Verde Environmental Consultants

Hydrogeological Impact Assessment including Assessment of Dublin City Council Basement Development Policy Requirements

Strategic Development Zone (SDZ) Commercial

& Strategic Housing Scheme (SHD)

City Block 9

North Wall Quay

Dublin

January 2021

TABLE OF CONTENTS

FIGURES

APPENDICES

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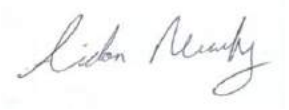
Created By	Aidan Murphy		1st Sept 2019	Principal Environmental Engineer
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EXECUTIVE SUMMARY

The site of the proposed development of mixed commercial and residential use with multiple basement levels is located along North Wall Quay and is contained entirely in an area known as City Block 9. The proposed development and associated basement structure are expected to extend to 16mBGL (to -12mOD). A progress report for the site in November 2020 outlined that at the time over half the pile wall is installed around the full City Block 9.

This report relates to the combined Strategic Development Zone (SDZ) commercial scheme and adjoining 1005 No. unit Strategic Housing Scheme (SHD). The site was investigated as a whole of 1.95 hectares identified in the 2014 Planning Scheme as "City Block 9".

Historical maps indicate the site was used for various industrial uses including a Vitriol Works, bathhouses and glassworks in the early 1800s. In the early 1900s the site was occupied by a large sawmill and timber yard. These historical site operations have caused contamination of the subsurface fill material and underlying subsoils together with the shallow groundwater within the subsoils.

Approximately 30m to the south of the proposed site boundary, North Wall Quay defines the boundary of the Lower Liffey Estuary. The river water quality status for the River Liffey at this location is classified by the EPA as "unpolluted". Surface water samples retrieved from three locations along the River Liffey near the site did not identify a pollutant linkage to the site. The boundary of the Dublin Bay SPA is located approximately 2.8km to the east of the project area; along the Liffey Estuary. The site is not recorded as being at risk of fluvial or coastal flooding.

Ground investigations conducted by IGSL, ARUP and RSK show that the site is underlain by a layer of made ground overlying a silt layer, which in turn is underlain by a thick sequence of gravels & sands overlying a boulder clay layer. Site investigation information from the site shows bedrock in excess of 17mBGL and therefore the basement excavation is not anticipated to encounter bedrock.

Groundwater on-site will need to be continually pumped during the construction phase, to allow site construction to proceed to install base structures in dry conditions and to avoid the risk of hydrostatic uplift.

The subsoil permeability is reported as being low so it is expected that the boulder clay will act as a confining layer and will limit the vertical migration of groundwater to the locally important limestone aquifer beneath the site. The boulder clay layer of unknown thickness is also thought to create a shallow groundwater system hosted in the overlying sand and gravel layer which is the main geological unit that requires dewatering for the construction works.

A waste classification programme of works for the site will dispose of the fill material and subsoils according to their classification to appropriate disposal routes. Ground settlement can occur in areas of groundwater lowering such as the downgradient region of the proposed basement structure which needs to be examined by a structural assessment.

The dewatering design for the site will take into account the on-site known groundwater contamination by installing a sufficient number of dewatering wells on-site. Some well locations will target the area of contamination in order to allow adequate on-site water treatment prior to discharge off-site. Pumping rates will be designed to allow for sufficient retention time on the water treatment plant to allow adequate treatment.

It is assumed however, that groundwater in the shallow gravel aquifer is likely to flow in a south to south easterly direction towards the River Liffey with minimal tidal influence (<0.3m) reported on the water table. Shallow groundwater flow from the sand and gravels is currently restricted by the presence of the quay wall at the River Liffey which has a 4m tidal range. There are no groundwater dependant features in the immediate vicinity of the site.

The presence of the proposed secant walls around the proposed excavation will result in a localised diversion of regular groundwater flow paths with localised groundwater mounding up-gradient of the pile walls and lowering downgradient of the pile walls. It is unlikely that significant diversion of groundwater flow paths will occur. Installation of monitoring well/wells outside the pile wall will provide information on any potential groundwater mounding/lowering. The main groundwater body for this area is within the underlying limestone bedrock aquifer which will not be impacted by the building development or operational phase of works.

