project	FLAC Analysis of Grand Canal Dock Quay Wall	**Date**	4 October 2002
Note		**Ref**	TQ/GCSC/300.rev1
Author	Suhol Bu/Michelle Phillipson/ David Raeside		

1 Introduction

The Grand Canal Stormwater Culvert is proposed to be installed alongside the Grand Canal Dock Quay Wall. Numerical Analysis of the Grand Canal Dock Quay Wall has been undertaken to establish the following:

1. Global and internal stability of the quay wall prior to culvert installation.

2. Global and internal stability of the quay wall following dredging but prior to culvert installation.

3. Global and internal stability of the quay wall following dredging and culvert installation

This report is supplementary to our previous report titled: Grand Canal Dock, Dublin. Extension to Stormwater Culvert: Geotechnical Report

2 FLAC Model

Numerical Analysis was undertaken using a software package called FLAC. FLAC is a two dimensional explicit finite difference program for engineering mechanics computation. This software models ground conditions based on the Mohr-Coulomb model and has assumed that the quay wall behaves as an elastic material.

3 Analysis Parameters

Two typical cross sections through the Grand Canal Dock Quay Wall were analysed using FLAC. Cross Sections were taken through the Grand Canal Dock Quay Wall (Lower) and the Grand Canal Dock Quay Wall (Upper). The following parameters were used for these cross sections.

Quay Wall

(a) Quay Wall

The quay wall is a masonry structure and for the purposes of this analysis has been modelled as C20 grade concrete.

Young's Modulus	20Gpa
Poisson's ratio	0.25
mass density	2300kg/m^3
friction angle between wall blocks	30°
cohesion between wall blocks	0
friction angle between wall and soil	2/3 soil friction angle
cohesion between wall and soil	0

(b) Timber Toe Pile

From the description given on historical drawing the timber toe piles have been assumed to act as a sheet pile wall. From BS 5628 the timber toe piles are taken to be the equivalent of Strength Class C14 for softwoods. This is a conservative assumption as it is thought that the piles would have been constructed from Oak.

Young's Modulus	
mass density	
Tension parallel to grain	
Compression parallel to grain	
Shear parallel to grain	
Bending parallel to grain	

Cross Section 1 (Lower Dock Quay Wall)

(a) Made Ground (Lower Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	

friction angle $\phi_c^{'}$	
cohesion, c_u	

(b) Gravel (Lower Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	
friction angle $\phi_c^{'}$	
cohesion, c'	

(c) Very Stiff Sandy Clay (Lower Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	
friction angle, $\phi_c^{'}$, cohesion, c'	

cohesion, c_u	

(d) Soft Silt Deposit (Upper Quay Wall)

The soft silt has been applied as a pressure and has been assumed to have zero strength.

Submerged mass density	

Cross Section 4 (Upper Dock Quay Wall)

(a) Made Ground (Upper Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	
friction angle ϕ_c'	
cohesion, c'	

(b) Soft Silt (Upper Quay Wall)

Shear Modulus	

Poisson's ratio	
mass density	
friction angle ϕ_c'	
cohesion, c_u	

(c) Gravel (Upper Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	
friction angle ϕ_c'	
cohesion, c'	

(d) Peat (Upper Quay Wall)

Shear Modulus	
Poisson's ratio	
mass density	

Friction angle, $\phi_c^{'}$, cohesion, c’	
cohesion, c_u	

(e) Loose Over-consolidated Gravel (Upper Quay Wall)

Shear Modulus	
Poisson’s ratio	
mass density	
friction angle $\phi_c^{'}$	
cohesion, c’	

(f) Sedimentary Silt (Upper Quay Wall)

The soft silt has been applied as a pressure and has been assumed to have zero strength.

Submerged Mass density	

4 FLAC Analysis

The following general assumptions have been made in the analysis:

- The load on the quay wall is 5kPa. We were informed by the client that there would be no surcharge on top of the quay wall. However we have analysed the wall with a surcharge of 5 kPa in case the loading condition changes for instance during an emergency situation.

- A second analysis was completed for the Inner Dock Wall acting under a surcharged load.

- The effects of the counterforts on stability of the quay wall are negligible.

- The excavation for the culvert will be overdredged by 0.5m.

- The water level on both sides of the quay wall is 3.4mOD.

- The design bed level for the quay wall is -1.48 m OD as indicated on historical drawings (see Fig 3).

- The toe pile is intact. However, stability of the quay wall has also been examined without the toe pile in place.

