Chapter 8:
Soils & Geology

ROD
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Chapter 8 Soils and Geology

8.1 Introduction

Trinity Wharf is a brownfield site, approximately 3.6 ha, located at the southern end of Wexford Town's quay-front. The site consists of reclaimed land that extends into Wexford Harbour and was gradually reclaimed with the northern part reclaimed around 1832 (initially as a dockyard area) and then extended south-eastwards through the late 1800s and early 1900s and was occupied by a number of industrial uses. Owing to the reclaimed nature of the site, the superficial soils are dominated by relatively deep layers of 'Made Ground'. Made ground has been defined as soil which has been altered in some way by human activity (imported and placed in-situ).

The characteristics of the proposed development that will impact soils and geology are described in the following paragraphs. The proposed development will involve raising the ground level using imported material. A new sea wall will also be constructed around the coastal boundaries of the site through sheet piles and the placement of rock armour along sections of the northern and southern edges. The structural design of the buildings will typically comprise a reinforced concrete superstructure. The foundation design is proposed to consist of driven steel or concrete piles extending to competent bedrock.

A 64 berth marina and associated breakwater units, pontoon walkways and finger berth is planned on the site's northern corner. The marina will be either piled or anchored. Pontoon berths and walkways will be restrained using tubular piles driven into the seabed or an alternative restraint system.

There will also be a 180m boardwalk structure at the northern corner of the site connecting Trinity Wharf with Paul Quay. The foundations for the boardwalk structure are proposed to be driven steel tubular sections which will be installed to immediately beneath the soffit level of the boardwalk deck where an integral connection will be made.

The chapter will assess the impact of these structures as part of the proposed development on the Trinity Wharf brownfield site. Full details of the project description and likely construction methodology is detailed in Chapter 4 'Description of Development'.

This chapter considers and assesses the likely significant impacts with regard to soils and geology associated with both the construction and operational phases of the proposed development. Measures to mitigate the assessed negative impacts of the development are proposed, and residual impacts are described. The 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 has been prepared in accordance with the following guidelines:

- Institute of Geologists of Ireland (IGI) (2013) *Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements*;

- 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*;
- Waste Management Act 1996 (as amended)

A desk study of the site of the proposed development was carried out in order to establish baseline conditions. The desk study involved collecting all relevant geological, hydrological, hydrogeological and meteorological data for the area. A suite of geological maps published by the Geological Survey of Ireland (GSI) were consulted as a part of the desk study. The maps included the bedrock, quaternary sediments, groundwater vulnerability and geological heritage sites, among other themes. Aerial and site-based photographs as well as historical maps and reports were also consulted as a part of the desk study. The desk study was followed by a walkover survey of the site of the proposed development by ROD Civil engineers in October 2018, with observations used in preparation of this chapter.

Previous Studies/ Reports

The following reports were consulted in the preparation of this chapter:

- Kavanagh Mansfield and Partners (2008): Report on a site investigation for a development at Trinity Wharf Wexford;
- RPS (2018): Trinity Wharf Marina Feasibility Study (project number IBE1115/D03)
- RSK (2018): Preliminary Asbestos Walkover Survey, Trinity Wharf, Wexford

Ground Investigations procured by Kavanagh Mansfield and Partners in 2008 consisted of 13 cable percussive boreholes in overburden and 9 rotary core boreholes in the bedrock. A suite of geotechnical laboratory tests for determination of the geotechnical soil parameters was carried out on the samples from the boreholes. The ground contamination testing was carried out on seven samples. The ground contamination testing was in accordance with "Murphy Suite" which determines the suitability of the soils for acceptance into licensed landfill facilities. The results of which are discussed in Section 8.3.

A Preliminary Asbestos Walkover Survey of the Trinity Wharf site was undertaken in October 2018 Sampling and testing of seven samples was undertaken and a map of general areas impacted with Asbestos Containing Materials (ACMs) was developed. The walkover survey and samples taken were confirmed by laboratory analysis as containing asbestos. The report recommended further work to be undertaken including the development of a remedial strategy and independent validation of the site prior to proceeding with the development. The Preliminary Asbestos Survey Walkover report is attached as Appendix 8.1 for reference.