A review of the combined basements in the neighbouring buildings to the east and west was undertaken and presented in a conceptual ground model as recommended in the Dublin City Council (DCC) Basement Development Guidance Document. The existing and proposed basements are not directly adjoining and therefore provide groundwater flow access corridors between the buildings which minimises groundwater flow pathways from extending around multiple basement structures.

A review of DCC basement development policy requirements was undertaken for each item in relation to the proposed development with appropriate environmental monitoring, traffic planning, construction management plan, drainage, landscape, flood risk and engineering responses provided with no impact predicted once the appropriate mitigation measures outlined are adhered to.

There are possible short-term impacts to groundwater quality from the vertical migration of contaminants with the excavation of the protective soil layers. In order to prevent the spread of contamination from a known contamination zone on the site pumping of groundwater will be limited to the northern section of the site, treated and discharged to a combined sewer off-site subject to conditions of the discharge licence.

The on-site water treatment plant will be designed to cater for the contaminants of concern that are known to be on-site within the shallow groundwater. Although the detection of free phase product was not reported on-site the water treatment system proposed will cater for light non-aqueous phase liquids (LNAPL) and dense non-aqueous phase liquids (DNAPL) if present. Treatment design well cater for all COC which will be verified by further baseline groundwater monitoring on-site prior to dewatering works.

Other mitigation measures during the operational dewatering phase of works will allow for continuous monitoring of the pumping operation flows and water quality (pH) via a telemetry system with alarms to allow for efficient and continuous dewatering operations to proceed during the construction phase of works.

Regular monitoring of the on-site treatment plant will be undertaken to ensure the discharge water is being adequately treated prior to discharge.

Overall the removal of contaminated fill material, subsoils and treatment of the contaminated groundwater during the dewatering construction works will improve the environmental quality of the area. There is not anticipated to be a direct negative environmental impact of the construction works on the soil/geological or groundwater on-site or on surrounding off-site environmental receptors (including Designated Sites) as long at the detailed dewatering plan and associated mitigation measures are implemented.

LIMITATIONS

This report represents the results from a review of provided site investigation reports conducted at the above referenced site. Best practice was followed at all times and within the limitations stated; works were undertaken according to budgetary considerations. This report is the property of Verde Environmental Consultants Limited and cannot be used, copied or given to any third party without the explicit prior approval or agreement of Verde Environmental Consultants Limited.

In this report consideration has been given to the possible impact of these dewatering works on the surrounding environment, however no geotechnical or structural survey/design has been undertaken or assessment of the impact that dewatering may have on the proposed construction or on the surrounding environment or structures. This is the responsibility of the project design team. It is recommended that the engineering design team for the project should check and validate that the proposed dewatering design does not pose any geotechnical or structural risk to the proposed construction or to surrounding or nearby structures.

1 INTRODUCTION

Verdé Environmental Consultants Ltd. (Verde) was requested by Waterside Block 9 Developments to undertake a preliminary environmental Hydrogeological Impact Assessment based on available existing data for a proposed development at City Block 9, North Wall Quay, Dublin. The proposed development consists of a development on the site of approximately 1.85 hectares at North Wall Quay, Dublin 1, as presented in Figure 1.

This report relates to the combined Strategic Development Zone (SDZ) commercial scheme and adjoining 1005 No. unit Strategic Housing Scheme (SHD). The site was investigated as a whole of 1.95 hectares identified in the 2014 Planning Scheme as "City Block 9". The City Block 9 site is principally bounded by: Mayor Street Upper to the north; North Wall Quay to the south; North Wall Avenue to the east; and Castleforbes Road to the west.

