Chapter 8
Soils and Geology

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8.1 Introduction

This chapter considers and assesses the likely significant effects with regard to Soils and Geology associated with both the construction and operational phases of the proposed River Suir Sustainable Transport Bridge. The proposed pedestrian, cycle and public transportation bridge will link the North Quays to Meagher's Quay on the south side of the River Suir in Waterford City. The proposed bridge layout is presented in Figures 4.2, 4.3, 4.4 and 4.5 of Volume 3 of this Environmental Impact Assessment Report (EIAR) while the proposed construction sequence is indicated on Figures 4.8 to 4.11 in Volume 3 of this EIAR.

Measures to mitigate the likely significant adverse impacts of the proposed bridge are proposed and residual impacts are described. This chapter initially sets out the methodology used (Section 8.2), describes the existing soils and geology environment (Section 8.3), examines the predicted impacts of the proposed development (Section 8.4), proposes mitigation measures (Section 8.5), and identifies residual impacts (Section 8.6).

8.2 Methodology

This chapter is prepared having regard to the requirements of sub-sections 2 and 3 of Section 50 of the Roads Act 1993, as amended. It also has regard to the Environmental Impact Assessment (EIA) Directive 2014/52/EU and the following guidance documents:

- National Roads Authority (NRA 2008) Environmental Impact Assessment of National Road Schemes – A Practical Guide;
- National Roads Authority (NRA 2008) Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes;
- Environmental Protection Agency (EPA 2017) Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports;
- Environmental Protection Agency (EPA 2015) Advice Notes for Preparing Environmental Impact Statements;
- Advice notes on Current Practice in the Preparation of Environmental Impact Statements, published by the Environmental Protection Agency (EPA) (2003); and
- Guidelines on the information to be contained in environmental impact statements, published by the EPA (2002).

8.2.1 Summary of Available Information

Information was initially obtained for a wider area which includes Waterford North Quays, the area to the north of the River Suir along with the proposed pedestrian, cycle and public transportation bridge crossing of the River Suir covered in this report. Details of the general environment in the vicinity of the site are provided where applicable. This chapter has been prepared using information from the following sources:

Mapping

Geological mapping from the Geological Survey of Ireland, covering the subsoils and solid geology of the location of the proposed bridge was reviewed. Digital mapping available at www.gsi.ie/mapping also shows the quaternary geology along with aquifer vulnerability, known groundwater wells and existing ground investigation information.

Aerial Photography

Ordnance Survey Ireland (OSi) aerial photography was obtained in the vicinity of the proposed bridge crossing to identify large scale ground characteristics. The areas to the north and south of the river generally consist of made ground. Aerial photography to the north of the River Suir shows brownfield lands associated with the now derelict North Quays. A number of industrial buildings have been demolished recently. An existing wharf structure runs alongside the river at the North Quays. To the south of the river, car parking extends along the length of the quays.

Ground Investigations and Surveys

A detailed ground investigation was carried out by IGSL Ltd. between June and October 2017 for the North Quays area along with the proposed bridge. The scope of this investigation was determined from analysis of previous ground investigation findings from the GSI website, aerial photography and site walkovers performed by Roughan & O'Donovan Consulting Engineers.

The investigation objectives were to determine the subsurface conditions, the extent of soft ground, made ground and likely depths to rock and rock strength. The investigation was also designed to assess groundwater levels and to investigate the presence of any contaminants across the site. As part of the ground investigation contract, a contamination assessment of the site was also carried out by O'Callaghan Moran (OCM) who were engaged by IGSL Ltd.

In addition to the exploratory holes and in-situ testing, a marine geophysical survey was carried out at the location of the proposed bridge crossing by Apex Geo-services.

Site walkovers by Roughan & O'Donovan Geotechnical Engineers during these investigations have also helped to identify the ground conditions associated with the proposed bridge structure.

Findings of the ground investigation are reported in the Ground Investigation (GI) Factual Report (IGSL Ref 20157 November 2017) and GI Interpretative Report (IGSL Ref 20157 January 2018). The findings of the Tier 2 and 3 Contamination Assessment were reported in the document Tier 2 Site Investigation and Tier 3 Risk Assessment North Quays Waterford Port (OCM December 2017).

