Galway Harbour Company

Galway Harbour Extension

Environmental Impact Statement

Brief of Evidence of

Dan Duggan

Chapter 6

Soils

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DAN DUGGAN – EXPERIENCE PROFILE

- I am Dan Duggan BSc (Hons.) in Geology 1985. I have over thirty years experience in Engineering Geology/Ground Engineering. I have been involved in the implementation and interpretation of over three hundred marine and land ground investigations both in Ireland and the UK. I have designed and managed the construction of large scale construction projects for motorways, bridges, long sea outfalls in the estuarine and marine environments. I has also been involved in the preparation of EIS's for road projects, land rehabilitation, landfills, quarry extensions and windfarms

  Qualifications: BSc (Hons) in Geology 1985

6.1 INTRODUCTION

The Galway harbour extension will primarily involve the construction of Quay walls, land reclamation and dredging. In order to gain an understanding of the Engineering Geological conditions a Marine Drilling Investigation was conducted. A Desk Study of available documents relating to the site was also undertaken. The brief of evidence herein relates to the assessment of soils which is covered in detail in Chapter 6 of Volume 2B (Part 1) of the EIS.The Figures referred to herein are contained within the EIS as published

6.2 INFORMATION SOURCES

Information sources used in the compilation of this Chapter include:

- Aerial Photography
- Geological Map and Memoir
- Admiralty Charts
- Coastal Site Walkover and geomorphology
- Bathymetric Survey [Survey of sea bed levels]
- Overwater Site Investigation [drilling conducted from raft]
- Laboratory testing
- Archaeological Report

6.3 SITE INVESTIGATIONS

6.3.1 Overwater Investigations

The investigation was carried out by Causeway Geotech Ltd in March 2012, using a C5 Combi-float jack up platform, 18x18m in plan fitted with four 17m long legs. .

Test locations were marked out using a buoy and the jack up rig was manoeuvred onto position using a work boat. The actual position of each investigation point was then surveyed using a GPS Trimble system.

Eight Shell and Auger Boreholes, three Rotary boreholes, twenty dynamic probes and seven CPTu(Cone Penetration Testing) tests were carried out at spacings of between 100m and 300m.

The extent of the investigation consisted of:

- Cable Percussive Boreholes
- In situ SPT testing and sampling
- In situ Vane testing
- Piezocone Penetration Tests
- Piston Sampling
- In situ dissipation tests
- Rotary Core Boreholes
- Dynamic Probes Super Heavy

The Borehole Layout is shown in Figure 6.3.1 of the EIS and Drawing No. 2139/2136A.

6.3.2 Geotechnical Testing

Laboratory Test Schedules were prepared to provide design information on soil type, classification, strength and consolidation characteristics of the Estuarine soils and the strength/mineralogy of the rocks. The purpose of the tests was to identify and ascertain the actual material properties of the soil and rock in situ and how these materials would be acceptable for reuse in the project

6.4 GEOLOGY

6.4.1 Soil Deposits

The existing Galway Harbour Enterprise Park was constructed on partly reclaimed ground using imported rockfill, recycled demolition material and selected Glacial till materials. The reclaimed area is protected by extensive rock armour, comprising individually placed large boulders, particularly along its southern margin.

The proposed Port Extension extends from the southern side of the existing facilities some 935m southwards into the Bay.

Seabed level in the boreholes varied from –0.30mCD in DP1 in the north to -7.8mCD in BH 8 some 1,300m south in the Bay.

The soils immediately south of the rock armour comprise alluvium, which consists of sand and interlayered silts and sands and with localised clusters of large angular boulders.

Grey slightly silty to silty SAND, is present along the shoreline but was not encountered at seabed level in the Boreholes

Very soft/loose dark grey and greenish grey slightly organic slightly clayey SILT with occasional shells was present in all of the boreholes. An upper layer, ranging in thickness from 1.60m to 3.30m, consisting of slightly sandy-to-sandy SILT was encountered in all boreholes with the exception of BH 8. The SILTs are interlaminated and interbedded with thin SAND and silty SAND layers. The depth of SILT ranged from 1.50m in DP1 to 12.50m in BH 4. The SILT is between 0.00m and 3.2m thick beneath Lagoons 1 to 5. Beneath Lagoon 6 its thickness varies from 5.2m to 7.1m. The thickest SILT is present beneath Lagoon 7 and varies from 9.0m in the South Western corner of the Lagoon to 12.5m in the east.

