Leixlip Road Wall, Lucan

Ground Investigation Report

LRRW-ROD-SRW-AE-RP-CE-50002
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Leixlip Road Wall, Lucan

Ground Investigation Report

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1.0 EXECUTIVE SUMMARY

Roughan & O'Donovan (ROD) has been commissioned to provide Geotechnical Consultancy Services for the assessment of the soil condition in the vicinity of a retaining wall that supports the regional road R835, near the village of Lucan in County South Dublin. This commission was due to the collapse of a section of this wall.

The area of interest is located approximately 50 meters to the South of the River Liffey, which runs parallel to the retaining wall. The wall was constructed to develop the local route and separate it from the estate of the Italian Ambassador's residence, which is on the banks of the River Liffey.

The existing information shows that the area is locally underlain by Alluvium, which is obscured by the Made Ground present, however the majority of the soil deposits beneath these comprise the glacial tills derived from Limestone and some associated end-glacial meltwater channels. Localised rock outcrops or subcrops are also identified in the vicinity of the site.

Geological maps indicate that the area is underlain by Lucan Formation, described as dark limestone and shale. Additionally, a fault is present approximately at than 100m to the East of the collapsed wall.

The land use of the site is substantially different at each side of the wall. At the South there is urban land, and to the North there is a private residential green area and a parkland, next to the riverbank. A spring was observed near there during a walkover survey.

Available information on flooding records showed the nearest previous flood events were approximately 500m to the East of the area of interest. Topographical survey drawings show that most susceptible areas to flooding near the zone of study are the low areas located at the North of the River Liffey.

An Emergency Inspection of the existing retaining wall was done by ROD in June 2019, commissioned by South Dublin County Council after its collapse. Successive walkover surveys were undertaken by ROD's geotechnical team.

For the purposes of this Ground Investigation Report a ground investigation campaign was conducted at the site in 2021 which consisted of 2 no. boreholes (cable percussion and drilling methods), 3 no. trial pits and 1 no. slit trench. 3 no. SPT tests and 1 no. Indirect CBR test were performed.

The laboratory tests undertaken are Natural Moisture Content, Atterber Limits, Particle Size Distribution, Organic matter content, Suites E, F, H and I and Environmental WAC tests.

The fieldworks executed revealed that the site is underlain by Limestone interbedded with weak thinly laminated Mudstone, which is characteristic of the Lucan (or Calp) Formation.

The area at the North of the wall is characterized by vegetation and the soil description is topsoil on top of soft clay (Made ground). The ground at the South of the wall, where the soils are retained, is composed of firm to stiff clay (Made ground) followed by very stiff Glacial till. The environment at this area is urban.

At both sides of the wall the Made ground was found up to 1.3m depth. Under this depth, glacial fine-grained till was found at the Southern side up to 5.0m depth, overlaying on Limestone bedrock.

Soil chemistry, and its influence on design, have also been assessed. The site was assessed for Aggressive Chemical Environment for Concrete (ACEC) classification for natural ground. The Water Soluble Sulphate results give a Design Sulphate class of DS-1. The pH values, assuming mobile groundwater conditions would give an ACEC Classification of AC-1.

2.0 INTRODUCTION

2.1 Scope and Objective of the Report

South Dublin County Council commissioned Roughan & O'Donovan to provide Geotechnical Consultancy Services for the assessment of the soil condition in the vicinity of a retaining wall that supports the regional road (R835) near the village of Lucan in County South Dublin. Previously, an emergency inspection was commissioned to ROD in June 2019 after a section of this retaining wall collapsed.

This Geotechnical Interpretative Report (GIR) has been produced following the completion of a Geotechnical Investigation.

The scope and objectives of this GIR are as follows:

- To present a summary of the available desk study information;
- To present the geotechnical information relevant to the area of interest;
- To evaluate the geotechnical information based on the site investigations stating the assumptions made in the interpretations of the available data and the limitations of the results.

This GIR has been produced in accordance with the recommendations in TII Publication DN-ERW03083 'Managing Geotechnical Risk' (Transport Infrastructure Ireland, 2019).

2.2 Description of the Project

Figure 1 shows the location of the site:

Figure 1 Site location on aerial image (Google Maps, 2021)

2.3 Geotechnical Category of the Project

The Geotechnical Category for this project, which will consist on the reconstruction of the retaining wall, is considered to be "2", in accordance with Eurocode 7: Geotechnical Design – Part 1: General Rules.

3.0 EXISTING INFORMATION

3.1 Topographical Maps

ROD reviewed the available topographic survey drawings and also consulted the topographical survey data from the following website: https://en-ie.topographic-map.com/maps/5h/Ireland/

The site is divided by the retaining wall alignment, which retains the soils from an urban environment at the South of the wall. The area at the North is a private residential green area comprising mature woodland and vegetation as a residential parkland amenity, and the difference in level between both areas at each side of the wall is approximately 2m. The natural area at the North slopes down to the North towards the River Liffey, that runs parallel to the structure.

Figure 2 Topographical map

3.2 Geological Maps

3.2.1 Reference

ROD reviewed the Geological Survey of Ireland online data viewer at 1:50,000 scale to obtain an overview of the superficial deposits, geomorphology and bedrock geology within the region.

3.2.2 Superficial Deposits

The type of superficial deposit shown by the GSI website under the area of interest is mainly Alluvium, underlain by glacial Till derived from limestones. The mapping also indicates that localised rock outcrops or subcrops occur in the vicinity of the area of interest, to the east and across the river to the north, associated with faulting in the bedrock formation. Figure 3 shows these superficial deposits.

Figure 3 Quaternary Sediments (Source: Geological Survey of Ireland webpage, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

These soils are expected to reach greater depths - deeper bedrock- below the areas along the river, coinciding with the Alluvium locations, based on the vulnerability map from the Geological Survey of Ireland. Shallower bedrock could be expected to the South of Leixlip Road and Dublin Road.

3.2.3 Geomorphology

ROD reviewed the geomorphology layer on the GSI online data viewer.

The location and route of the River Liffey is considered to be a function of the faulting in the underlying bedrock. Two meltwater channels leading into the River Liffey are indicated in Figure 4. These channels were mainly formed when the original channel of the river was blocked by ice. Meltwater builds up behind the blockage and, once the pressure is released, the energy causes the river to erode vertically, creating rapidly-eroded meltwater channels. Subsequent alluvial deposits may infill them so the material classified as undifferentiated (as in the deposits are neither classified as cohesive silt/clay nor cohesionless or granular sand/gravel).

Figure 4 Quaternary Geomorphology (Source: Geological Survey of Ireland webpage, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

3.2.4 Bedrock Geology

ROD reviewed the GSI Bedrock Geology map at 1:100,000 scale. The area is underlain by Lucan formation, described as dark limestone and shale. The formation comprises dark-grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey. This has also been referred to as Calp Limestone. There are rare dark coarser grained calcarenitic limestones.. The formation ranges from 300m to 800m in thickness.