The findings of the geophysical surveys, ground investigations and the contamination assessment are hereby presented:

Geophysical Surveys

The marine geophysical survey consisted of seismic refraction along with underwater multichannel analysis of surface waves (MASW) which have been used to identify the soil and bedrock profile at the bridge crossing location across the river. This survey was undertaken on the 28th July 2017. Findings from the geophysical survey were reported in the Report on the Geophysical Investigation at Waterford North Quays (AGL 17059_01) produced by Apex Geoservices Limited. The area investigated as part of the geophysical survey is shown in Plate 8.1.

A total of three seismic refraction spreads were recorded across the site as indicated in Plate 8.1.

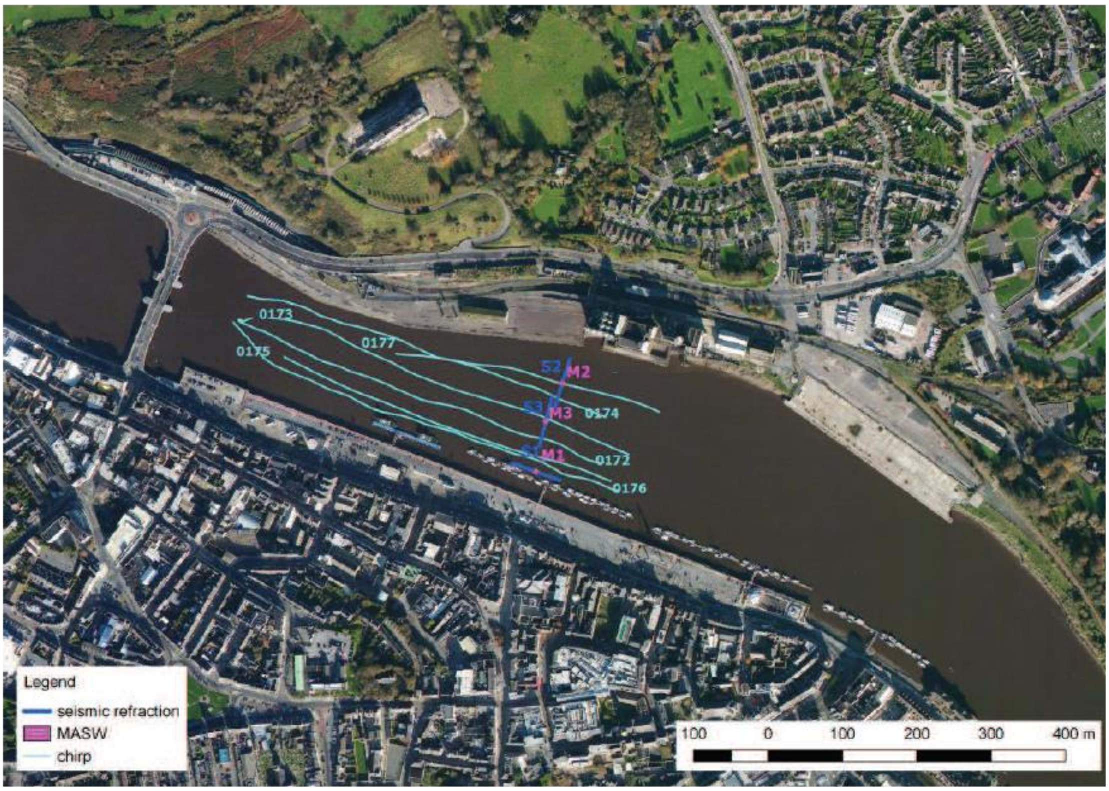

Plate 8.1 Geophysical Survey Site Location Plan

Strong currents in the river hampered deployment of the seismic refraction hydrophone receiver cable across the southern portion of the river. As a result of this, the geophysical survey undertaken was rotated through ninety degrees to improve the signal to noise ratio of the data.