- The quay wall is a masonry structure. The masonry blocks in the wall are not grouted together and rely purely on friction for stability. Five shear planes at intervals along the height of the quay wall were set up in the FLAC model to encourage the interaction between the masonry blocks.

- There is no disturbance, other that that modelled, from construction activities.

4.1 Global and Internal Stability of the Quay Wall Prior to Culvert Installation

The stability of the quay wall was analysed for the upper and lower sections without the toe pile. This analysis shows that the quay wall is stable with the factors of safety for the two sections is 1.41 and 1.45, respectively. Critical State Parameters have been used in the analysis and a factor of safety greater than 1 is required for stability.

4.2 Global and Internal Stability of the Quay Wall Following Dredging, Pre-Culvert Installation

(a) Lower Quay Wall

The analysis revealed that the quay wall, with the toe pile intact, is stable with a 1.4m deep excavation, approximately 1.5m from the wall toe. The maximum horizontal wall displacement is approximately equal to 3mm. The sliding between wall blocks is practically negligible.

If the toe pile fails the wall will be unstable with the excavation at 1.5m away from the quay wall. However, the wall is stable if the excavation is 4m away from the base of the wall. The maximum horizontal wall displacement is approximately equal to 3mm. The sliding between wall blocks is practically negligible.

This model has assumed that a trench with vertical sides will be cut into the stiff clay. This is only a temporary situation as “strain softening” will cause the sides of the trench to progressively fail gradually reducing the factor of safety on stability of the quay wall.

(b) Upper Quay Wall

FLAC results for the quay wall analysed with and without the toe pile show that the quay wall is unstable when the excavation is 1.4m deep and 4m away from the toe of the wall. It is observed that the collapse of the gravel slope in the excavation triggers a progressive failure of its adjacent soil mass leading to a global failure of the quay wall. Moving the excavation to 8m away from the toe of the quay wall will alleviate this problem. FLAC analysis is included in graphical form for the following cases:

Upper (or Inner) Dock Wall (8m offset from Quay Wall)

Case No.1 - Wet Dock with surcharge load (FOS - 1.3).

Case No.2 - Dry Dock with surcharge load (FOS - 1.24).

Case No.3 - Wet Dock with lateral load (FOS - 1.18).

Case No.4 - Dry Dock with lateral load (FOS - 1.15).

Lower (or Outer) Dock Wall

Concrete Box Culvert

Case No.5 - Wet Dock with no surcharge load (FOS - 1.07 at distance 6m from wall).

Case No.6 - Dry Dock with no surcharge load (FOS - 1.14 at distance 6m from wall).

Twin Pipes

Case No.7 - Wet Dock with no surcharge load (FOS - 1.11 at distance 4m from wall).

Case No.8 - Dry Dock with no surcharge load (FOS - 1.17 at distance 6m from wall).

4.3 Global and Internal Stability of the Quay Wall Following Culvert Installation

FLAC analysis shows the quay wall to be stable after installation of the culvert.

5 Conclusions

From stability analyses of the Upper and Lower Grand Canal Dock Quay Wall the following conclusions can be made:

- The quay wall in its existing condition is stable
- The critical condition for stability of the quay wall is during excavation of the trench in front of the quay wall.
- The Upper Dock Quay Wall indicates that when the base of the quay wall lies on gravel, the trench excavation (1.4 m deep) would destabilise the wall when it was placed a minimum of 5.5m away from the toe of the wall. This is regardless of whether the toe pile at the base of the quay wall is intact. Temporary measures such as a sheet pile could be installed to stabilise the quay wall during trench excavation. However analysis to assess the validity and practicality of such temporary measures have not been considered here.
- The Lower Dock Quay Wall indicates that when the base of the quay wall lies on stiff clay the quay wall is stable when the excavation (1.4 m deep) is placed 1.5m away from the toe of the quay wall with the toe pile intact. If the toe pile is not intact the excavation must be 4m away from the quay wall for it to remain in a stable condition.
- Following installation of the culvert the quay wall is stable

6 Recommendations

In light of the results from this analysis the following recommendations are made:

- The integrity of the toe pile should be checked.
- It is difficult to predict how long it will take for strain softening and progressive failure to occur in the vertical excavation in stiff clay. It is possible that this could happen within two to three days following excavation. Therefore further stability analysis of the Lower Dock Quay Wall is recommended to assess the effects of having oblique side slopes in the excavation in stiff clay on stability of the quay wall. Oblique side slopes in the trench would prevent progressive failure and allow the trench to be open for a longer period of time.
- Other construction activities which could affect stability of the quay wall should be considered.