A fault is also present at less than 100m to the East of the collapsed wall. Figure Figure 5 shows the location of this fault.

Figure 5 Bedrock Geology Map (Source: Geological Survey of Ireland webpage, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

3.2.5 Aquifers

Information on Groundwater resources (aquifers) was consulted in the GSI website for the area of study and its surroundings. Figure 6 shows that there is a Locally Important Aquifer – Bedrock which is moderately productive only in local zones. It also shows a bedrock aquifer fault approximately at 100m to the East of the area of study.

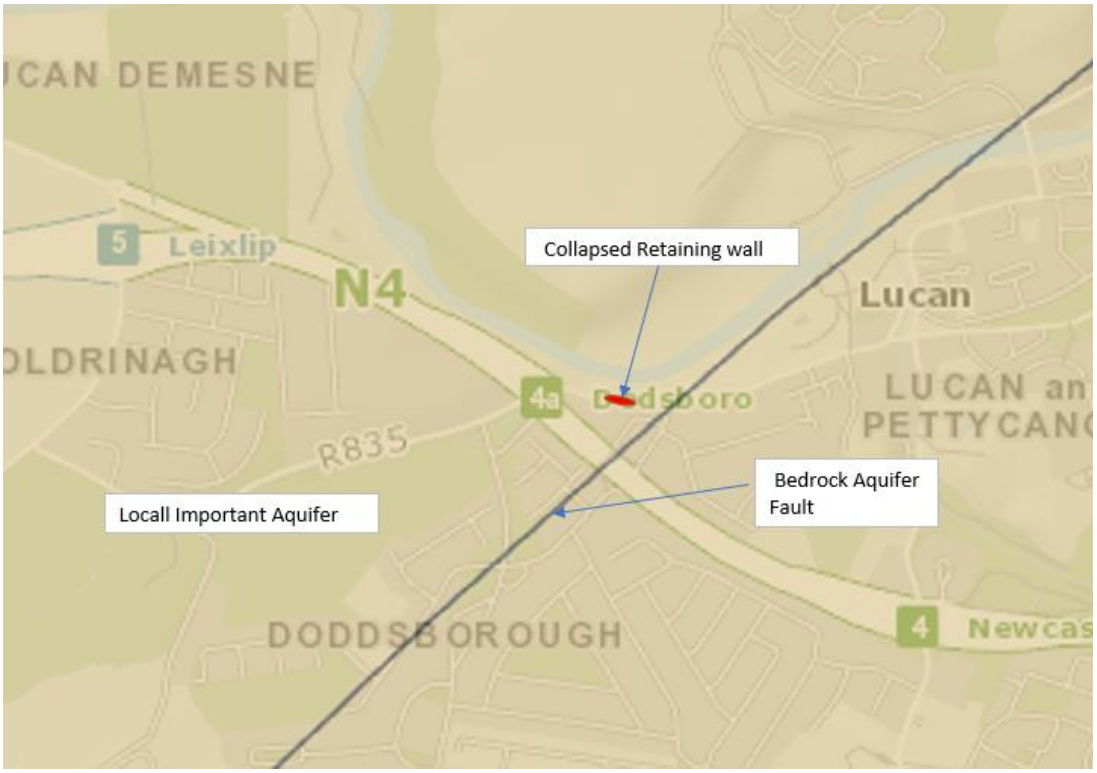


Figure 6 Groundwater resources Map (Source: Geological Survey of Ireland webpage, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

3.3 Records of Mines and Mineral Deposits

There is a quarry near the site of study which has potential to be utilised in the sourcing of fill material, if required by the design solution adopted. It is called Belgard Quarry, located in Fortunestown, Tallaght.

There are some mineral deposits near the site. In these locations some of the key materials that are identified are limestone, dolomite, clay, pottery, iron, galena, lead and brick.

3.4 Land Use and Soil Survey Information

The land is clearly divided by the layout of the retaining wall, where urban land is to the South side and a private residential green area and parkland are to the North of the wall. To the North of the site there is also the River Liffey, with its riverbank, approximately 40m distance from the structure.

3.5 Archaeological and Historical Information

The following historical map was obtained from Geohive website.

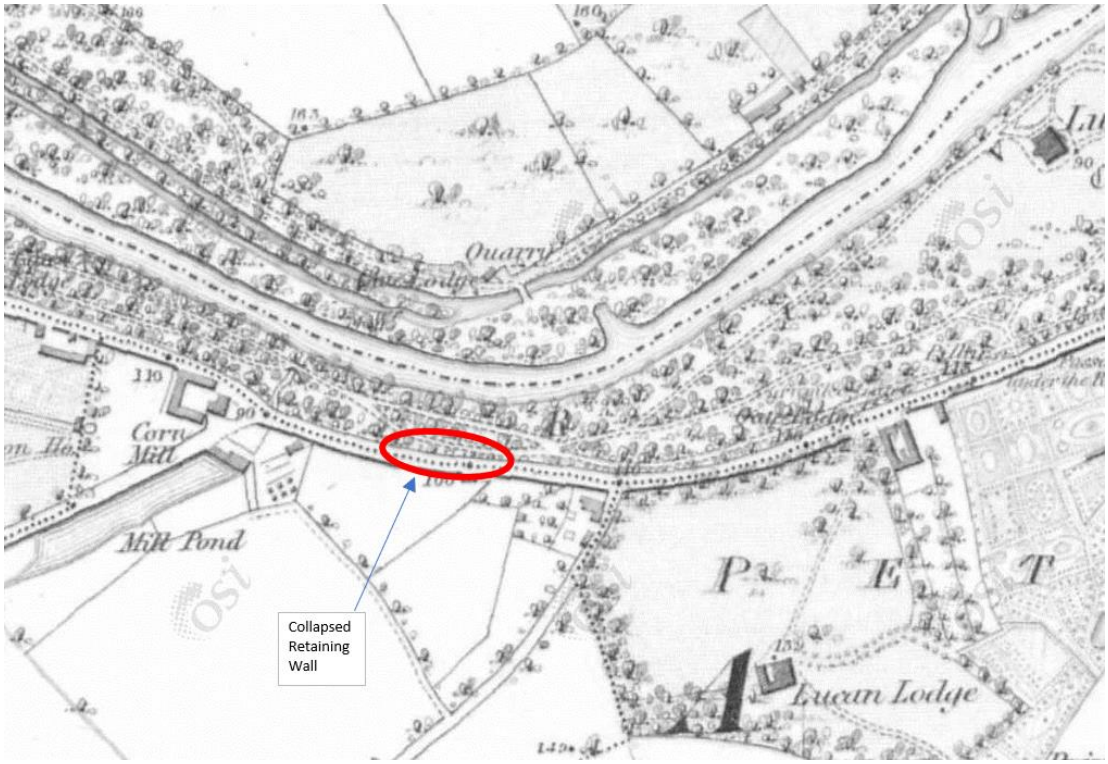


Figure 7 Historical map 6" Ordnance Survey of Ireland, First Edition B&W (Source: Geohive webpage)

3.6 Existing Ground Investigations

The Geological Survey of Ireland Spatial Resources website was consulted in order to identify the previous ground investigations carried out near the area of interest. A campaign was undertaken at Crowes Corner, Lucan, at the junction of the Celbridge Road and the main Dublin-Galway road, for the purposes of constructing a bridge on the site to support the proposed Lucan By-Pass that would over-pass the Celbridge Road at this point.