In the central part of the river the currents also affected equipment and gun deployment resulting in a low signal to noise ratio. As a result, the data in the central part of the river could not be processed but Apex Geo-services Limited accessed sub bottom profiler CHIRP data to assist in interpretation of the sub surface profile.

The marine geophysical report includes the interpretation of the ground profiles.

The following conclusions and recommendations are relevant to the geotechnical constraints of the proposed bridge and approaches.

Ground Investigations

In total, the following exploratory hole information is available to assess overburden and bedrock characteristics at locations along the proposed bridge:

- 8 cable percussion boreholes with rotary follow-on (6 of these boreholes and rotary core holes were carried out over water).

The geologic profile is shown in Plate 8.2. The cross section also shows Rotary Core (RC)215 and RC216, located at the north quays. These boreholes are not relevant to the design of the proposed pedestrian, cycle and public transportation bridge.

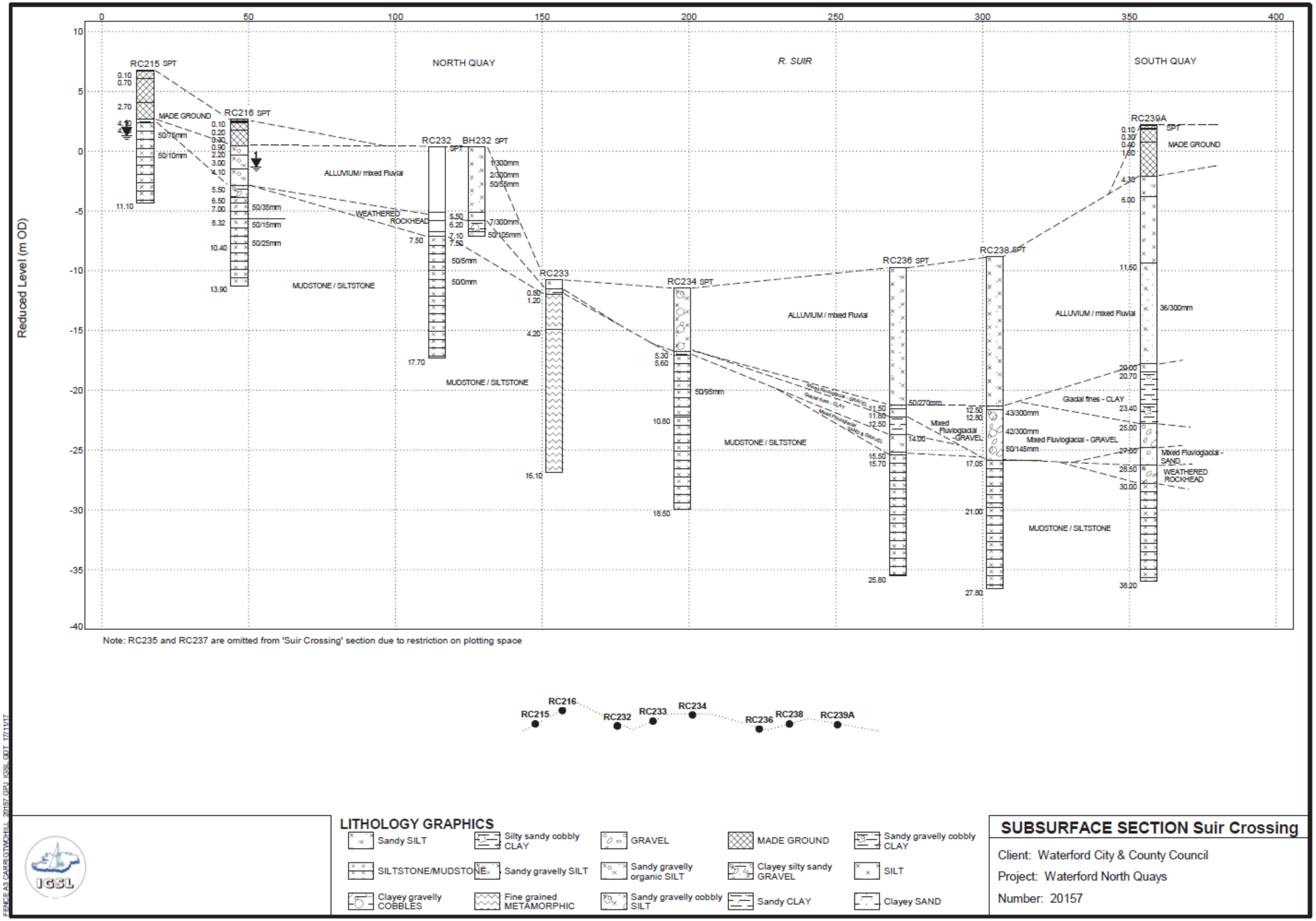

Plate 8.2: **Geological profile at the location of the proposed pedestrian, cycle and public transportation bridge crossing**

Geotechnical laboratory testing of selected samples collected during these works was carried out. Sufficient geotechnical information was available for the preliminary design of the proposed bridge structure.

Contamination Assessment

IGSL Ltd. requested O'Callaghan Moran & Associates (OCM) to complete a Tier 1 Risk Assessment in accordance with the EPA Guidance Document, Code of Practice (CoP) for Environmental Risk Assessment for Unregulated Waste Disposal Sites (2007), as specified in the scope of the ground investigation.

The Tier 1 Assessment identified potential contamination sources and recommendations were made for the completion of Tier 2 Site Investigations and the Tier 3 Risk Assessment. The Tier 3 assessment is based on the data collected from the investigation locations.