The SDZ relates to a site of 0.921 hectares. This comprises the SDZ Scheme of 0.85 hectares to be developed. The larger figure of 0.921 hectares reflects the 0.071 hectare of SHD lands that are overlapped to facilitate a pocket park in the SDZ Commercial Scheme in the scenario that the SHD Scheme delivery is delayed or not being developed, as presented in Figure 2. The proposed development will consist of 3 No. commercial office buildings (identified as four blocks (Blocks B1-B4)) ranging in height from 5-storeys to 9-storeys over a 2 – storey basement. Construction of two levels of basement (15,832 sq m), accommodating: plant rooms; waste storage facilities; employee changing / drying / locker facilities; a bike repair area; a goods' storage area; 2 No. loading bays; 107 No. car parking spaces; 14 No. motorcycle parking spaces; and 570 No. bicycle parking spaces, with vehicular access provided by ramp from Castleforbes Road.

The SHD relates to a site of 1.1 hectares, of which c. 1.10 hectares is within the hoarding line (Figure 2). The proposed development will consist of 1,005 No. residential units (with balconies and winter gardens) arranged in 3 No. blocks ranging in height from 8 No. storeys to 45 No. storeys over a triple-level basement. Construction of three levels of basement (22,499m^2), accommodating: waste storage areas, plant rooms, maintenance / management offices, courier / parcel rooms, laundry rooms, ancillary residential storage, WCs, a gym / spa, a gym storage room, screening rooms, an indoor plant cultivation room, 176 No. car parking spaces, 10 No. motorcycle parking spaces and 1,693 No. bicycle parking spaces, with vehicular access provided by ramp from North Wall Avenue.

The proposed developments include associated site excavation, infrastructural and site development works above and below ground, associated retaining features, and associated site servicing (foul and surface water drainage and water supply). A progress report for the site in November 2020 outlined that at the time over half the pile wall is installed around the full City Block 9.

2 SCOPE OF WORKS

The following scope of works was undertaken as part of this assessment:

- An initial desk-based study which included a review of the following:
  - Review of all available information pertaining to the site;
  - Review of all available geological and hydrogeological information.
- Preparation of a hydrogeological impact assessment report, including:
  - Development of a conceptual understanding of the hydrogeological regime in the area based on available data;
  - Identification of potential impacts of the proposed basement on groundwater;
- Preparation of the report on the above including provision of any recommendations or mitigation measures, if required.
- Review of Dublin City Council Basement Development Guidance Document and Basement Development Policy Document, Version 1, September 2019.

3 ENVIRONMENTAL SETTING

3.1 Site Location of City Block 9

The site is located in the North Wall area of Dublin with is an area to the east of the northern inner city. The site location is presented in Figure 1 and the Ordnance Survey of Ireland (OSI) x, y coordinates for the site are 717785, 734505. The adjacent land uses are described in Table 3.1 below.

Table 3.1– Adjacent Land Uses

BOUNDARY	LAND USE
North	The north of the site is bounded by Upper Mayor Street which hosts the tracks of the Luas Red line which has its terminus at the 3 Arena to the east of the site. Upper Mayor Street is bordered by a commercial complex to the north which houses the radio stations of FM104 and Radio Nova.
South	The south of the site is bounded by North Wall Quay and the River Liffey Estuary.
West	The west of the site is bounded by Castleforbes Road which is bordered by a commercial complex to the west which houses the Central Bank of Ireland, the National Treasury Management Agency and Home Building Finance Ireland (HBFI).
East	The east of the site is bounded by North Wall Avenue which is bordered by the 3 Arena further approximately 60m east.

3.2 Site History

Primary sources used to research the history of the site included available extracts from historical Ordnance Survey Ireland (OSI) maps, aerial photographs, anecdotal information from the previous site owner Shay Murphy obtained in 2013 and planning information from Myplan.ie.

The maps consulted include the OSI 6-inch historic maps from 1837 to 1842, the OSI 25-inch historical maps surveyed between 1888 and 1913 and the OSI 6-inch Cassini map surveyed in the early 20th century. Table 3.2 below gives further details of the site history and the land use of the surrounding area.