8.3 Description of Receiving Environment

The proposed development is located on reclaimed land adjacent to the southern bank of the Wexford Harbour, south of the Wexford town centre. The site is flat, with generally low and sparse vegetation. The site is rectangular in shape, connected to the original bank at its southwestern side. The other three sides (north, east and south) that make the coastline are partially protected by historical concrete and masonry sea wall.

The sea bed depth at the location of the marina ranges from -2.5m OD (Ordnance Datum) to -7m OD while the depth at the location of the proposed boardwalk ranges from 0m OD to -2m OD. The site does not contain any Geological Heritage features or quarries.

Bedrock Geology

The GSI 1:100,000 bedrock map indicates that the site is underlain by the Shelmaliere Formation consisting of white and purple quartzites with slates. Cullenstown Formation (grey-green metagreywacke & slate) and Ballysteen Formation (limestones and shales) are also found in the vicinity.

The ground investigation carried out in 2008 indicate that the site is underlain by the moderately weak to strong, thin to medium bedded, slightly cherty limestone. The limestone was locally found to be interbedded with dark calcareous mudstone. This description matches well with the Ballysteen Formation features. Only one borehole (RC15) indicated the presence of interbedded sandstones and siltstones. Refer to borehole locations Plate 8.1 below.

The bedrock in the northern part of the site is typically observed at 10.2 – 11.5 m below ground level (bgl), overlain by the 0.5 -1m of weathered bedrock returned as angular clayey gravel. The bedrock at the southern end of the site was observed at approximately 5m bgl, overlain with 1m of weathered bedrock returned as angular clayey gravel. The central part of the site exhibits a very deep zone of highly weathered bedrock. For instance, borehole RC7 shows the weathered rock, recovered as gravel and cobbles, to extend from 11m bgl down to 22m bgl, with no competent bedrock encountered in this borehole.

Soils and Subsoils

The area is entirely covered by the made ground of very heterogenous composition. Clay, rubble, stone, ash, concrete and slag were all observed as constituents. The strength and density vary accordingly and the thickness of the made ground varies from 1.5m to 4.1m.

The made ground is underlain by alluvial soil typical of riverbanks. The alluvial soils are predominantly encountered as soft to firm sandy silts and loose silty sands. The thickness of the alluvial soil ranges from 1m to 5m. These soils have undergone a degree of consolidation under the made ground layer and building loading which is why no very soft material was encountered during the ground investigation in 2008.

Firm to stiff gravelly clay (widely known as glacial till or boulder clay) underlies the alluvial soils and overlies the weathered bedrock. The thickness of the gravelly clay ranges from 2m to over 8m in BH16. (Refer to Plate 8.1).

Plate 8.1 Borehole locations investigated by IGSL in 2008

Environmental Testing

A suite of Waste Acceptance Criteria (WAC) chemical tests were undertaken on seven samples as a part of the 2008 geotechnical investigation procured by Kavanagh Mansfield and Partners and undertaken by IGSL. The WAC testing followed the Murphy Suite Criteria to determine the suitability of the soils for acceptance into licensed landfill facilities. The location of the boreholes' locations investigated by IGSL are illustrated in Plate 8.1. The samples were taken using the 'Shell and Auger' technique of soft ground boring. All boring operations sampling and / or logging of soils and in-situ testing complies with the recommendations of the British Standard Code of Practice BS 5930 (1981), 'Site Investigation' and BS 1377:1990, 'Methods of text for soils for civil engineering purposes'.

Parameters forming part of the chemical testing included:

- Polychlorinated Biphenyls (PCBs)
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Mineral Oil
- BTEX & Petrol Range Organics (PRO)
- Total Organic Carbon (TOC)

Leachate analysis for metals and major anions and cations was also undertaken to assess potential for movement into groundwater.