Samples taken from exploratory holes were sent to the Chemtest Laboratory in the UK for chemical testing. Results were assessed based on commercial and residential Suitable 4 Use Levels (S4ULs) developed in the UK for a range of land use settings ranging from residential with home grown produce to commercial settings and public open spaces near residential or commercial areas.

The commercial S4UL limits were not exceeded in any boreholes at the location of the proposed bridge.

The hazwaste online classification engine was used to determine the waste classification of samples recovered. Samples recovered from Bore Hole (BH) 235 at 1m, BH237 at 1m, BH239A at 1.5m, BH239A at 3m, BH239A at 4.5m and BH239A at 13m were classified as non- hazardous. Samples tested from BH239 also meet the inert limits.

8.3 Description of the Receiving Environment

The results of the geophysical investigation indicate the area is characterised by thin sediments over shallow weathered – fresh rock in the northern area with thicker sediments present in the south. There is no clear indication of a bedrock fault on either of the two seismic refraction spreads. The results of the geophysical survey indicate a 4 layer ground model across the site:

Layer 1 – Saturated Sediment:

In the south of the area (Profile S1), this layer is approximately 3.7m thick. In the north of the area (Profile S2), this layer is approximately 0.3 to 2.3m thick.

Layer 2 – Stiff / Dense Sediments:

In the south of this area, this layer is between 1.8 and 9.7m thick (Profile S1) and in the north (Profile S2) it is 0.5 to 2.9m thick.

Layer 3 – Highly / moderately weathered rock / very dense Gravel:

The depth to the top of this layer, on spread S2 varies between 2.6m and 13.4m below bed level (bbl) in the south and is between 1.0 and 4.9mbbl in the north (Profile S1).

Layer 4 – Slightly weathered / Fresh rock:

This layer is only present on profile S2. Where present, the depth to the top of this layer varies between 5.0m and 5.7m bbl, as presented in Plates 8.3 and 8.4 which are extracted from Factual Report (IGSL Ref 20157 November 2017).