Table 3.2 – Site History

MAP	DETAILS & COMMENTS
OSI 6-inch (1837-1842)	This series of maps describes the area surrounding the proposed site as a series of apparently empty plots (possibly fields), covering what is now the north Dublin Docklands area. Several small-scale industries can be seen in proximity to the proposed site, including a Vitriol Works (sulphuric acid manufactories), bathhouses and glass works. On the proposed site, there are no features recorded, suggesting the site was wither greenfield or idle at the time of recording.
OSI 25-inch (1888-	This map series records a significant change from the previous map; with the area on and

1913)	surrounding the proposed site, being dominated by high-density industrial premises. The proposed site contains several separate premises; a large saw mill (with chimney and yards) and timber yard comprise the majority of the site; with a small cattle pen area in the southeast corner of the site. To the immediate east of the site, a large terminal rail depot is recorded as Goods Station, which shows a coal yard abutting the eastern boundary of the proposed site. To the west of the site, a slate & tile yard is recorded with scattered cattle pens and an iron works beyond.
OSI Dublin Surveys (1886-1887)	This detailed map of the docklands area shows a scenario to those in the 25-Inch maps, with a portion of the proposed site occupied by the saw mill and associated lumber yard. The added site details in this map show the position of a crane and weighing station on the site.
OSI 6-inch Cassini (Early 1900s)	These maps record a similar setting as the previous map series, with the Timber Yard (and assumed saw mills) dominating the proposed site. The sites to the north of the proposed site now show timber yards, suggesting an expansion of timber/lumber activities in the areas surrounding the site. The coal yard to the east of the site is not recorded in this map; neither is the iron works to the east.
Aerial Photo (1995)	These relatively low resolution images show that the docklands are dominated by low-rise, high-density commercial and industrial "shed" premises. The Docklands are clearly yet to undergo large-scale redevelopment. The sites to the east show the previous arrangement of the Point Theatre with its associated open space. The old North Wall train line terminus and goods station is still visible to the east of the site. The nature of the commercial and industrial units on, or around, the proposed site is not now but it thought to be largely commercial and retail.
Aerial Photo (2000)	These images show the same general setting as the previous images. The most notable change is in the apparent demolition of the North Wall good train station to the east. On the proposed site, it appears that the eastern side of the site has been repurposed as a storage yard of some kind.
Aerial Photo (2005)	These images show some change from the previous series; with some evidence of higher-rise development to the north of the site, and demolition of a large number of the low-rise commercial units. The proposed site appears to be largely the same as previous images.
2005 - Present Day	ESRI aerial imagery between 2016 and 2018 show the clearing of the proposed site, including the demolition of all structures on the site. Similar images from 2016-2018 show that the site to the immediate east was also demolished, cleared and underwent subsequent medium-rise development.

3.3 Site Physical Setting

Details of the site physical setting are outlined in Table 3.3. Information on the site location, hydrology, geology hydrogeology and ecology of the area has been obtained from records held by the Geological Survey of Ireland (GSI), Environmental Protection Agency (EPA), Ordnance Survey of Ireland (OSI), Water Framework Directive Maps, National Parks and Wildlife Service (NPWS) databases and on-line resources of Department of Environment, Community and Local Government (myplan.ie).

Table 3.3 – Site Physical Setting

FEATURE	DETAILS & COMMENTS
Topography	The site is generally flat with an elevation of c.5mOD.
Geology	Overburden: The GSI subsoils database shows the proposed site and the surrounding area is underlain by Made Ground; which is typically composed of a moderately permeable mix of soils, clays and anthropogenic materials. The GSI's geotechnical depth to bedrock models for the Dublin area show the site is expected to be underlain by bedrock at a depth of 15-25m; with the deeper areas on the northeast side of the site.
	Solid Geology: The site is underlain by the dark "Calp" limestones and shale mudstones of the Lucan Formation, as is typical for much of the Dublin area. The Lucan Formation comprises dark-grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey.
Hydrogeology	Regional Classification: According to the GSI the Lucan Formation below the area of interest is classified as a Locally Important aquifer, bedrock which is moderately productive only in local zones. This type of bedrock aquifer unit it typically capable of supplying locally important abstractions (e.g. smaller public water supplies, group schemes), or 'good' yields (100-400 m3/d). Groundwater flow occurs predominantly through fractures, fissures and joints (secondary permeability). This type of aquifer typically has a limited and relatively poorly connected network of fractures, fissures and joints, giving a low fissure permeability which tends to decrease further with depth. A shallow zone of higher permeability may exist within the top few metres of more fractured/weathered rock, and higher permeability may also occur along fault zones. These zones may be able to provide larger 'locally important' supplies of water. In general, the lack of connection between the limited fissures results in relatively poor aquifer storage and flow paths that may only extend a few hundred metres
	Recharge: The GSI groundwater recharge information for the site includes the following; Hydrogeological Setting (4m) of Made Ground, effective rainfall of 294mm/yr and an average recharge of 59mm/yr. As this area of Dublin is largely covered in hardstanding, recharge is largely restricted to green areas together with artificial recharge from leaking sewers, drains and water mains.
	Vulnerability: The vulnerability rating for the aquifer beneath the site is classified as Low indicating the depth to bedrock is greater than 10 metres below ground level (mBGL).