The silt gave off a slight odour of hydrogen sulphide during drilling. The odour dissipated very rapidly when aerated.

The SILT's moisture content ranges from 25% to 82% with average moisture content of about 54% based on 45 measurements.

Particle size distribution tests show between 71% and 99% of the material is SILT. The clay content is very low ranging from 1% to 10%.

The results of Atterberg limit tests indicate that the material is predominantly of intermediate plasticity with a liquid limit ranging from 36% to 46 %.

Laboratory test results confirm that the SILTs are normally consolidated alluvial soils with high to very high compressibility.

The silts are primarily mineral soils. The organic content is typically less than 2%. These silts, as a consequence, will lend themselves to soil consolidation and will benefit from surcharging and vertical drainage to accelerate the consolidation required.

At the base of the silt thin organic layers were encountered in BH's 6,7, 8 and RC03, about 0.20m thick, at between 6.60m and 8.60m depth. The layer consisted of firm brown PEAT or peaty SILT. In BH RC01 a 0.40m thick layer of Oyster shells in an organic silt matrix, was encountered at 2.6m depth. These layers rest directly on the Glacial Deposits.

Glacial deposits are present beneath the Alluvium in all of the Boreholes The Glacial deposits consists of very stiff to stiff grey gravely clayey SILT/ CLAY with cobbles/boulders and with layers of very dense sandy silty GRAVEL with cobbles/boulders The Glacial tills are also exposed along the shoreline east of the Enterprise Park and on Hare Island.

In situ Standard Penetration Tests in Boreholes record N-values typically greater than 50, which indicate that the glacial soils are very dense in situ. It is considered that the glacial till will behave predominantly as a cohesive material .

6.4.2 Regional Bedrock Geology

The bedrock geology of the Galway region is described in detail in a Memoir (titled Geology of Galway Bay) prepared by the Geological Survey of Ireland to accompany the 1:100,000 scale Bedrock Geological Map Series Sheet 14. These map series are representative of the distribution of rock types exposed at the surface or under the cover of superficial soil deposits.

A portion of the geological map in the vicinity of the proposed harbour is presented in Figure 6.4.2.

The Bedrock Geology in the area is quite complicated with rocks from the Ordovician, Devonian and Carboniferous Ages present.

Beneath the existing docks and the Galway Harbour Enterprise Park are rocks of Ordovician age, which are between 440 and 495 million years. These rocks are part of the Metagabbro and Orthogneisss suite. These rocks are metamorphosed and are very low permeability hard abrasive materials

The Galway Granite is Devonian aged, from about 380 to 410 million years old, and is about 65km to 20km in area. These rocks are primarily fine-grained felsic granites. Dolerite Dykes have been recorded in the Galway Granite. These rocks are predominantly very low permeability hard abrasive rocks

Carboniferous rocks are present east of the Harbour Enterprise Park and consist of undifferentiated Visean Limestones

South of the existing Enterprise Park bedrock with clusters of large angular boulders is exposed at low tide along the eastern and western sides of the proposed extension. Aerial Photography, Figure 6.4.3 , indicate that the rock/boulders extend from the present shoreline due south about 250m into the Bay.

Metagabbro outcrops are exposed along the shoreline east of the Enterprise Park. Very Strong GRANITE was encountered in the Boreholes drilled at Lough Atalia Bridge.

In the Boreholes Bedrock was encountered between 3.4m and 14.4m below seabed level, which equates to –4.4 m CD and –16.6m CD. Rockhead slopes generally at less than one degree from North to South.

The rock encountered in the Boreholes consisted of grey, pink and dark grey Granites, with some pale green chloritisation along discontinuities. The rocks are predominantly intact and moderately strong to strong which will therefore be difficult to remove, hence the design has minimised the requirement for rock removal

6.4.3 Impacts on Geology

The proposed development will contribute to the current understanding of the Quaternary and Bedrock Geology in the eastern end of Galway Bay. The nearest recorded mineral deposit is the Rinville Mine, where galena, pyrite and sphalerite were mined from Carboniferous Limestones until about 1849. Carboniferous rocks are not present beneath the proposed development.