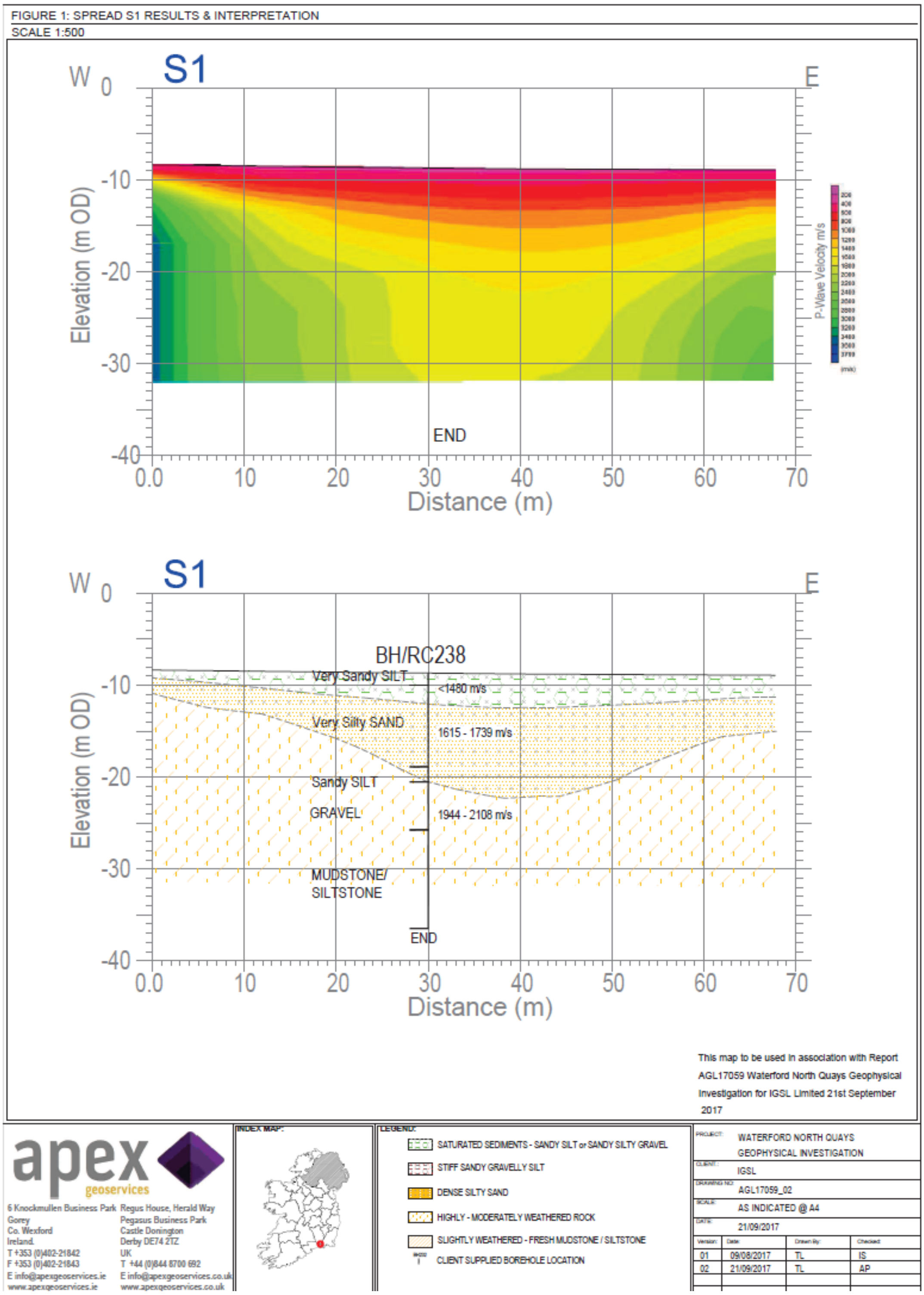

Plate 8.3 **S1 Results from Ground Investigation at the location of the proposed Sustainable Transport Bridge**