	Well & Spring Search: There are several wells recorded in the GSI groundwater well database within 1km of the proposed site. Approximately 320m to the northwest of the site, two wells are recorded. These wells were both drilled in 1998 to depths of 6.5m and 7.8m in overburden. The wells are not recorded as being producing water wells or springs. Their current status and use is unknown. Across the River Liffey, approximately 800m south of the site, a well is recorded on Barrow Street which was drilled in 1938 to a depth of 9.8m. This well is recorded as having a good yield (261m^3/day) and was installed for industrial use. Its current usage and status is unknown. 100m further southwest of this well location, a cluster of five monitoring wells are noted. These wells were reportedly installed by Iarnród Eireann in 1999 and range in depth from 4.8m to 9.8m. There are not thought to be in use for well water production.
Hydrology/Ecology	Surface Water Courses/ Abstractions Approximately 30m to the south of the proposed site boundary, North Wall Quay defines the boundary of the Lower Liffey Estuary. The river water quality status for the River Liffey at this location is classified by the EPA as "unpolluted". This transitional water body connects the River Liffey to the Liffey Estuary and the wider Dublin Bay area; roughly 2-3km to the east. Across the Liffey Estuary, 360m to the southeast of the site, the Dodder River enters the Liffey Estuary from the south.
	Water Framework Directive (WFD) status: Under the Water Framework Directive (WFD) the groundwater body beneath the site is Dublin GWB (code: IE_EA_G_008) and is classed as having Good status and is currently classified to be Not At Risk of deterioration in the future. Under the Water Framework Directive (WFD) the transitional waterbody south of the site is the Liffey Estuary Lower (code: IE_EA_090_0300) and is classed as having Moderate status and is currently classified to be At Risk of deterioration in the future.
	Protected Areas: *Grand Canal Proposed Natural Heritage Area* The closest protected area to the site is the proposed natural heritage area of the Grand Canal located approximately 330m to the south of the site.
	Royal Canal Proposed Natural Heritage Area The proposed natural heritage area of the Royal Canal located approximately 500m to the east of the site.
	South Dublin Bay and River Tolka Special Protection Area The boundary of this site is located approximately 2.8km to the east of the project area; along the Liffey Estuary. This SPA occupies a substantial part of Dublin Bay and comprises extensive intertidal flats which support wintering waterfowl which are part of the overall Dublin Bay population
	Flooding: According to OPW flood mapping the site appears to be at risk of localised pluvial flooding in extreme events (Appendix A). The site is not recorded as being at risk of fluvial or coastal flooding.

3.4 Site Investigation History

Ground investigations conducted by IGSL, ARUP and RSK, summarised below, show that the site is underlain by a layer of made ground overlying a silt layer, which in turn is underlain by a thick sequence of gravels & sands overlying a Boulder Clay layer of unknown thickness. Cross sectional summaries of the site sub strata are included in Appendix B.