6.5 GROUNDWATER

6.5.1 Soils

The overburden consists of interbedded silts and sands with some clays. These units are locally underlain by sandy gravels. Continuous pore water pressure measurements were undertaken at 7 locations. These show a steady increase in pore water pressure with depth. All these deposits are under lowest tidal water level and contain high volumes of saline groundwater.

6.5.2 Bedrock

The bedrock beneath this part of the bay consists of very low permeability GRANITES with some metamorphic rocks. On land these rock units are classified as poor aquifers, which are generally unproductive except for local fracture zones. Where groundwater flow is encountered it is generally in localised systems with little continuity between systems. Examination of the rock core indicates that the rock is unfissured and typically has no visual porosity.

6.5.3 Impacts on Hydrogeology

The saline water contained within the soils is not considered a viable source of clean potable groundwater. It is expected that the bedrock beneath the proposed development will contain little or no groundwater.

6.6 SEDIMENT QUALITY

6.6.1 Granulometry

Section 7.5.3 and 7.5.4 of the EIS presents an assessment of the sediment granulometry.

There will be only be small or minor changes to the rate of sedimentation and erosion in the area of the development, although a reduction in sedimentation east of the development is anticipated

Information from the Harbour Master suggests that maintenance dredging occurs ca. every 10 years or when the channel has filled in to ca. +50 cm over the last dredging, which gives an annual build-up rate of 5 cm in one year or 0.015 cm per day.

6.6.2 Sediment Chemistry

Section 7.5.3 and 7.5.4 of the EIS presents an assessment of the sediment chemistry.

These results indicate that there are no reasons to suggest that mobilisation of deep sediments will impact on water or sediment quality during the dredging operations.

An Bord Pleanala, in their scoping document for the EIS recommended that sediment samples be collected off South Park, which had served as a municipal dump some decades previously to determine any evidence of contaminants.

Marine sediment samples were collected at South Park for selected contaminant analyses carried out.

The analysis presented in Section 7.5.4 does not indicate any long term or residual contaminant leakage or seepage from the historical municipal dump at Southpark.

6.7 GEOTECHNICAL IMPLICATIONS

6.7.1 Bund Construction

The details of bund construction is outlined in Chapter 4 of Volume 2B Part 1 of the EIS.

The development will consist of 7 bunded lagoons. The walls of lagoons 1, 2 and 5 will be constructed by the loose tipping of selected silt free washed granular Class 6A material directly into water. The lagoon walls will be lined internally with geomembrane to facilitate controlled drainage of the dredged fill. A layer of free draining stone fill will be placed over the geomemberane to protect it during main filling operations. The walls of lagoons 3, 4 and 6 will be of two types – walls formed using Class 6A material and walls formed by combiwall piles. The walls of lagoon 7 will be constructed using combiwall piles. Details of lagoon wall construction are presented in Section 4.5 of the EIS

No compaction is required where Class 6A material is used. Above tidal level fill materials will be spread and compacted by standard earthworks plant. The selected Class 6A Material will be clean rockfill 500mm to 50mm in size. This grading does not comply strictly with 6A, which requires at least 15% passing 10mm sieve. The selecting out of material less than 50mm is proposed to curtail silt wash into water.

Where granular fill is placed onto the granular materials or bedrock the stability of the side slopes of the bunds will be satisfactory. Settlement in the gravels will be immediate, long term settlement of the glacial till will be nominal and there will be no ground settlement where the fill rests directly on bedrock. Where thin, less than 2.0m, of very soft/loose alluvium is present beneath the bund walls it will be removed by dredging in advance of rockfill placement.

The site investigation information indicates that it is possible to construct a haul road as far south as CPT 3 without significant settlement or stability issues along the east side of lagoons 1, 2 and 5.

Along the west side ground conditions are suitable for rock bund construction as far as at least RC01. South and South West of RC01 up to 7.1m of very soft fine grained soils are present.