The report and trial pit logs in particular show that these ground investigation works were undertaken in 1985 by IGSL. The investigations were requested by Mc Carthy and Partners Consulting Engineers to inform the design of the N4 Lucan Bypass traversing steep ground between the existing road and the nearby hotel lands adjacent to the nearby stream. Figure 8 shows the location of these works, approximately 100m to the West of the area of study.

Figure 8 Earlier investigations near the site (Source: Geological Survey of Ireland webpage, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

The scope of the fieldwork that was performed in 1985 is as follows:

- 11 No. Cable percussion holes;
- 3 No. Rotary core holes;
- SPT tests were performed in boreholes;
- 2 No. Trial pits;
- 4 No. 100mm Standpipes were installed.

No map showing the location of each specific hole was available in the consulted documents.

3.7 Consultation with Statutory Bodies and Agencies

Communications with Dublin South County Council were held for coordination of the works. Also, communications with the owner of the area at the northern side of the retaining wall, the residence of the Italian Ambassador, were predominantly arranged by South Dublin County Council via Italian Embassy and the Department of Foreign Affairs, in order to grant access to his site to undertake the relevant investigations.

3.8 Flood Records

The mapping of historical flood events in the area sourced from OPW Flood Hazard Mapping (Office Public Works), as shown below in Figure 9, gives a general indication, based on reported past flood of locations vulnerable to flooding.

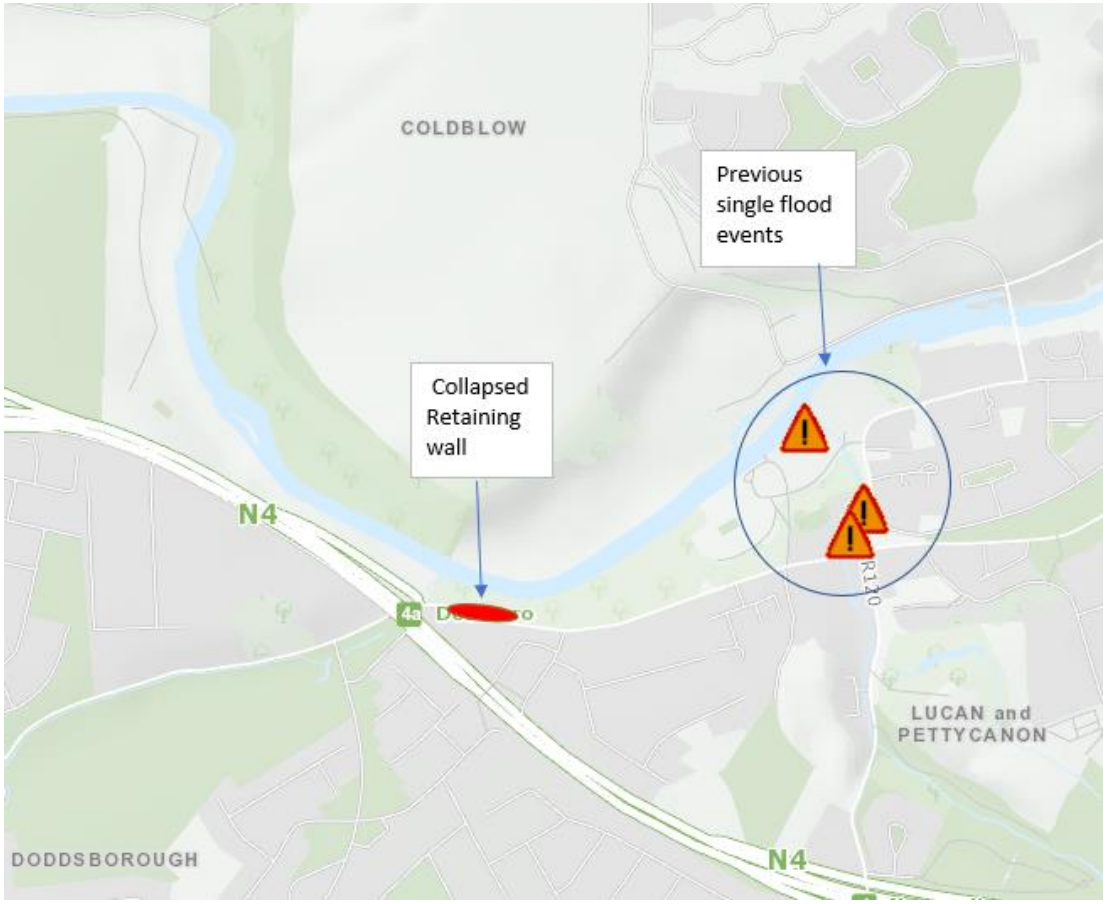


Figure 9 Previous flood events (Source: OPW © Office of Public Works, Contains Ordnance Survey Ireland information © Ordnance Survey Ireland)

Three previous single flood events are recorded approximately 500m to the East of the area of study.

Topographic survey drawings show that low areas, susceptible to flooding, are generally found at the northern side of the river, as well as in the zone where previous single flood events were recorded, as shown above in Figure 2.

3.9 Contaminated Land

A search of the EPA website (Environmental Protection Agency, 2019) was carried out. Following this search, sources potentially likely to cause ground contamination have not been found from any previous industrial activity. However, it is noted that a fuel station is present next to the site, which suggests that there is some low risk for contamination under the present soil surface.

3.10 Other Relevant Information

3.10.1 Seismicity

The site is not in a seismically active area.

3.10.2 Hydrology

The site is adjacent to the River Liffey, which runs parallel to the retaining wall, approximately 40m to the North.

There is a stream of water that flows next to Celbridge Rd and falls into River Liffey. The stream passes approximately 100m to the West of the site of study.

3.10.3 Natural Cavities (Karst)

GSI karst database (Geological Survey of Ireland) does not show any indication of karstification at the site or in the immediate vicinity of the site, however, a spring was observed during a walkover survey below the site, associated with the faulted bedrock. It is not considered that it could constitute a possible karst feature. The nearest karst feature to the site identified by GSI data base is a spring which is shown approximately 2km to the Northwest of the site, at the North of Leixlip.

The historical ground investigations carried out near the site stated that the rock appears to be reasonably fresh and free from cavities. No evidence of karstification was found either in the ground investigations undertaken for this project.

4.0 FIELD AND LABORATORY STUDIES

4.1 Walkover Survey

An Emergency Inspection of the existing retaining wall was done by ROD the 19th June 2019, commissioned by South Dublin County Council after its collapse, prior to the removal of any of the debris to determine the condition of the structure.

Successive walkover surveys were undertaken at the site by ROD's geotechnical team in 2020 and 2021 during the ground investigation operations.