The testing found elevated levels of Polycyclic Aromatic Hydrocarbons (PAHs) and sulphates in the made ground stratum in five out of seven samples. In general, low to moderate levels of contamination have been noted. A summary of the results are presented below:

- Dissolved Mercury, Benzene, Toluene, Ethylbenzene, Total Xylene, PCB's, Total Phenols, and Dissolved Cadmium were below the respective Limit of Detection (LOD) in all boreholes.
- Elevated levels of Mineral Oil were identified at boreholes 16 and 17 (south-eastern end of the site) – all other boreholes recorded values below the LOD of 1 mg/kg.
- Slightly elevated levels of Total Dissolved Solids (TDS) were identified at a depth of 2.5m below ground level at borehole 16, with all other samples categorised as Inert in terms of WAC (< 4000 mg/kg). The levels observed at borehole 16 categorise this material as Stable Non-reactive with respect to WAC guidance.
- Dissolved Antimony was either below the LOD or was within the inert criteria limits and were below 0.06 mg/kg with the exception of borehole 22. The levels observed at borehole 22 categorise this material as Stable Non-reactive with respect to WAC guidance.
- Dissolved Arsenic, Barium, Chromium, and Copper concentrations were found to be either below the LOD or within the inert criteria limits.
- Elevated levels of Total Organic Carbon (TOC) above the inert criteria were identified in five of the seven samples. Only boreholes 12 and 16 (in the deeper soil layers) fall below the Inert Landfill Threshold of 3%. For waste disposal purposes to landfill, the levels which were observed would classify the material as hazardous.
- Elevated levels of PAHs were identified in all samples analysed. Borehole 4 was found to have the highest concentrations of PAHs among the boreholes tested.

Further detail is available in the Kavanagh Mansfield and Partners Report from 2008 as appended to this EIAR as Appendix 8.2.

The Preliminary Asbestos Walkover Survey undertaken on 18th October 2018, identified fragments of asbestos cement and floor tiles and / or floor tile debris in numerous locations across the surface of the site. Seven samples were collected by RSK and asbestos was confirmed in five out of the seven samples. The preliminary findings indicate that Asbestos Containing Materials (ACMs) are broadly concentrated along the retaining wall in the northern portion of the site; along the edges of floor slabs; adjacent to and within many of the demolition stockpiles and in the gravel track along the eastern boundary. No suspect ACMs were identified within the grassed area or were visible on the surface of the stockpiles in the southern portion of the site. The Preliminary Walkover Asbestos Report is included as Appendix 8.1 of this EIAR.

The sea bed in the vicinity of the Trinity Wharf development, corresponding to the location of the boardwalk and the sea wall / revetments was sampled and tested as a part of the Trinity Wharf Marina Feasibility Study by RPS Group (November 2018). A comprehensive sampling programme was undertaken in July 2016 by Hydrographic Surveys Ltd to inform the feasibility study, whilst the sediment quality analysis was undertaken by the RPS Laboratory Services, see sampling locations in Plate 8.2 below.

The samples from the north west side of Trinity Wharf (A, B & C) were found to have values above the upper guidance threshold for OCPs and PAH levels that are substantially in excess of the lower guidance limit (there is no upper limit established at present). Station A, furthest from the Wharf, contained the least contaminated sediments on this side of the development area with stations B & C, closer to the Wharf, showing increasing levels of contaminants.

Station B had samples taken at both the surface (B1) and 1m below the surface (B2) and held the greatest amount of contaminants out of the three stations on this side of Trinity Wharf. The sample collected at depth tended to have higher levels of contaminants than the surface sample. Metals levels above the lower guidance levels were found for arsenic, copper, nickel, lead and zinc. PAH levels were also above the lower guidance level in both the surface and -1m samples, with the deeper sample recording total values approximately twice that of the surface sample. PCB, Organotin and TPH levels were satisfactory. OCP levels were all above the threshold effects level and the parameters for which limits have been set, Lindane and HCP were both above the upper guidance level.