Where these materials are removed by dredging in advance of rock bund construction it is feasible to construct a lagoon wall to the south of lagoon 4 with Class 6A material.

Lagoon bund walls will be protected by revetment systems comprising two zones of rock armour placed on the outside face of the lagoon walls.

6.7.2 Marina and Quay Construction

The proposed construction method involves the driving of a double pile wall to create a cofferdam. The wall will consist of a combination of steel tubular piles, up to 1.5m in diameter, with intermediate sheet piles in groups of three. The Quay walls will act as a self supporting gravity structure. Its stability is dependent on the properties of the fill used to backfill within the walls and the type of soil/rock at foundation. Soft soils will be removed to reach an adequate foundation which will not be prone to settlement when rock fill is then placed over them.

Above the bedrock layers of very dense gravel and boulders are present. These layers would require very heavy driving to penetrate and would result in damage to some of the piles. It is proposed therefore to excavate/dredge this layer in advance of pile driving.

The bedrock consists of moderately strong to very strong GRANITEs with probable DOLERITES and metamorphosed rocks. The steel piles will not penetrate into bedrock without pre-treatment of the rockmass by fragmentation. Blasting will require the drilling of a series of closely spaced holes 3m to 5m into bedrock. The holes will be charged with explosives and stemmed at the top of bedrock. The maximum instantaneous charge will be limited to reduce the effect of any shock wave generated by the blast events. Noise and vibration limits are stated in Section 10 of Volume 2B Part 2 of the EIS.

The cofferdam will be backfilled with free draining fill materials to provide lateral stability and immediate solid quay base. This quay will then be able to receive back hoe dredged material from barges, for delivery to the lagoons 1 to 6.

6.7.3 Land Reclamation

Stage 1 will consist of lagoons designated 1 to 6. Lagoons 1,2 and 3 will initially receive sediment being a mixture of silt or sand with occasional gravel dredged by a Trailer Suction Hopper Dredger. This material will be, in effect, fluidised, with moisture contents in the 100% plus range.

On completion of suction dredging Lagoons 1 to 6 will be filled with the stiffer material dredged using a backhoe excavator. These materials will be predominantly SILT with some sand, clay with occasional gravel and organic matter.

The walls of the lagoons will be built using granular fill lined internally with a geomembrane to facilitate drainage of the dredged materials.

In Lagoons 1,2,3,4 and 5 the foundation strata are predominantly granular soils and it is expected that these relatively free draining soils will consolidate during construction of lagoons. The dredged materials will comprise initially fluidised silts from the Suction Dredging, followed by excavated slightly denser cohesive soils placed on top. The lagoons will be filled in stages dependent on the availability of material from dredging operations. These materials would require a period of years to consolidate naturally as the soils slowly drain and consolidate.

Therefore, it is proposed to accelerate the rate of consolidation by installing prefabricated vertical band drains, surcharging, cambering the surface and by the placement of a permeable layer on top of the surcharge. The efficient use of band drains can result in significant reductions in the time required for consolidation of the soils. Band drains are proposed on a 1.5m triangular grid to give the required rate of settlement.

This will allow the necessary settlement to allow removal of surcharge material after 2 years. Note yards will be flexibly paved and buildings piled, to allow for residual settlement.

Where foundation material has an insitu silt of depth up to 10m (e.g. Lagoon 7), there will be settlement of the insitu soils and the placed material,. Material will have to be placed in stages to allow soil stability to develop. It will require to be placed in a balanced fashion to allow wall structural stability to be generated and protected. As this material will derive from the stripping of the surcharge from Lagoons 1 to 6 by conventional earth works methods this work can be scheduled accordingly.

6.7.4 Capital Dredging

The development will require extensive dredging and it is estimated that up to 1.815million m^3 consisting of 1.705 million m3 of sediment during Stage 1 will be placed in lagoons 1 to 6 and a further 0.11 million m3 of sediment will be placed in lagoon 7 during Stage 3 .

Two types of Dredging will be utilised

- Trailer Suction Hopper Dredger(TSHD)
- Pontoon Mounted Backhoe Longarm Excavators

The first system is a self propelled vessel, fitted with suction pipes, suitable for use in very soft and soft soils and the dredged material will be hydraulically pumped into lagoons 1 to 3. The suction dredger can ensure minimal silt plume by removing a concise deep area of the softer material rather than wide shallow area.