The following photographs have been included in this report to help visualize the area of study.

Photograph 1 Looking to the East. R835 Road with Traffic Management System in place during the ground investigations. Retaining Wall at the left side

Photograph 2 Looking to the West. View showing the location of the collapsed wall which is the boundary between the green land area and the R835 Road retained by the wall before its failure

Photograph 3 Retaining wall failure

Photograph 4 Looking to the South. Remaining retaining wall section

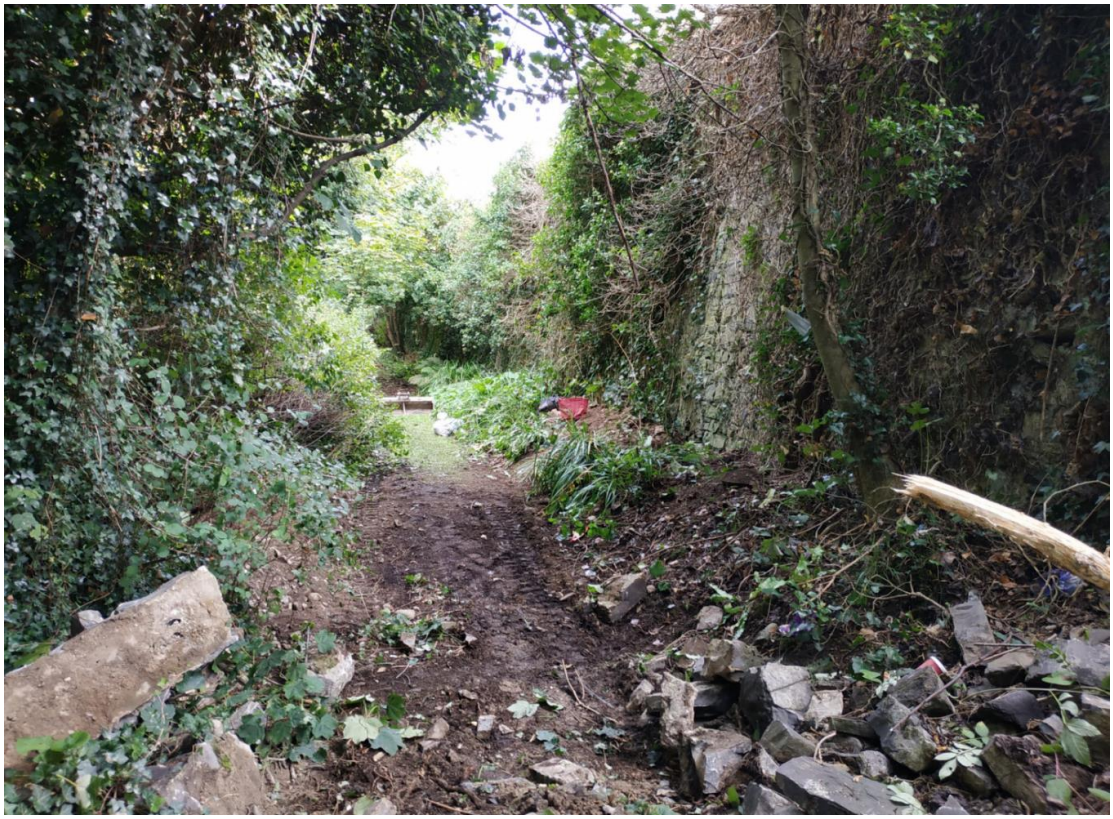
Photograph 5 Looking to the South. Collapsed retaining wall section

Photograph 6 Collapsed retaining wall section. Services exposed

Photograph 7 Collapsed retaining wall section. Services exposed

Photograph 8 Services exposed following collapse

Photograph 9 Looking to the West. The ground slopes down to the North towards River Liffey (image taken during ground investigations)



Photograph 10 Looking to the East. Remaining retaining wall section

4.2 Geomorphological/Geological Mapping

No project specific geomorphological or geological mapping has been carried out as part of field and laboratory studies.

4.3 Ground Investigation

4.3.1 Description of Fieldwork

The exploratory hole locations are shown in Figure 10 below. Results are discussed in Section 5.

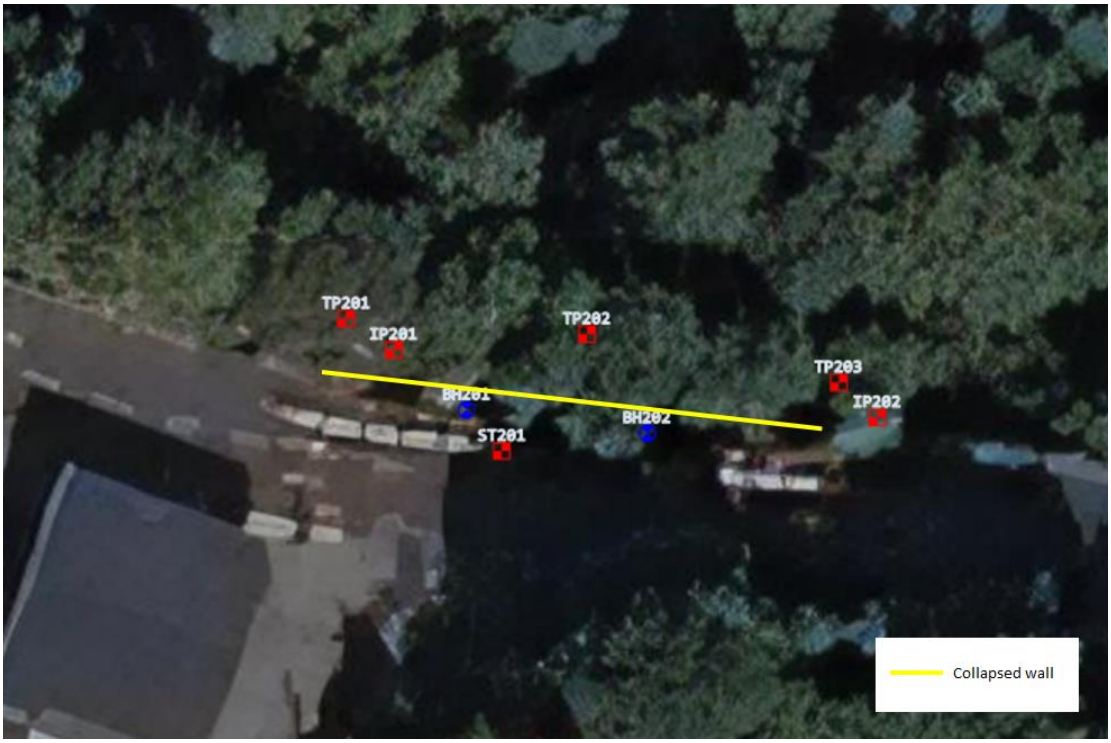


Figure 10 Fieldwork Exploratory holes

The ground investigations to date have comprised the following locations:

- 2 no. Boreholes, using dynamic (windowless) sampling methods and rotary follow-on methods.;
- 3 no. trial pits excavated by mechanical means;
- 1 no. Slit trench excavated by hand and mechanical means;

4.3.2 Factual Report

The factual report produced is: Lucan Road Retaining Wall Collapse – Ground Investigation. Report No. 20-1187 (Causeway Geotech Ltd, 2021).