Station C was a surface sample and contained elevations above the lower guidance level for arsenic, cadmium, nickel and zinc in the metals suite. Polycyclic Aromatic Hydrocarbon (PAH) and PolyChlorinated Biphenyl (PCB), Organotin (TBT and DBT) and total petroleum hydrocarbon (TPH) levels were acceptable. As with the other samples in the OCP suite, the results for Lindane and HCP were both above the upper guidance level for Station C, and the other parameters tested were above the Threshold Effects Level (TEL) published in the guidance.

Station D had samples taken at both the surface (D1) and 1m below the surface (D2). The samples were collected from the small accumulation of sediment immediately adjacent to the Wharf at the boundary with the navigation channel. In the metals suite, the two samples (surface and depth) recorded generally quite similar values, with the exception of copper, where the depth sample recorded a substantially higher value and both samples were above the upper guidance level. In keeping with many of the other surrounding stations, values for arsenic, nickel lead and zinc were also above the lower guidance level. PAH levels were acceptable; with the samples taken at depth recording levels almost three times lower than the surface sample. PCB levels were found to be above the lower guidance limit; however the deeper samples were four times higher than the surface sample. Organotin and TPH levels were satisfactory. OCP levels were also generally within acceptable thresholds.

Station E had samples taken at both the surface (E1) and 1m below the surface (E2). The sample collected at depth from station E was substantially more contaminated than the surface sample. In the metals suite, Station E was the only station which did not record elevated levels of arsenic or nickel. Sample E1 (surface) recorded only slight elevation of copper and all other metals levels were acceptable. Sample E2 (at depth) had slightly raised levels of cadmium and lead with all other metals at acceptable levels. In respect of PAH, the surface sample was well within the acceptable level however the sample collected at depth was over seven times higher and above the lower guidance limit. Similarly, the surface sample was totally clean of PCBs however the sample collected at depth recorded levels over 25 times higher and was again over the lower guidance level. Organotin and TPH levels were satisfactory. OCP levels were also generally within acceptable thresholds.

Generally speaking, the area returned results showing mild levels of contamination in the sediments although in a limited number of instances there were moderate levels of contamination present. Further information on the results of this sediment Analysis are found in Appendix 4.3

The exact disposal avenue for contaminated material excavated from the site will be determined in accordance with the actual level of contamination and Waste Acceptance Criteria following a comprehensive laboratory analysis of the material taking place prior to construction.

Plate 8.21: Location of sediment sampling stations at Trinity Wharf (Source: RPS Feasibility Study, 2018).

Groundwater and Hydrology

The groundwater was observed during the 2008 GI at approximately 1.5m – 2.0m below ground level, coinciding with the sea level.

Groundwater vulnerability is indicated as low on GSI's 1:100,000 map. However, the site-specific assessment was carried out, accounting for up to 4 m of predominantly high permeability made ground and further deeper layers of glaciofluvial gravels, up to 10m of moderate permeability soils such as sandy silts and up to 7m of low permeability cohesive glacial till over bedrock. Groundwater vulnerability ranges between moderate and high across the site depending on the exact thickness of the deposits present, according to the GSI Groundwater Vulnerability Classification Table 8.1 below.

Table 8.1 GSI Groundwater Vulnerability Classification Table

Vulnerability Rating	*Hydrogeological Conditions*				
	Subsoil Permeability (Type) and Thickness			*Unsaturated Zone*	*Karst Features*
	High permeability (sand/ gravel)	Moderate permeability (e.g. sandy subsoil)	Low permeability (e.g. clayey subsoil, peat)	(Sand/ gravel aquifers only)	(<30m radius)
Extreme (E)	0-3.0m	0-3.0m	0-3.0m	0-3.0m	-
High (H)	>3.0m	3.0-10.0m	3.0-5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0-10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

The main surface water body receptor in the study area is the Lower Slaney Estuary with made ground being the primary pathway for received precipitation.

8.4 Description of Potential Impacts

The made ground stratum exhibits low to moderate levels of contamination, primarily from PAHs and sulphates remaining from the historical industrial use of the site. In addition to that, the asbestos containing materials have been identified on the surface of the site. Mild to moderate levels of contamination with OCPs and PAHs were found in the samples from the sea bed undertaken as part of the Trinity Wharf Marina Feasibility Study by RPS Group (November 2018).