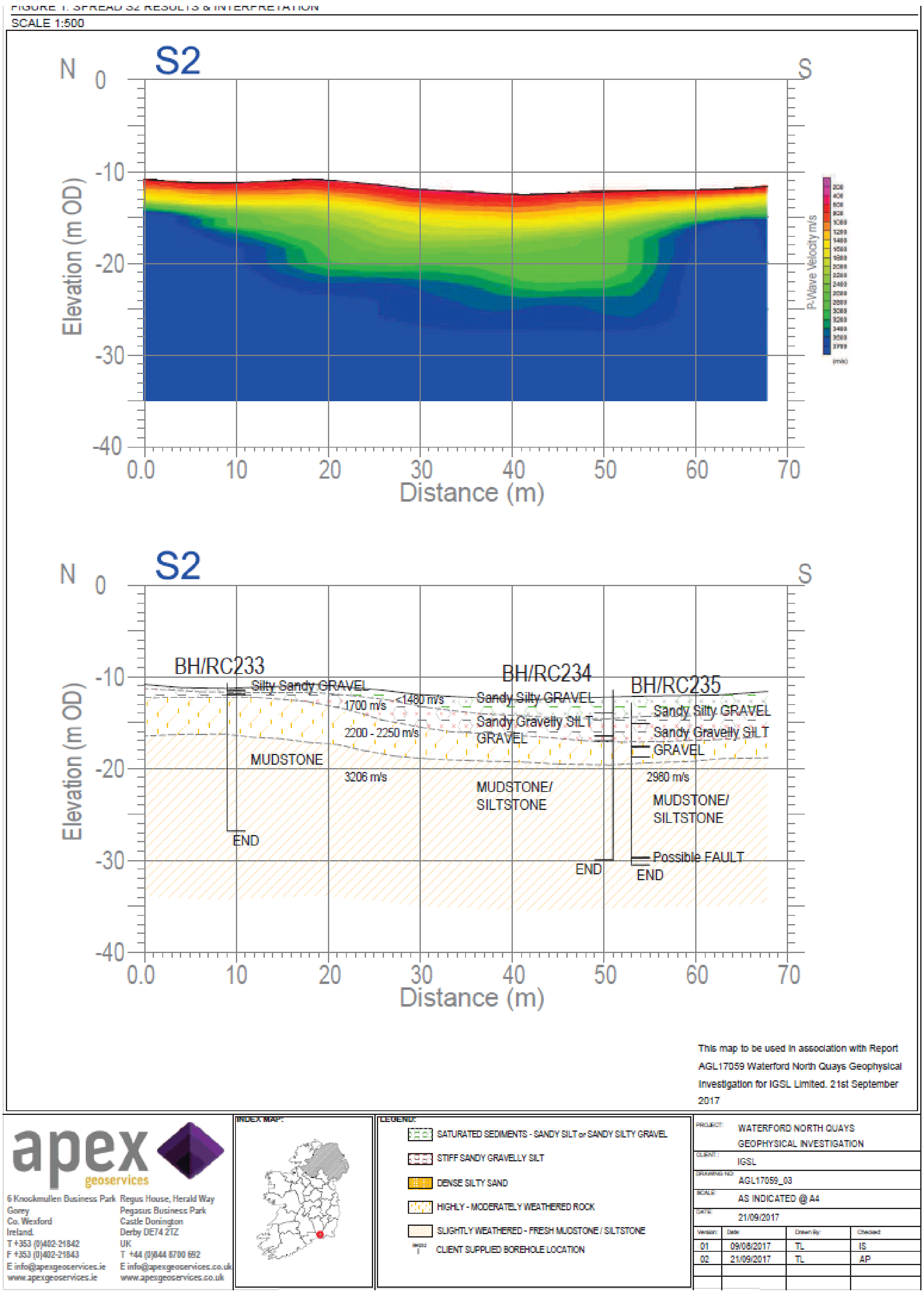

Plate 8.4 **S2 Results from Ground Investigation at the location of the proposed Sustainable Transport Bridge**

Existing Soils

Alluvium and Alluvial Gravels

Alluvial materials deposited by river action have been identified in areas along the proposed River Suir crossing from the marine boreholes and the boreholes carried out at the north and south abutments. These deposits generally consist of soft to very soft silts and very loose to loose sands and gravels, as presented in Figure 8.1 of Volume 3 of this EIAR. The depth of alluvium encountered ranges from 1.2mbbl (below bed level) in BH233 to 20.7mbgl in BH239A. In general, the thickness of alluvial material increases from north to south.

This information from rotary coring generally agrees with the interpretation of geophysical survey data indicating that alluvial thickness increases from north to south along with a decrease in the level of bedrock from north to south.