The backhoe system will excavate the lower stiffer materials from the sea bed and load them onto barges. The back hoe will use a large volume laser directed closeable bucket which will not shed its silt load when rising through the water. Once in the barge, mixing with free water will be eliminated. The pontoon will be towed onto position. The barges will transport the dredged soils to the initial section of commercial quay where materials can be loaded into dump trucks to allow placement in the lagoons as per Section 4.5.2.6. The internal haul roads required for distribution of the materials into the lagoons s have been designed as the bund walls.

Dust suppression on haul roads will be required at this stage.

6.7.5 Dredging Monitoring

An environmental monitoring program will be adhered to throughout the works. Monitoring of suspended substances concentration, effects of velocity and direction of water currents and measurements of turbidity, noise and vibration will be undertaken. Turbidity meters will be installed at dredge sites to record and indicate appropriate working conditions over water to ensure that dredging is controlled as proposed in Section 4 of the EIS.

6.7.6 *Construction Monitoring*

Prior to commencement of construction instrumentation will be installed to monitor the response of the alluvium to the construction processes. Instrumentation will include piezometers, inclinometers, and settlement plates. Instruments will be installed within the lagoons in a grid pattern and outside lagoon bunds prior to commencement of construction works The measurements taken will facilitate the safe construction of the works and enable a comparison between design geotechnical parameters and the actual response of the soils to the works.

6.7.7 *Maintenance Dredging*

Maintenance Dredging will be required at the following locations:

i) The newly dredged channel to the old port.

The new channel to the old port will have the benefit of increased velocities at low tide which will help keep suspended solids from settling hence it will have a reduced maintenance dredging volume requirement when compared to the existing channel.

ii) The new channel to the new commercial port, turning circle, commercial berths and fishing pier berths

The new channel to the new commercial port will also have the benefit of increased velocities. The maintenance dredging required for the new turning circle, commercial berths and fishing pier berths will have short term I localised negative Impacts similar to those that already occur.

6.8 IMPACTS AND MITIGATION

6.8.1 *Impact:*

Potential impacts from dredging comprise the release of suspended solids into Galway Bay, with associated siltation on seabed as well as the potential release of contaminants from Increased Suspended Sediment Concentrations during Dredging

Discussion and Mitigation:

Turbidity meters will be positioned at dredge sites to record and control appropriate working over water in order to ensure that dredging is controlled as proposed in Section 4.5 of Volume 2B Part 1 of the EIS.

Proposed Land reclamation works involving the construction of lagoon walls lined internally with geomembrane will act as fixed silt curtains and will contain the dispersion of suspended sediments when being pumped as land reclamation material within the marine environment.

Sediment Granulometry and Chemistry Analysis indicates that there are no reasons to suggest that mobilisation of deep sediments will impact the water or sediment quality during the dredging operations. Chapter 8 (section 8.4.2) of Part 2 of Volume 2B of the EIS details the sedimentology study that has been undertaken for the proposed development.

6.8.2 Impact:

Dust Emissions and Release of H_2S during land reclamation works

Discussion and Mitigation:

Chapter 9 of Volume 2B Part 2 of the EIS addresses the impact of the proposed development on air quality including airborne pollutants and dust emissions.

Hydrogen Sulphide release will be controlled by alternating placement of materials into different lagoons in accordance with weather conditions and wind direction On excavation of silts, odours are given off by decomposing organic matter. These odours, although initially quite pungent, rapidly reduce as soil aerates. Discharge points for suction dredged materials will be established at a number of locations to facilitate the distribution of materials within the lagoons. Where suction dredged and excavated materials are deposited directly into water it is considered that odours generated will be limited. Above the tidal level materials will be placed in the dry and subject to evaporation and desiccation. To control dust the top surface of the materials will be sprayed as necessary with water to suppress the generation of dust.

Haul roads will be water sprayed to control dust and will be surface dressed prior to operational use.