While the intention is for the construction works to be carried out with the least feasible disturbance of soils, some relatively minor amount of soil stripping or excavation can be expected. This primarily pertains to the construction of the foul sewage pumping station (located in the western corner of the site) and may be required for any deep service trenches or chambers identified during detailed design.

The pronounced heterogeneity of made ground and the relatively high compressibility of the alluvial soils can result in excess settlements stemming from structure loading. Any soil excavation has the potential to induce movement and settlement of surrounding ground during the construction phase.

All material excavated in the made ground stratum at the site shall be assumed to be contaminated. Appropriate testing of this material by a suitably qualified and licenced waste contractor shall take place for all aspects of ground contamination. Any contaminated material that is required to be excavated will be disposed of to a suitably licensed and permitted contractor to a licenced landfill site, which will be determined in accordance with the actual level of contamination and Waste Acceptance Criteria. Inert, non-hazardous and hazardous waste. Such contaminated material will be stored in separate bunds and will be disposed of to a suitable licensed facility. The mitigation measures for handling ACMs are presented in Section 4.4.5 in Chapter 4 of this EIAR.

8.5 Mitigation and Monitoring Measures

The mitigation measures for the impacts outlined in the section 8.4 above are outlined in this section.

Although the existing ground surface and all contaminated material is planned to be encapsulated in the thick imported granular material that will form the new surface, the removal of surface will be undertaken to ensure potential ACMs negative impacts to the environment is appropriately addressed prior to future development.

The following mitigation and control measures, in addition to the asbestos mitigation measures outlined in Section 4.4.4 in Chapter 4, will be adopted before the start of the construction works:

- Prior to the start of any construction works further asbestos surveys, intrusive asbestos surveys and site investigation and a Remediation Strategy will be developed prior to site clearance works and the subsequent construction of the site. The Asbestos Surveys and a Remediation Strategy will inform the site clearance strategy and removal of asbestos from the site. All site clearance works will be required to be undertaken by a suitably qualified, experienced and licensed asbestos contractor.
- All site clearance and excavation works will be required to follow the mitigation measures of this EIAR in this Chapter and those detailed in Chapter 4 as well as any future mitigation measures to be detailed in the Remediation Strategy (to be completed). For all site clearance works and excavation works suitably qualified,

experienced and licensed personnel will be required to undertake this specialist work in accordance with the 'measures for working with asbestos'. Any ACMs discovered in areas required for excavation, will be required to be disposed of by a licenced contractor to a licenced waste facility in accordance with waste management legislation, as appropriate.

- The 'Asbestos Survey and Remediation Strategy' will be undertaken prior to construction. All mitigation measures/ recommendations from these surveys and the remediation strategy will be required to be implemented as part of the proposed development.
- Remediation Verification Report will be produced to demonstrate that all mitigation measures proposed by the contractor to prevent the spread of asbestos or risk of fibre release and all associated remedial works implemented will be independently validated prior to proceeding with the redevelopment of the site.
- 'Measures for working with asbestos' as detailed in Chapter 4 shall be implemented by contractors as appropriate as part of the construction phase.
- The specialist contractor will ensure secure containment and transport of all contaminated materials to the appropriate licenced waste disposal facility.
- Contractors shall be required to submit and adhere to a Construction Method Statement indicating the extent of areas likely to be affected and demonstrating that this is the minimum disturbance necessary to achieve the required works. All associated hazardous waste residuals will also be stored within temporary bunded storage areas prior to removal by an appropriate EPA approved waste management contractor for off-site treatment/recycling/disposal. Any other building waste will be disposed of within on-site skips for removal by a licensed waste management contractor. The contractor will be required to submit a Construction and Demolition Waste Management Plan to the Council for approval which will address all types of materials to be disposed and the location of the licenced waste disposal facilities that will be used, as appropriate.
- Imported good-quality granular soils materials and rock armour revetment will be imported from local sources where possible. The nearest suitable licensed quarries are outlined in the Section 4.4.10 of the Chapter 4.
- To minimise any impact on the underlying subsurface strata from material spillages, all fuels, oils, solvents and paints used during construction these will be stored within specially constructed temporary bunded areas or within dedicated bunded containers. Spill kits and hydrocarbon adsorbent packs will be stored on the site compound and operators will be fully trained in the use of this equipment. Fuel for vehicles will be stored in a mobile double skinned tank.