4.3.3 Summary of results of in situ tests

The number of in situ tests are summarised in Table 11:

Table 1 Summary of In-situ Testing

Type	No.
SPT N Value (cable tool & rotary borehole)	3
Indirect CBR test (Dynamic Cone Penetrometer)	1

4.4 Drainage Studies

No drainage studies were carried out as part of these ground investigations.

4.5 Geophysical Surveys

No geophysical surveys were scoped or done.

4.6 Pile Tests

No pile tests have been specified or undertaken for this project to date.

4.7 Other Fieldwork

4.7.1 Groundwater Monitoring

A groundwater monitoring standpipe was installed in one borehole. Two readings have been made available to date. The first reading was done on the 15th December and the second reading on the 12th of January. The result for both cases was "Dry". Further readings may be taken during the next months.

No water strikes were noted in any of the exploratory holes carried out.

4.8 Summary of Results of Laboratory Investigation

4.8.1 Description of Tests

Soil testing included:

- Soil classification: moisture content measurement, Atterberg Limit tests and particle size distribution analysis;
- Soil Chemistry: organic matter content;
- Environmental: Suites E,F,H and I.

No rock testing was undertaken.

Laboratory testing was conducted in accordance with: British Standards Institute BS 1377:1990 parts 2, 4, 5, 7 and 9.

4.8.2 Summary of Tests Results

Table 2 Summary Laboratory Testing – Soils

Type	No.
Natural Moisture Content (NMC)	2
Atterberg Limit	2
Particle Size Distribution (PSD)	2
Organic matter content	3
Suites E, F, H and I	11
Environmental WAC Tests	2

5.0 GROUND SUMMARY AND MATERIAL PROPERTIES

5.1 Ground Summary

The site is underlain by Limestone interbedded with weak thinly laminated Mudstone. No karst features are present in the area of study. The type of soil encountered on site is different for the areas located at each side of the wall. To the North side of the wall, the lower ground level soils are composed of topsoil underlain by soft clay (potentially a mixture of alluvium or reworked glacial till and made ground). To the South of the wall there is Made ground associated with the roadway and footpath surfacing being retained at the higher ground level. The underlying soil is composed of firm to stiff clay (Made ground) followed by very stiff Glacial till. Rock was only found at the southern side, at depths of 4-5m.

5.2 Soil Types

Figure 11 shows a sketch of the general composition of the ground

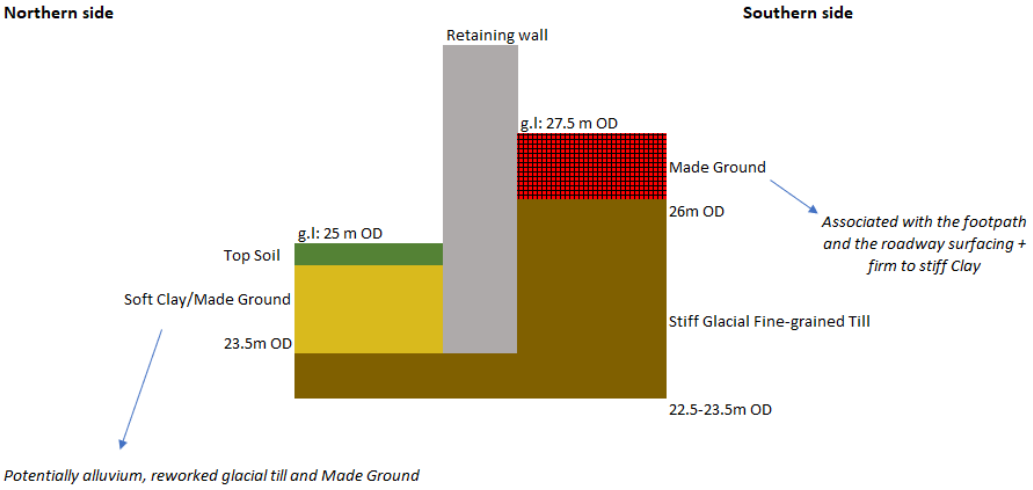


Figure 11 General composition of the ground

Geotechnical parameters are discussed in Section 5.3 below and moderately conservative parameters are indicated in Table 34 and Table 4.

5.3 Material Properties

The following subsections cover each defined soil type separately and for each soil type the relevant geotechnical parameters are discussed. The typical range of test results and suggested moderately conservative values of materials are summarised in in Table 34.

5.3.1 Topsoil

Topsoil is only present at the northern side of the structure, as this is the area where vegetation is fully present. It is described to contain grass and rootlets, and the typical thickness is 0.2m.

No assessment of engineering properties has been undertaken for topsoil materials.

5.3.2 Made Ground

Made ground was encountered at both sides of the retaining wall and its composition and properties is different at each side.

- To the North of the retaining wall:

Made ground is found under the topsoil and potentially it is alluvium or reworked glacial till. It appears at a typical level of +25.0m OD and its proven depth is 1.6m. It is typically described as soft brown sandy, gravelly slightly silty CLAY. Under 0.6m depth it becomes firm and its cobble content increases from low to medium.

- To the South of the retaining wall:

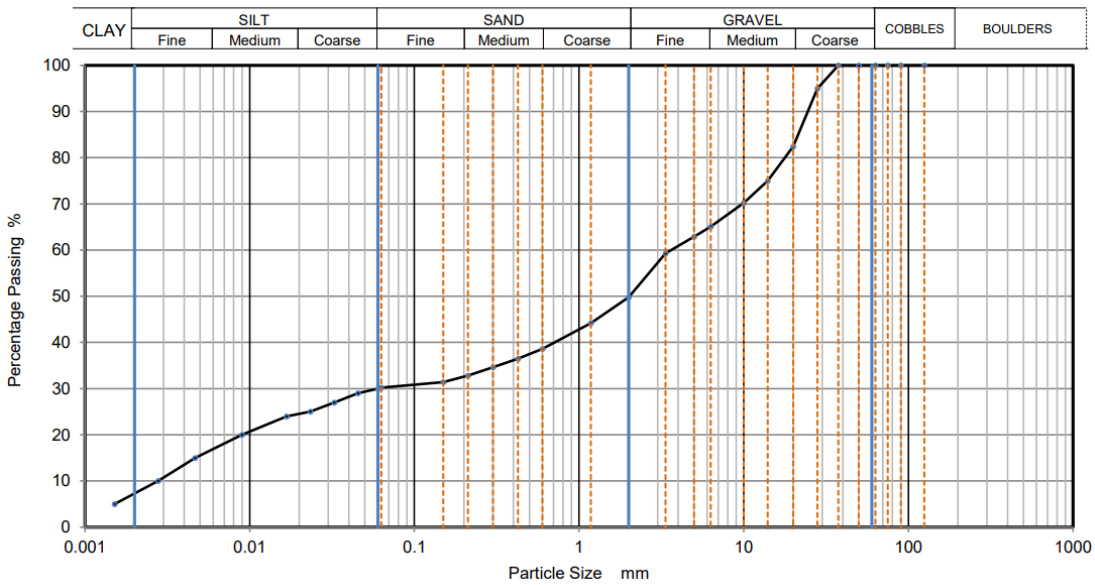
Typically at +27.5m OD. This soil is associated with the roadway and footpath surfacing and the firm to stiff clay present below. The composition of this soil is the following: Bitmac is present at the top 0.1m, followed by another 0.1m of grey sandy GRAVEL of mixed lithologies. Below this layer, up to 1.3m depth, there is a layer of firm to stiff slightly sandy gravelly CLAY with low cobble content, however, a layer of Lean mix concrete can also be present to a depth of 0.9m, as shown by BH202.