Glacial Tills and Glacial Sands and Gravels

The site is underlain by glacial till derived from sandstone. The depth range of the till occurring within the site has been confirmed by cable percussion borings during ground investigation. Glacial till material was generally encountered beneath the alluvial material and was noted as firm to stiff sandy gravelly Clay in BH232 from 6.2 to 7.1mbbl, in RC236 from 12.5 to 14mbbl and in RC239 from 20.7 to 25mbgl.

Sands and gravels were noted in BH236 from 10.5 to 15.7mbbl, in RC237 between 10.3 and 15.75mbbl, in BH238 from 12.5 to 17.5mbbl and in RC239 from 25 to 28.5mbgl.

Made Ground

Man-made ground is present at the north and south abutment locations of the proposed bridge structure. An existing reinforced concrete wharf structure is located at the north abutment and an existing reinforced earth quay wall is located at the south abutment. At the south abutment, car parking extends along the quay wall. BH239/239A, located at the south abutment and south plaza, encountered tarmacadam overlying granular fill material followed by dense granular fill material to a depth of 4.3mbgl.

Table 8.1 presents a summary of the properties of the soils discussed above.

Table 8.1 Typical Soil Properties

Soil Type	Particle Size / Type	Strength	Compressibility
Made Ground	Variable	Variable	Variable
Glacial Till	Fine and Coarse	Variable	Low-medium
Alluvium	Fine	Poor	High
	Coarse	Variable	Low - Medium

Existing Bedrock

Existing geological formations underlying the site have been identified from the Geological Survey of Ireland's (GSI's) geological online mapping for the area, as presented in Figure 8.2 in Volume 3. The site is underlain by Ballylane Formation from the centre of the river to the north and the site is underlain by Ross Member formation from the centre of the river to the south. The map also indicates a fault running along the River Suir.

The Ballylane Formation is described as green and grey slate with thin siltstone. Andesitic volcanic flows and tuffs occur locally and the formation is pyritic. The Ross Member formation is described as dark grey slate with thin siltstone. It consists predominantly of massive grey shale, shale with silty laminations, and thin greywackes with minor debris flow deposits and acid tuffs.

Due to the tectonic movements that occurred during and since volcanic activity, faulting is potentially present in the vicinity of the site. One large fault line in particular is shown to follow along the course of the River Suir. No evidence of this fault line was noted during the intrusive investigation. Much of the site is within the zone that may have been influenced by these movements. Faulting affects the quality of rock which can often be intensively fractured.

Coring at both land and marine borehole locations has proven siltstone, sandstone or interbedded mudstone rocks with discontinuities that are generally closely to widely spaced and with two sets of joints, typically at dip angles of 40° and 80°. Local degraded cubic pyrite is noted within the bedrock. Generally, at least 10m of predominantly solid rock core have been recovered from the boreholes. The variation in the depth to rock profile at the location of the bridge crossing is shown on the cross section in Plate 8.2.

8.4 Impacts of Development

8.4.1 Impacts on Soils

Bridge foundations will require construction of 1200mm diameter driven steel tubular piles at the north bridge abutment and pier locations. A combi-wall (combination of steel tubular piles and sheet pile panels) is proposed at the south abutment location in front of the existing quay wall to form the abutment foundations. Tubular piles will be installed using an impact hammer while sheet pile panels will be vibrated.

The south abutment of the bridge will tie into the south plaza approximately 1.8m above the existing quay ground surface level. This plaza level will reduce to the existing ground level at the existing Clock Tower.

A new sheet pile wall will be installed immediately in front of the existing quay wall at each side of the south abutment for a length of approximately 35m in order to retain the increased levels at the south plaza and approach to the bridge. The sheet pile will be installed using vibrating hammers. This solution can avoid the demolition and excavation of the existing quay wall, other than locally at tie in of the new sheet pile wall to the existing quay wall.