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Memo

Grand Canal Dock, Dublin
Contamination Results

INTRODUCTION

The results of the soil and groundwater analysis carried out on the samples obtained during the site investigative works at the Grand Canal Docks have been reviewed with respect to the disposal of the materials they represent.

As it is understood the materials will be disposed in the Netherlands, the soil, leachability and water results have been compared wherever possible to the 'Intervention' values (Dutch Standards 1994) put forward by the Ministry of Housing, Spatial Planning and Environment of the Netherlands.

In the case of the soil analysis, where a value is not available for a particular determinant in the Dutch Standards, then a value has been obtained from either the 'Upper Threshold Concentrations' or the 'Leachate Quality Threshold' levels presented within the Environment Agency document entitled 'Guidance on the Disposal of "Contaminated Soils" Version 3, April 2001.

In the case of the water samples, where no corresponding Dutch groundwater 'Intervention Value' exists then the results have been compared to the prescribed concentrations presented in the 'Water Supply (Water Quality) (Scotland) Regulations 1991.

A full set of the results are included in Geotech Specialists Limited's Ground Investigation Report No. 172045. It is recommended that this summary should be read with reference to the full set of these results. It should be borne in mind that depending on the nature and quantity of the materials that are actually excavated, further sampling and analysis may be required to facilitate the appropriate means of disposal.

DESCRIPTION OF SOILS

The soils for disposal will be obtained from two excavations. The first comprises the land based excavation area, which it is anticipated will be excavated to depths of in the region of 6 to 10m below current ground level. The second excavation will be within the dock area itself and will comprise the excavation of 1 to 2m of dock sediments.

Land Excavation: The samples obtained which represent the land-based excavation were obtained from BHs 1, 2 and 3. The materials encountered in these excavations to depths of 10m bgl have been described as comprising:

Made Ground Materials:	The made ground materials within these boreholes were found to be black to brown in colour and variable between granular materials (cobbles, sand, gravel), ranging to predominantly silt or clay rich deposits. Secondary constituents including ash, brick and pottery. No odours were recorded associated with the made ground materials in BHs 1, 2 and 3.
Natural Materials:	Within BHs 1 and 2, the natural materials below the made ground were found to predominantly comprise sand and gravels, occasionally with horizons of silt. BH3 however encountered a sequence alternating between of clay and gravel. Peat or peat rich horizons were also noted within these boreholes.

The natural deposits (within all three boreholes) were recorded as exhibiting evidence of contamination. A summary of the contamination related notations follows:

	BH & Depth		Loggers Description
•	BH1	3.0-4.0m	'Contaminated'
•	BH1	9.2m	'possibly contaminated but no obvious odour'
•	BH2	at 6m	'Strong hydrocarbon odour'
•	BH3	below 4m	'Slight hydrocarbon odour'
•	BH3	below 5m	'with strong hydrocarbon odour'
•	BH3	at 5.8m	'Slight hydrocarbon odour'

Dock Based Excavations: BHs 4, 6, 7 and 9 were excavated in the dock area. The deposits encountered to a depth of 2m are described as follows:

Made Ground Materials:	Where deposits described as made ground were encountered they were typically described as dark grey or brown clayey gravels.
Natural Materials:	The natural materials encountered comprised dark grey brown, sandy, gravelly clays, or silts (locally gravelly). A summary of the contamination related notations follows:

	BH & Depth		Loggers Description
•	BH6	010-1.0m	'strong hydrocarbon odour'
•	BH9	0.0-1.0m	'strong hydrocarbon odour'

- BH9 1.0-2.2m 'slight hydrocarbon odour'

TOTAL SOIL ANALYSIS RESULTS

A total of 21 samples obtained from the investigation were selected for analysis to represent the materials described above. The analysis suite included a wide range of potential contaminants including metals, inorganic and organic species. The results of the analysis have been compared to screening levels as described earlier.

Dutch Intervention

Of the determinands analysed for only **lead** (on one occasion, BH2 at 2.0m – 4570mg/kg – land based) was found to be elevated with respect to the corresponding Dutch Intervention Values of 530mg/kg .

Dutch Target

As the vast majority of results were below the Dutch Intervention Values, a comparison was carried out with respect to the more stringent Dutch Target Values. For the purposes of disposal the results have been separated into Land based samples (BHs 1, 2 and 3) and Dock or Water based samples (BHs 4, 6, 7 and 9).