5.3.2.1 Geotechnical Testing and Parameters

Classification

A Particle Size Distribution test was undertaken for a sample obtained from the inspection pit IP202, at the northern side of the structure, at a depth of 1m, for which the log describes it as "MADE GROUND: Brown sandy gravelly silty CLAY". Figure 1211 shows the representation of the results of this test.

Figure 12 Particle Size Distribution chart



This chart shows a diverse composition of particle sizes. The chart shows a total fine content of 30%, most of it being Silt. The rest of the particles are sands and gravels, the latter with a total content of 50%.

Atterberg classification indices were obtained for two samples from two inspection pits at the northern side of the wall, both of them at 1m depth, where the soils were described as MADE GROUND: brown, sandy silty gravelly clay. The Liquid Limit

values are 40% and their Plasticity Index values are 17%. Their moisture content is 10 and 12%.

Organic Matter

Three organic matter tests were carried out at the northern side of the wall, all of them at 0.5m depth, where the soils are described as MADE GROUND: Soft light greyish brown sandy gravelly CLAY with low cobble content. The result values of the tests are 5.7, 1.9 and 1.4% of organic matter content. These tests were carried out in accordance with British Standards Institute BS1377, Methods of test for soils for civil engineering purposes; Part 1 (2016), and Parts 2-9 (1990).

Strength

Due to the minor available data a conservative approach for the assessment of design parameters for these localised soils has been assumed based on the available tests and the exploratory hole descriptions.

For the short term behaviour, a characteristic undrained shear strength of 40kPa has been adopted for the backfill made ground at both sides of the wall

A characteristic angle of shear resistance ϕ' of 29 degrees has been conservatively adopted for the backfill made ground at both sides of the wall.

Compressibility

No Oedometer tests were undertaken. A conservative approach has been followed assuming that the backfill made ground at both sides of the retaining wall can be considered reworked alluvial soils. From this consideration a characteristic Volume change coefficient of 3 m2/MN and a Coefficient of consolidation of 2 m2/yr have been adopted after reviewing a published reference on Irish alluvial soils called "Limerick Tunnel Approach Roads -Design, Construction and Performance, by Fintan Buggy and Eamon Curran (2011)".

Indirect CBR test (Dynamic Cone Penetrometer)

An indirect CBR test was conducted at the location of the slit trench (ST201), at the south side of the retaining wall. It was done using a Dynamic Cone Penetrometer (DCP), at 0.85m depth, where the soil was described as MADE GROUND: firm to stiff greyish brown slightly sandy gravelly CLAY with low cobble content and fragments of red brick, concrete and plastic. The results indicated the increase of stiffness with depth, up to almost 1.4m. The CBR values were derived from Kleyn & Van Heerden (1983) with the following expression:

$$\text{Log CBR} = 2.48 - 1.057 \text{ Log (mm/blow)}$$

The CBR values obtained are greater than 5% for all depths tested.

5.3.3 Glacial fine grained till

Glacial fine grained till are found, at the southern side of the structure, overlaying rock and below firm to stiff made ground. It reaches an approximate depth of 5m, or an approximate level of +22.5m OD. They are described as: very stiff brown sandy gravelly CLAY. It is suspected that they are also at the northern side, probably under a layer of alluvial soils and under the encountered made ground. These are soils formed as a consequence of glacial compressive and moving action over them for long periods of time during ice ages. Consequently, glacial fine grained till are

typically found as over consolidated and include all types of grain sizes. They typically show high bearing capacities and low compressibilities which make them a suitable material for road and structures construction.

5.3.3.1 Geotechnical Testing and Parameters

Classification

No classification tests were conducted for these soils. The soil descriptions from the logs indicate a diverse composition of particle sizes being Clay the main one.

Strength

Three Standard Penetration tests were performed during the execution of the two cable percussion holes, at the southern side of the wall. They were done at 2.5 and 4.0m depth, where clays were encountered, and the results are N values of 50 for the three tests done, being therefore very stiff clays.

No other strength tests were carried out.

As not enough geotechnical information is available to establish empirical relationships with different tests a conservatively moderate value has been estimated based on the SPT tests, the amount of test results obtained and the knowledge from previous experience. An undrained shear strength value of 150 kPa has been adopted for this type of soil.

Long term effective shear stress parameters, likewise, has been selected based on general experience with these type of soils, as not enough geotechnical data is available. A characteristic angle of shear resistance ϕ' of 32 degrees has been conservatively adopted.
For the moderately conservative approach, a c' of 0 kPa is adopted.

Compressibility

No oedometer tests were conducted. No compressibility parameters can be derived as not enough geotechnical data has been obtained for this type of soil. These parameters have been conservatively adopted based on general knowledge of this type of soil:

-Volume change coefficient, M_v: 0.1 m^2 /yr

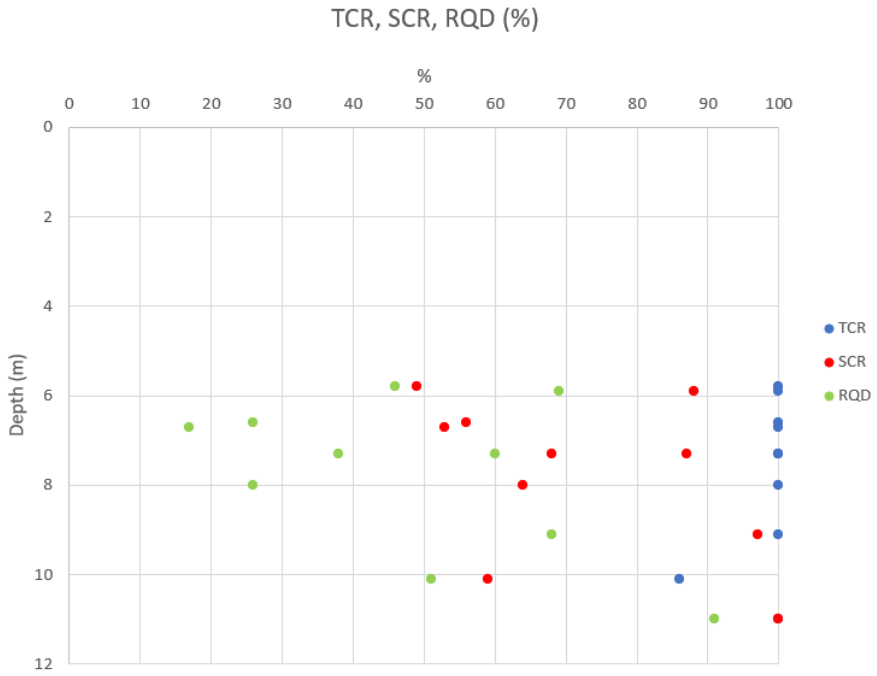
-Coefficient of consolidation: C_v: 2.0 m^2 /yr