The raising of the levels at the South Quays for the purposes of the south plaza ramp will require the importation of a small amount of general fill. The fill's weight will induce the settlements in the underlying soft soils. If untreated, this would cause a significant long-term negative impact. The mitigation measures for this may include surcharging, (with or without vertical wick drains) or piling, explained in more detail in Section 8.5 Proposed Mitigation Measures. The surcharging will include the handling and temporary placing of a reasonably small quantity of general fill (approximately 1m height) on the ramp footprint, causing a slight temporary negative impact, for a period of up to 14 months. The piling option will be specified as Continuous Flight Auger (CFA) piles, which will minimise noise and vibration and introduce a need for disposal of a small quantity of arisings (less than 50 m^3), causing a slight short-term impact. The surcharge option will improve the geotechnical parameters of the existing soil, while the piling option would introduce new concrete foundation elements into the soil and is preferred in terms of reduced construction programme.

The existing floating jetty located at the south abutment will be removed at the bridge footprint. The impact associated with this operation is minor and adverse.

The north abutment construction will be performed in front of the existing north quay and will not require demolition of the existing wharf to execute piling. The north abutment will tie into the proposed north quays development which is located approximately 5.00m above the existing level of the north wharf. The impacts on soils associated with this location are likely to be negligible.

Cofferdams are required for construction of the foundation supports to the bridge piers within the river. Cofferdams will be constructed using vibratory driven sheet piles. During piling construction operations within the river, there is the potential for contamination of the river due to sediments and runoff associated with construction works or fuel spills entering the river. Mitigations to reduce adverse impacts to river water quality are described in Section 8.5. This impact is also examined in more detail in Chapter 9 Hydrogeology whilst noise and vibration impacts are considered in Chapter 12 of this EIAR.

8.4.2 Impacts on Solid Geology

No potentially significant adverse impact from the development on the solid geology (bedrock) of the site has been identified. No geologic heritage sites or accessible rock materials of economic value will be impacted.

Piling operations will install structural foundations through to competent bedrock. Rock sockets drilled to the specified diameter and installing concrete in the lower sections of piles may also be required in specific locations. Loading, stresses and deformations applied to the bedrock will be well within the capacity of the rock mass and tolerance of bridge structure. Piling construction and rock excavations will therefore have a negligible impact on the existing rock conditions.

8.5 Proposed Mitigation Measures

In general, the temporary and permanent impacts on soils and geology are considered minimal and will be managed by a number of best practice control measures including:

- All suitable material excavated for installation of pile caps shall be re-used to the greatest possible degree as fill material on the development;
- All unacceptable material excavated shall be disposed of in accordance with legislative requirements with due regard for the impact on the licensed waste disposal site. Where possible this material will be utilised in landscaping of the development;
- A geotextile screen and boom with oil barrier will be required around marine works to prevent runoff, silt, oil or other deposits generated by construction activities such as setting and driving steel casings and boring in overburden or rock from polluting the river. An Incident Response Plan (IRP) shall also be required to deal with any unexpected spills during construction (See Appendix 4.1 A);
- Minimisation of excavation and removal of potentially contaminated soils where alternative engineering solutions can be used in the proposed development to ensure the existing ground is capable of providing adequate formation to the south plaza.
- Temporarily surcharging the footprint of the south plaza with an additional height of general fill in order to speed up the settlements in the underlying soft soils and alleviate the settlements in the operational phase. The surcharge will need to be held for 12 to 14 months. This hold period can also be significantly improved (down to 3 – 6 months) by installing vertical wick drains under the surcharge.

Installing of wick drains is fast and produces minimal noise and vibration over general construction traffic levels. After the surcharge hold period, the temporary surcharge can be reused in other areas such as in the proposed park areas.

- Surcharge height will be tapered back on the approach to the Clock Tower in order not to include the settlements to the protected structure. In addition, the Clock Tower will be equipped with the suitable monitoring equipment and instrumentation to closely monitor ground and vibration levels in real-time.
- In case a piling option is selected to prevent the settlements under the south plaza, CFA piles at suitable depth and spacing will be specified in order to avoid the excessive noise and vibrations in close proximity to the surrounding sensitive receptors.

8.6 Residual Impacts

No significant residual impacts of soils and geology are anticipated as a result of the proposed development.