An odour management plan will be implemented during the construction phase, using resident data, meteorological data and site operator knowledge to mitigate potential odour issues and implement remedial action using a developed strategy. The management plan will include but will not be limited to odour monitoring proposals, odour control mechanisms and responses to any odour complaint procedures.

During construction of lagoons above tidal level, dust suppression will be accomplished by damping the deposition surface with seawater. The top surface of the surcharge layer will be reprofiled and trimmed to facilitate surface water runoff prior to the placement of the drainage layer/work platform for the vertical drains.

A site dust monitoring programme will be put in place during the construction phase with secure monitoring locations to ensure compliance with dust deposition limits. A dust management plan will be implemented during the construction phase, using resident data, meteorological data and site operator knowledge to investigate any dust complaints/potential dust complaints and implement remedial action using a developed strategy.

The soils, having relatively high silt content will 'bake' when drying out and will not lead to wind blown dust unless disturbed by traffic. These soils will not be trafficked until they have stabilised and are being reworked to final formation levels and being covered with yard base material.

6.8.3 *Impact:*

Sediment suspension by Propeller Wash

Discussion and Mitigation:

The sediment re-suspension due to an increase in leisure craft during the operational phase will be a minimal impact as the great majority of these vessels have a draft considerably less than the -3.5m C.D. new channel. The larger commercial vessels will be operating in deeper water than they currently do as they will not have to enter the old port. For this reason, it is considered that the propeller wash will not re-suspend the sea floor sediments as much as presently happens. For this reason the operational phase of the port is not seen as having any additional impact on sediment re-suspension. Section 8.4 of Chapter 8 of Volume 2B Part 2 of the EIS details the hydrodynamic and sediment modelling for the proposed development.

6.8.4 *Impact:*

Alteration to current directions at the proposed development site resulting in a shift of existing erosion and deposition sites

Discussion and Mitigation:

The current direction is not expected to be significantly altered resulting in low potential impact severity. Section 8 .4 of the EIS details the hydrodynamic analysis that has been undertaken for the proposed development.

6.8.5 Impact:

Sediment Re-suspension by Maintenance Dredging Operations

Discussion and Mitigation:

The sediment re-suspension due to maintenance dredging will be of a low impact severity. The dredging expected will not be of a significant quantity. It will be sediment which will have been deposited through tidal and hydrodynamic processes. The most recent maintenance dredging volume at the existing port was 65,000 m^3. As detailed in Section 8.2 of the EIS, since there will only be the same amount of sediment or less coming in from the river/sea, the rate of deposition will be at most the same as it is at present. With the Mutton Island causeway in place and the sewage pipes shut down both in the Corrib River, and off South Park, the sediment loadings will be somewhat less than in previous years. This in turn suggests a slower build-up of material within the proposed development area over time than is the case at present.

The New Channel to the old port will be relatively self cleansing and the new channel to the new port is largely screened from river alluvium.

6.9 CONCLUSIONS

The Geology underlying the proposed Harbour Extension consists of Alluvial and Glacial soils above competent bedrock. Overwater investigations identified no anomalous or exceptional ground condition that would preclude or constrain the construction of the project

The results of the investigations were incorporated into the design to optimise the re use of materials and minimise rock excavation.

The proposed design incorporates a beneficial use of dredged sediments for fill and surcharge. The design facilitates the re-use of all dredged soils for land reclamation purposes. Rock excavated within the site will be incorporated into the construction of lagoon walls and quays.

The development will enhance the current understanding of the quaternary and bedrock geology in the eastern part of Galway Bay

The proposed design has been developed to satisfy the following requirements:

- Removal of soils from over rock to curtail soil disturbance from the drilling, blasting and removal of rock.

- Minimum rock dredge with appropriately controlled drilling, blasting and rock excavation as per the noise and vibration limits detailed in Chapter 10 of Volume 2B Part 2 of the EIS.
- Balance of sediment dredging and re-use as land reclamation.
- Minimum release of suspended sediments to sea by the implementation of suitable construction methods and practices thereby ensuring Minimum impact on the surrounding Galway Bay Environs.
- Practical phasing of development which best suits the methodology of construction regarding lagoons, dredging and quay construction.
- The working of soils as proposed will not have a significant impact on the waters where work will be undertaken.