Land Based Samples – from BHs 1, 2 and 3

Determinand (mg/kg)	**'Target Value' (mg/kg)**	**Total No. of Analysis from BHs 1, 2 &3**	**No. Exceeding Screen**	**Maximum Concentration (mg/kg)**
GRO	50	10	1	836
DRO	50	10	3	864
Arsenic	29	10	1	30
Copper	36	10	3	97
Lead	85	10	4	4570
Mercury	0.3	10	4	1.0
Nickel	35	10	1	41
Zinc	140	10	2	306
PAH	1	6	6	21.3
Phenol	0.05	2	2	0.6
Xylenes	0.05	3	1	0.123

Dock/Water Based Samples – from BHs 4, 6, 7 and 9

Determinand (mg/kg)	'Target Value' (mg/kg)	Total No. of Analysis from BHs 4,6,7,&9.	No. Exceeding Screen	Maximum Concentration (mg/kg)
DRO	50	6	3	305
Arsenic	29	6	1	32
Cadmium	0.8	6	6	3
Copper	36	6	4	142
Lead	85	6	4	537
Mercury	0.3	6	3	4.0
Nickel	35	6	1	37
Zinc	140	6	4	640
PAH	1	3	3	54
Phenol	0.05	2	1	1.2

Comparisons of the results of the analysis with the 'Intervention' and 'Target' values indicate relatively low to moderate concentrations of contaminants within the materials sampled for both areas.

Organic Contaminants

Several of the ground materials logged the engineer were described as emitting slight to strong hydrocarbon odours. The results of the analysis however do not seem to reflect this. It may be that particularly odorous components, such as naphthalene, which has been detected in some of the samples at relatively low concentrations, may account for the descriptions of odours. A summary of the organic analysis results is presented in the following table:

Gasoline and Diesel Range Organic Results – Total Soil Analysis

Determinand	Units	Minimum Conc.	Maximum Conc.	Sample Location	Intervention Value
GRO	mg/kg	<0.2	836	BH2 (Land)	5000
DRO	mg/kg	<10	864	BH3 (Land)	5000
GRO+DRO	mg/kg	<10.2	1048	BH2 (Land)	5000

A number of samples exhibited low concentrations of individual SVOCs, these were essentially found to comprise PAHs. To give an indication of the species present, where the individual compounds have been positively found to reach a nominal value of 4mg/kg (equivalent to $^{1}/_{10}$ of the Dutch Intervention for the sum of 10 PAHs) they have been summarised below:

Semi-Volatile Organic Compound Results – Total Soil Analysis

Determinand	Units	Sample ID	Sample Location	Conc.
Naphthalene	mg/kg	BH2 2.0m	Land	14.9
Benzo(a)anthracene	mg/kg	BH6 1.0-2.0m	Dock/Water	4.0
Benzo(a)pyrene	mg/kg	BH6 1.0-2.0m	Dock/Water	4.5
Chrysene	mg/kg	BH6 1.0-2.0m	Dock/Water	4.0
Phenanthrene	mg/kg	BH6 1.0-2.0m	Dock/Water	4.3
Pyrene	mg/kg	BH6 1.0-2.0m	Dock/Water	6.4
Bis(2-Ethylhexyl)phthalate	mg/kg	BH9 0.0-1.0m	Dock/Water	4.3

LEACHABILITY ANALYSIS RESULTS

A total of 5 samples were selected for analysis. These were selected on the basis of the descriptions provided in the logs, to represent the materials with the anticipated highest levels of contamination. The results were then compared to the Dutch 'Target' Groundwater concentrations where available or the EA Leachate Quality Threshold Values. If a sample does not exhibit a potential contaminant in excess of the detection limit of the analytical method employed then it is assumed that it does not exceed the screening threshold.

The following tables contain the list of determinands found at elevated concentrations with respect to the screening values employed. Again the tables have been split up to separate the results of the analysis from the land boreholes and the water/dock boreholes.

Land Based Samples – from BHs 1, 2 and 3

Determinand	Units	'Target Value'	No. Exceeding Screen	Maximum Concentration	Total No. of Analysis
Iron	µg/l	100 *	1	110	3
COD	mg/l	30 *	1	33	3
PAH	µg/l	0.1	3	<14.3	3
Arsenic	µg/l	10	1	12	3
Phenol	µg/l	0.2	3	3.4	3

- EA Leachate Quality Threshold

Dock/Water Based Samples – from BHs 6 and 7

Determinand	Units	'Target Value'	No. Exceeding Screen	Maximum Concentration	Total No. of Analysis
PAH	μg/l	0.1	1	0.92	1
Phenol	μg/l	0.2	2	0.8	2
Ammoniacal N	mg/l	0.5 *	1	1.1	2

* EA Leachate Quality Threshold

From these results it is anticipated that the materials will generally have a low leachability with respect to most potential contaminants. However, these materials do appear capable of leaching relatively low concentrations of organic species particularly PAH and to a lesser extent phenols.