5.3.4 Rock

Rock has been found at the southern side of the retaining wall, under the glacial fine grained till, at an approximate depth of 5m, approximately at a level of +22.3m OD. Its depth has been proven up to 11.5m (+15.7m OD) The main type of rock encountered is Limestone, and it is interbedded with Mudstone. It is described in the logs as: medium strong thinly laminated dark grey LIMESTONE interbedded with weak thinly laminated dark brown calcareous MUDSTONE, with occasional white calcite veins of various orientations (1-5mm thick). It is partially weathered: slightly reduced strength, closer fracture spacing, orangish brown discolouration on some fracture surfaces. The bedding fractures are closely spaced, planar and smooth to rough. The joints are planar to undulating and smooth.

Figure 1312 presents the Total Core Recovery (TCR), Solid Core Recovery (SCR) and the Rock Quality Designation (RQD) data for the rock encountered at the two boreholes.

Figure 13 TCR, SCR and RQD vs Depth



The figure shows that all rock cores, except one, has an TCR value of 100%. Almost all the cores have an SCR greater than 50%, 40% of these samples recorded values over 85% (average of 72%). All RQD values are very scattered from 16% to 91% (average of 49%).

Table 3 Moderately Conservative Parameters for Soils

Material	Typical Description	Geol. Code	Depth BGL	Classification			Strength				Deformation	
				BD	NMC	PI	N	c_u	c'	ϕ'	m_v	c_v
				KN/ m^3	%	%	Value	kPa	kPa	degrees	m^2/MN	m^2/yr
Made Ground – Northern side	Soft to firm brown sandy gravelly slightly silty CLAY with low/medium cobble content	**MG**	**1.6**	18	11	17	-	*40	0	*29	3	2
Made Ground – Southern side	Firm to stiff brown slightly sandy gravelly CLAY with low cobble content	**MG**	**1.3**	19	-	-	-	*40	0	*29	3	2
Glacial fine grained till	Very stiff sandy gravelly CLAY	**GF**	**5.0**	20	-	-	50	*150	0	*32	*0.1	*2

Notes: * Insitu / Laboratory testing data not available nor enough data for applying correlations. Values conservatively estimated based on experience with these soil types

Table 4 Moderately Conservative Parameters for Rock

Material	Typical Description	Geol. Code	Depth BGL	Classification			Strength				Stiffness, E_d	
				BD	NMC	PI	N	c_u	c'	ϕ'	Lower bound	Upper bound
				KN/ m^3	%	%	Value	kPa	kPa	degrees	GPa	GPa
Rock	Medium strong thinly laminated dark grey LIMESTONE interbedded with weak thinly laminated dark brown calcareous MUDSTONE	**R**	**-**	24							3	20

Notes: Insitu / Laboratory testing data not available nor enough data for applying correlations.

5.4 Soil and Groundwater Chemistry

Soil and groundwater chemistry, and its influence on design, will be assessed in accordance with the principles established in BRE Special Digest 1 (2005). The results of chemical testing are presented in Table 56.

Table 5 Chemical Analysis Results

	No.	Range of Test Values
pH	2	8.5 to 8.6
Sulphate SO4 Water Soluble	2	<0.010
Organic content	3	1.4% to 5.9%

The area at the North of the structure, for which relevant environmental test results are available, was assessed for Aggressive Chemical Environment for Concrete (ACEC) classification for green field. The design Sulphate and ACEC Class for the soils has been determined below based on Table C2 of BRE Special Digest 1.

All environmental tests were done for the Made Ground, as it is the only soil type encountered at this particular area. The Water Soluble Sulphate results give a Design Sulphate class of DS-1. The pH values, assuming mobile groundwater conditions would give an ACEC Classification of AC-1.

6.0 GEOTECHNICAL RISK REGISTER

Table 66 illustrates the geotechnical hazards that future works may suppose following different possible designs. It also includes the potential impacts and proposed design mitigations.

Table 6 Geotechnical Hazard and Risk Register

Geotechnical Hazard	Potential Impact of Geotechnical Hazard			Design Mitigation of Geotechnical Hazard			Comment
	Impact on Earthworks	Impact on Structures	Impact on Environment	Earthworks Mitigation	Structures Mitigation	Environmental Mitigation	
Low Shear strength.	Instability in slope sides and / or foundation, significant ground movements.	Instability of foundation excavation. Insufficient bearing capacity.	Failure of excavations and embankments impacting adjacent land and potential for pollution of watercourses.	Removal of soft and/or made ground. Use of stable slope angle, Monitoring using instrumentation.	Remove soft /made areas or adopt pile foundations.	Careful handling and placement of excavated material at stable angles in designated areas.	Contractor to adopt appropriate control and working methods.
High Strength Rock / Boulders in Till.	Unable to excavate or rip. Difficult to excavate.	Unable to excavate or rip for foundation. Limitations for some pile equipment.	Vibration, dust, noise.	Use of hydraulic breakers, blasting.	Use of hydraulic breakers, review foundation level. Check rig capabilities.	Follow required standards and legislation. Control within contract limits.	Contractor to adopt appropriate control and working methods.
High Groundwater / Flooding.	Damage to and instability of excavations, weakening of foundation soil.	Instability of excavations, weakening of foundation soil or erosion of fill/soils. Higher loading on retaining structures.	Flooding, siltation.	Maintain existing or Installation of new, drainage measures. Provide erosion protection.	Installation of drainage measures. Provide adequate protections against erosion / scour.	None. Low lying Areas already prone to flooding.	Contractor to adopt appropriate control and working methods.

7.0 PRELIMINARY DESIGN RECOMMENDATIONS

The recommended preliminary design solution would be the construction of a new wall supported on piles extending down through the glacial fine-grained till or into the bedrock to reach the required resistance.

No deep excavations beside the local road should take place due to limitations in the working space, the potential to cause further instability of the retaining wall and due to the live carriageways that would need to be kept in services.

Granular fill should be placed to form a piling platform, enabling a suitable rig to install bored piles to reach rock (requirement for embedment subject to design). A pile-cap would be constructed on top to support the construction of a new replacement masonry wall built on top, tying into the wall at either end of the selected section.

All drainage, services, footpath and carriageway surfacing should be renewed.