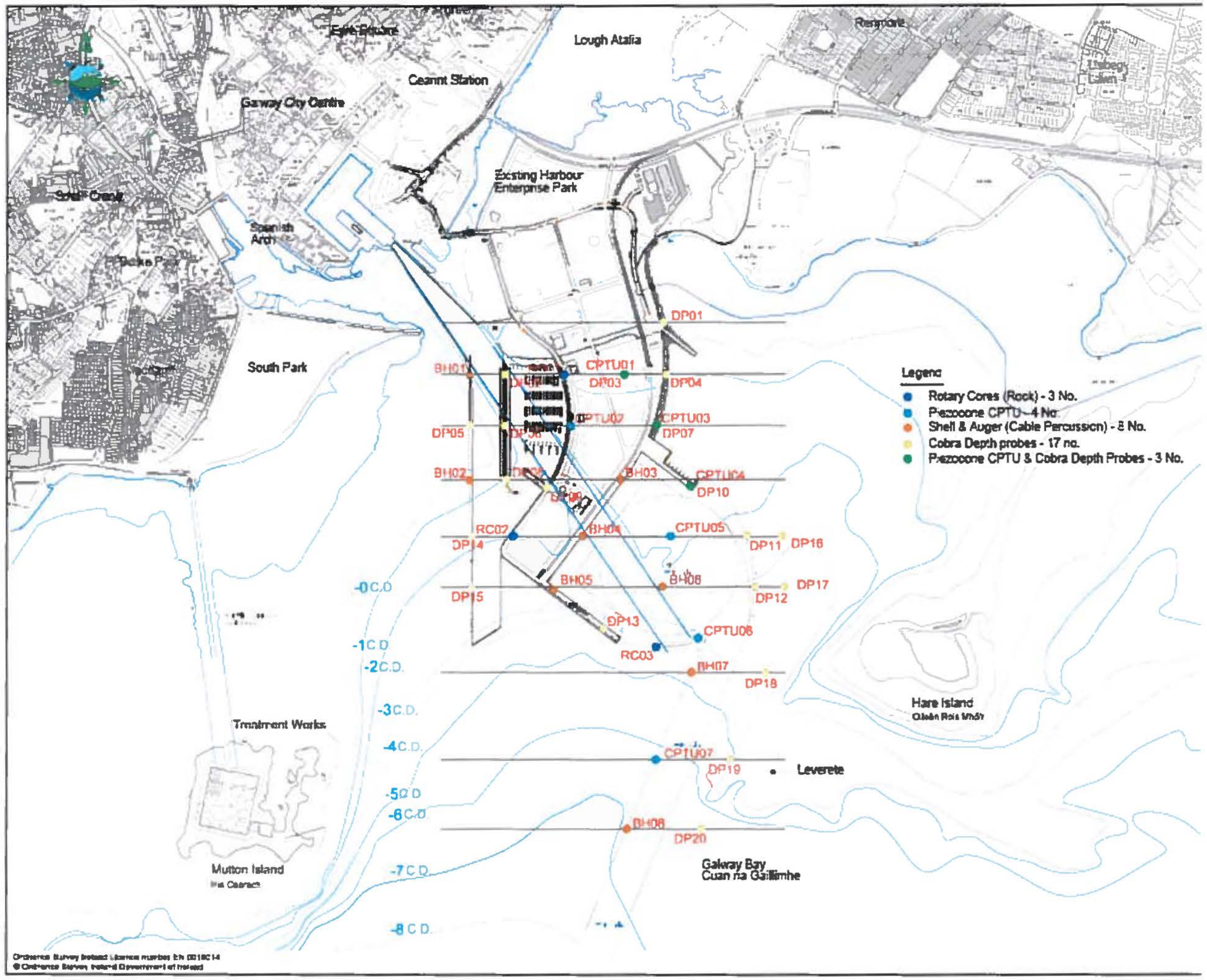

Figure 6.3.1 - Borehole Layout

Figure 6.9.2 - Vicinity of Proposed Harbour - Extract from Geology of Galway Bay, Geological Survey of Ireland 2003

Figure 6.9.3 - Aerial Photography at low water level showing existing features and outline of proposed development