COMMENTS AND CONCLUSIONS

The results of the total soil analysis indicates that the materials tested, from both proposed excavation areas (land and dock/water), contain low to moderate concentrations of metal and organic contaminants, generally not exceeding the Dutch Intervention Values.

From the leachability test results the materials analysed generally have a low leaching potential with respect to most contaminants tested. However, these materials do appear capable of leaching relatively low concentrations of organic species particularly PAH and to a lesser extent phenols.

GROUNDWATER ANALYSIS RESULTS

Samples of the groundwater were collected from boreholes 1, 2, 3 and 5. The results have been compared to the Dutch 'Target Values' for groundwater, where a value for a particular determinand is not given in the Dutch standards, the results have been compared to the Water Supply (Water Quality) (Scotland) Regulations 1991. The full suite of analysis is presented in Geotech Specialists Limited Ground Investigation Report, however the determines exceeding the screening criteria are summarised below.

Determinand	Units	'Target Value'	Min. Conc.	Max. Conc.	No. of Analyses	No. Exceeding Screen
Conductivity	µS/cm	1500*	1220	49100	4	2
Chloride	mg/l	400 *	51	19800	4	2
SO_4	mg/l	250 *	24.1	2670	4	2
Boron	mg/l	2 *	<0.05	4.4	4	1
Ammoniacal N	mg/l	0.5 *	0.2	17.5	4	3
Nitrate	mg/l	0.1	<0.5	1.7	4	2
GRO	mg/l	0.05	<0.1	<0.19	4	1
TPH	mg/l	0.05	0.22	1.2	4	3
Naphthalene	µg/l	<2	<2	9	4	1
Acenaphthene	µg/l	<2	<2	2	4	1
Acenaphthene	µg/l	<2	<2	15	4	2
Fluoranthene	µg/l	<2	<2	9	4	1
Pyrene	µg/l	<2	<2	7	4	1
Chromium	µg/l	0.4	<0.1	4	4	1
Arsenic	µg/l	10	7	96	4	2
Selenium	µg/l	10	<10	70	4	2
Cyanide (total)	mg/l	0.01	<0.05	0.27	4	2
Benzene	µg/l	0.2	-	1	1	1
Phenol	µg/l	0.2	-	5.4	1	1
Cresols	µg/l	0.5	-	3.2	1	1
Dimethylphenols	µg/l	-	-	11.6	1	-
Trimethylphenols	µg/l	-	-	3.8	1	-

* Water Supply prescribed concentration

From this exercise it can be seen that the groundwater sampled contains a number of contaminants at elevated concentrations with respect to the screening criteria employed. The most notably elevated species being conductivity, chloride, ammoniacal nitrogen, total petroleum hydrocarbons, phenols (including cresols, dimethylphenols and trimethylphenols).

HEALTH AND SAFETY ISSUES

The results of the soil analysis do not indicate that the soils sampled are particularly heavily contaminated. However ground materials and the distribution of contamination within these materials can be highly variable between locations and strata. To limit the level of risk associated with the presence of contamination in the soils, the consideration and implementation of appropriate Health and Safety precautions is important. The following are suggestions for a minimum standard:

- All personnel present on site during excavation work should be equipped with overalls, safety boots, gloves, goggles and dust masks (in addition to equipment required on any construction site). The necessity for goggles and dust masks to be worn will depend on conditions encountered and should be at the discretion of the site manager.
- There should be no smoking, eating or drinking on site.
- Sufficient washing facilities should be provided for personnel to wash their hands before eating, drinking or smoking.
- Cuts and grazes should be covered while working.
- Handling of soils should be kept to a minimum and gloves always worn.
- If oily or tarry materials in liquid or sludge form are encountered, work in the area should cease and the material sampled with care. The area should be fenced or taped, hazard signs put up and personnel excluded until the analysis is known.
- Water spraying equipment sufficient to damp down the site in dusty conditions should be provided.
- A first aid kit should be provided on site, and its location known to all personnel. There should be a qualified first aider present during working hours.
- A Health & Safety information sheet explaining the potential hazards and listing the above rules should be issued to all staff and contractors.