In order limit the risk to human health and the surrounding aquatic environment by exposure to contaminated material through excavation, it is proposed to retain the majority of the made ground in place. The current ground level across the entire site will be raised for the proposed development (1.5m raise on average), using imported good quality granular material. It is also proposed that the uppermost 250mm of this material will comprise of compacted clay with a low permeability of 1 x 10-7 ms-1 (refer to Chapter 9 for details) to limit infiltration to percolating water. A minor volume of excavated material planned to be excavated pertaining to the foul sewage pump-out station and any deep service trenches or chambers will be identified during detailed design. Temporary works design and monitoring will ensure that the there are no unacceptable ground movements and settlements of the adjacent ground. This material will be required to be tested for contaminants.

All buildings will rely on driven piles for foundations. This will minimise the need for the excavation and handling of the made ground layer and soft alluvial layers beneath it, as no in-situ ground needs to be displaced or handled during the execution of this type of piles. The alternative solution of bored piles was eliminated as it would produce contaminated soil arisings. Furthermore, transferring all loads on piles will avoid the settlements in the underlying strata (particularly in made ground and soft silts). The detailed design of driven piles will include a consideration of the allowable stresses in the bedrock so as to avoid fracturing the bedrock. The encapsulation of the contaminated ground will prevent contact between the contaminated ground and the environment and end-users in the operational phase.

It is noted that the due to the stringent requirements for the rock used in the revetments, not all quarries are able to produce such stone. Quarries in strong metamorphic and volcanic rocks typically tend to produce suitable stone for revetment. Two quarries in Co. Wexford, in Ballykelly (37km) and Gorey (41km), quarry should contain suitable type of stone.

The steel driven piles were selected as the foundation option in order to avoid the handling of the contaminated pile arisings and reduce the environmental impacts related to the arisings disposal.

Sheet piles forming the sea wall on the site perimeter and the option of either bored piles or tubular steel piles and screw piles (helical anchors) for the foundation of the marina and boardwalk elements (to be decided during detailed design) are also selected as their installation requires no excavation or dredging. A sheet-piled wall will provide a new sea wall for the site, raising the site level to meet flood requirements and providing a barrier to contain contaminated material within the site.

The mildly contaminated made ground soil retained by sheet piled wall will be buried below the surface and the flow path for the potential contaminants will be largely severed by the sheet pile wall. The sheet pile wall will also provide for additional coastal protection and flood defence. The rock armour revetment and the armour underlayer will be placed directly on in-situ riverbed silt, in order to avoid the need for the handling and removal of contaminated silt.

8.6 Residual Impacts

There are no likely significant residual soil or geological impacts associated with the Trinity Wharf development.

8.7 Difficulties Encountered

No significant difficulties were experienced in the completing this assessment. While adequate information is available from previous investigations, additional and more detailed ground investigations will take place at the development site prior to detailed design stage in order to further classify ground conditions for design and also to quantify the disposal options for excavated material which may be contaminated. It is not considered that this affects this impact assessment due to the design, construction methodology and the mitigation measures provided in this EIAR.

8.8 References

Institute of Geologists of Ireland (IGI) (2013) *Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements*

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*

Government of Ireland. Waste Management Act 1996 (as amended)

Kavanagh Mansfield and Partners (2008): *Report on a site investigation for a development at Trinity Wharf Wexford*

RPS (2018): *Trinity Wharf Marina Feasibility Study (project number IBE1115/D03*)

RSK (2018): *Preliminary Asbestos Walkover Survey*, Trinity Wharf, Wexford.