8.0 REFERENCES

TII Publication DN-ERW03083 'Managing Geotechnical Risk' (Transport Infrastructure Ireland, 2019).

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Geohive Maps – Government of Ireland, accessed at geohive.ie, 2021-2022

OPW Flood Hazard Mapping – Office Public Works, accessed from https://www.floodinfo.ie/map/floodmaps/ , 2021-2022 - Contains Office of Public Works information © Office of Public Works

EPA (Environmental Protection Agency, 2019). Mapping accessed from https://gis.epa.ie/EPAMaps/. Contains Environmental Protection Agency information © Environmental Protection Agency

Kleyn E. G. and Savage P. E., 1982, "The Application of the Pavement DCP to Determine the Bearing Properties and Performance of the Road Pavements," Int. Symposium on Bearing Capacity of Roads and Airfields, Trodheim, Norway, pp.238-246.

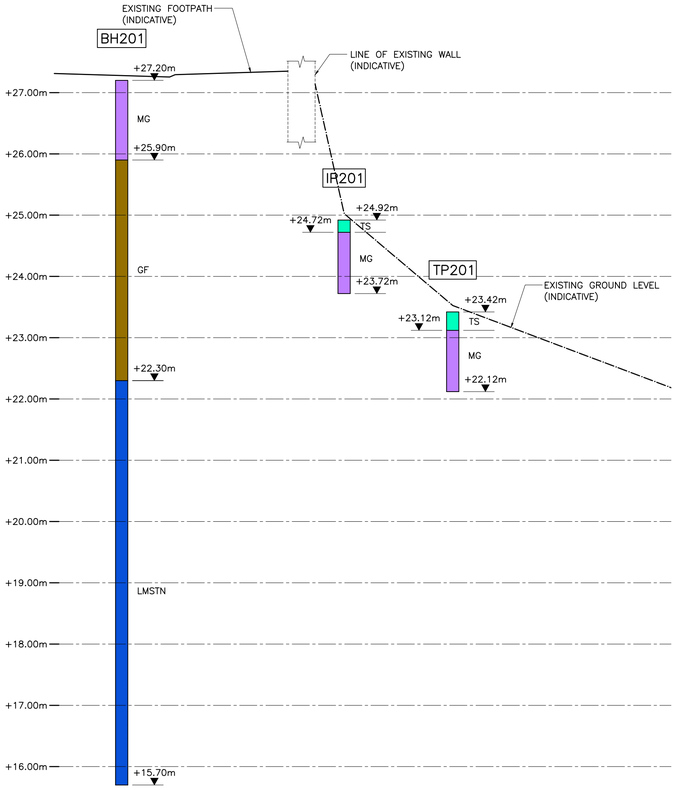
'BRE Special Digest No. 1: Concrete in Aggressive Ground', (2005), British Research Establishment.

British Standards Institute BS1377, Methods of test for soils for civil engineering purposes; Part 1 (2016), and Parts 2-9 (1990).

Limerick Tunnel Approach Roads -Design, Construction and Performance, by Fintan Buggy and Eamon Curran (2011)". Paper presented at Engineers Ireland.

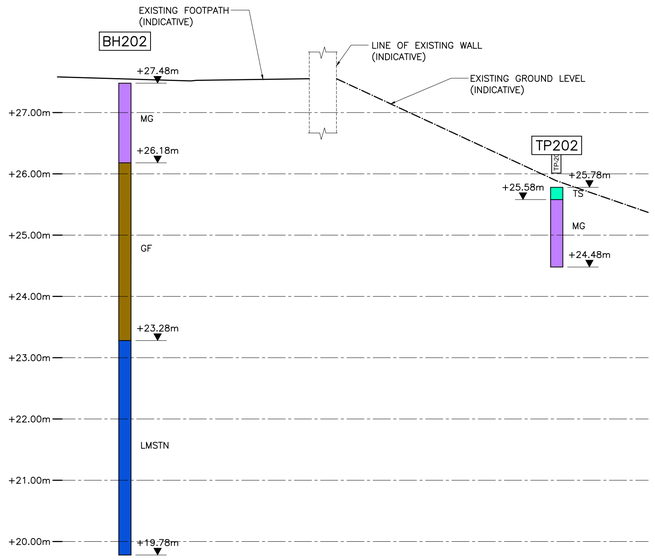
IS EN 1997-1, Eurocode 7: Geotechnical Design – Part 1: General Rules

APPENDIX A
Ground Investigation Drawing



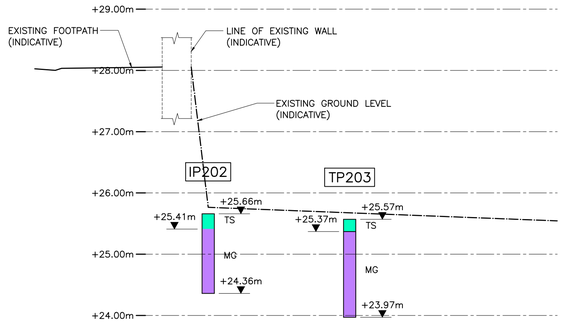
PROFILE P1

A1 SCALE 1:50
A3 SCALE 1:100



PROFILE P2

A1 SCALE 1:50
A3 SCALE 1:100



PROFILE P3

A1 SCALE 1:50
A3 SCALE 1:100

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS, UNLESS OTHERWISE NOTED.
2. ALL LEVELS ARE IN METRES TO ORDNANCE DATUM MALIN HEAD.
3. ALL CO-ORDINATES ARE IN METRES TO IRISH TRANSVERSE MERCATOR (ITM).

LEGEND

ABBREVIATION	DESCRIPTION	HATCH COLOUR
TS	TOP SOIL	
MG	MADE GROUND	
GF	GLACIAL FINES	
LMSTN	LIMESTONE	

PART PLAN ON SURVEYED AREA

A1 SCALE 1:100
A3 SCALE 1:200

LEGEND

TRIAL PIT

BOREHOLE

SLIT TRENCH

CO-ORDINATES (Irish Transverse Mercator)

TRIAL PIT	Easting	Northing
TP201	702552.800	735017.700
TP202	702571.800	735016.900
TP203	702591.600	735013.500
IP201	702556.600	735015.300
IP202	702594.700	735010.800
BOREHOLES	Easting	Northing
BH201	702562.400	735010.700
BH202	702576.600	735009.200

Comhairle Contae Átha Cliath Theas
South Dublin County Council

No.	Revision	Date	By	Chk'd	App'd
P0	Issue For Information	2022-02-04	OB	JC	JK

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Drawn	Designed	Checked	Approved	Suitability Code - Description
OB	JC	PK	JK	S3 - Review & Comment

Project Stage:

Project Title: Leixlip Road, Lucan

Drawing Title: GROUND INVESTIGATION

Drawing Number: LRRW - ROD - VGT - SW_AE - DR - CB - 50002

Scale (A1)	Date	Job No:	Rev:
AS SHOWN	Feb' 2022	19.122	P0

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DO NOT SCALE USE FIGURED DIMENSIONS ONLY