All made ground on the site should be treated as contaminated, since contaminated patches cannot be reliably distinguished visually. Where excavation is to be undertaken, site workers should be on the alert for any unusual ground conditions, which may indicate contaminated materials, such as odorous, oily or discoloured materials. If such materials are encountered it may be necessary to carry out further sampling and analysis of the suspect materials, and if these materials are found to contain high levels of contaminants, in particular semi-volatile or volatile organic compounds further consideration may need to be given to their disposal.

Appendix C

Limitations and Exceptions

THE GROUND INVESTIGATION WAS CONDUCTED AND THIS REPORT HAS BEEN PREPARED FOR THE SOLE INTERNAL USE AND RELIANCE OF DUBLIN CITY COUNCIL. THIS REPORT SHALL NOT BE RELIED UPON OR TRANSFERRED TO ANY OTHER PARTIES WITHOUT THE EXPRESS WRITTEN AUTHORITY OF HALCROW GROUP LTD. IF ANY UNAUTHORISED THIRD PARTY COMES INTO POSSESSION OF THIS REPORT THEY RELAY ON IT AT THEIR PERIL, AND THE AUTHORS OWE THEM NO DUTY OF CARE AND SKILL.

The findings and opinions conveyed via this report are based on information obtained from a variety of sources as detailed within this report, and which J B Barry believes are reliable. Nevertheless, HALCROW GROUP LTD. CANNOT AND DOES NOT GUARANTEE THE AUTHENTICITY OR RELIABILITY OF THE INFORMATION IT HAS RELIED UPON.

The report represents the findings and opinions of experienced geotechnical and environmental consultants. Halcrow Group Ltd does not provide legal advice and the advice of lawyers may also be required.

The opinions presented in this report are based on findings derived from a site inspection and walk-over and ground investigation, a review of records and historical sources. Halcrow Group Ltd has found indicators that suggest that hazardous substances exist at the site at levels likely to warrant mitigation or consideration appropriate to the end use stated by Dublin City Council. NOT FINDING SUCH INDICATORS DOES NOT MEAN THAT HAZARDOUS SUBSTANCES DO NOT EXIST AT THE SITE.

The most recent site inspection/walkover survey was performed during April 2002. Dublin City Council is advised that the CONDITIONS OBSERVED BY HALCROW GROUP LTD. ARE SUBJECT TO CHANGE. Certain indicators of the presence of hazardous substances may have been latent at the time of the most recent site reconnaissance and may subsequently have become observable.

It is possible that Halcrow Group Ltd's research, while fully appropriate for a geotechnical study, failed to indicate the existence of important information sources.

Assuming such sources actually exist, their information could not have been considered in the formulation of Halcrow Group Ltd's findings and opinions.

Similarly, the work carried out for the ground investigation can only investigate and monitor a small part of the subsurface conditions. Certain indicators or evidence of hazardous substances may have been, outside the very limited portion of the subsurface investigated or monitored, latent at the time of this work or only partially intercepted by the works and thus their full significance could not have been appreciated. Groundwater levels are particularly susceptible to variation. Accordingly, it is possible that Halcrow Group Ltd's work failed to indicate the presence or significance of hazardous substances. Assuming such materials present a hazard, their presence could not have been considered in the formulation of Halcrow Group Ltd's findings and opinions. The subsurface geological profiles and other plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths sampled and tested.

In preparing this report it has been assumed that all past and present occupants have provided all relevant and other information, especially relating to known or potential hazards. This report is not required to identify insufficiencies or mistakes in the information provided by the user/owner or from any other source, but has sought to compensate for these where obvious in the light of other information

Appendix D

Drawings

TQ/GCSC/GEO/01	Site Plan
TQ/GCSC/GEO/02	Plan and Geological Profile Sheet 1 of 4
TQ/GCSC/GEO/03	Plan and Geological Profile Sheet 2 of 4
TQ/GCSC/GEO/04	Plan and Geological Profile Sheet 3 of 4
TQ/GCSC/GEO/05	Plan and Geological Profile Sheet 4 of 4
TQ/GCSC/GEO/06	Ringsend Road/Hanover Quay/Sir John Rogerson's Quay Cross Sections
TQ/GCSC/GEO/07	Case A – Dredging within Undrained Dock
TQ/GCSC/GEO/08	Case B – Sheet Piling with Quay Wall Exposed
TQ/GCSC/GEO/09	Case C – Sheet Piling Away from Quay Wall