3.4.1 IGSL Ground Investigation Report Reference 19965 (dated May 2017)

IGSL were appointed to conduct a ground investigation and prepare a factual report. This investigation was conducted between March and May 2017:

- 6 no. cable percussive boreholes up to 15.5mBGL;
- 6 no. rotary boreholes drilled in the bedrock to depths of 27.5mBGL;
- 13 no. trial pits;
- Groundwater and gas monitoring;
- Geotechnical testing; and
- Laboratory testing of 41 soil samples from the made ground to assist with soil classification.

No interpretative reporting was undertaken on the soil samples.

3.4.2 ARUP; Preliminary Site Assessment (PSA). Reference 257849-00 (dated 7 August 2018)

ARUP conducted a PSA including a site walkover in September 2017. The desk-based study showed that the site had a number of previous uses which could have been sources of contamination including a saw mill and timber yard.

As part of the PSA conducted by ARUP, the IGSL site investigation was review and the following conclusions were made:

- There is an area in the north-central section of the site showing physical signs of hydrocarbon contamination (odour, sheens etc.) in the top 4m of made ground;
- In the west-central section of the site strong hydrocarbon odours were detected at 21mBGL.

3.4.3 ARUP; Detailed Site Assessment (DSA). Reference 257849 18_08_03 (dated 7 August 2018).

ARUP carried out a DSA following their PSA report. The works carried out included ground investigations, Generic Quantitative Risk Assessment (GQRA) and waste soil classification. The following was concluded;

- A buried pit was located to the north of the site which was likely used in the treatment timber by soaking the wood in creosote;
- Leaks from the buried pit and localised areas of contaminated groundwater were found in the deep made ground and the sand and gravel layer beneath the buried pit.
- Creosote impacted groundwaters were not found in the sand and gravel layer beyond 75m downgradient of the buried pit.

- It was found that a previously installed monitoring well (BH02) was a pathway for contamination to enter the water bearing sand and gravel layer. The well has been fully decommissioned and the pathway fully removed.

3.4.4 RSK; Environmental Assessment and Soil Classification. Reference 602387 R01 (dated April 2019)

An environmental assessment and soil classification was undertaken at the site by RSK. The soil classification included the collection of five hundred and sixty-eight (568) soil samples from across the site and carrying out WAC analysis and Hazwaste analysis on the laboratory results. An environmental assessment carried out on the natural subsoils showed no risk to human health.

3.4.5 RSK; Generic Quantitative Risk Assessment (GQRA). Reference 602387 R02 (00) (dated July 2019)

A GQRA was conducted by RSK in July 2019 in order to identify any potential pollutant linkages present for the site. In conclusion the following was found:

- The groundwater GACs were exceeded in a number of boreholes;
- Surface water samples retrieved from three locations (upstream, adjacent and downstream) along the River Liffey as a sensitive environmental receptor. No surface water GACs were exceeded so no pollutant linkage was identified;
- The boulder clay encountered at depth on the site would likely act as a barrier to the downward migration of groundwater to the locally important aquifer beneath.

3.5 Potential Contaminants of Concern

Creosote is composed of various coal tar distillates and was commonly used to treat wood products. It is still used in certain timber-treating operations and as a component of roofing and road tars. Creosote is a multicomponent DNAPL composed of hundreds of polycyclic aromatic hydrocarbons; phenols; benzene, toluene, ethylbenzene, and xylene; and other compounds. Creosotes and coal tars are complex mixtures of variable composition containing primarily condensed aromatic ring compounds (coal-derived substances) or phenols (wood creosote).

Creosote contains many hydrocarbons, primarily polycyclic aromatic hydrocarbons (PAHs) and phenolic compounds (Environment Agency, 'DNAPL Handbook', 2003). Creosote may be blended with up to 50% of a carrier fluid (such as diesel fuel) prior to use.

3.5.1 Fate and Transport of Creosote

The density of creosote typically ranges between 1,010 and 1,130 kg/m^3, depending on the amount and type of any carrier fluid. Creosote is therefore one of the least dense DNAPLs of environmental interest. It often takes a long time for movement to cease following initial release into the subsurface because creosote is only slightly denser than water and has a relatively slow downward migration. Creosote which is a highly viscous DNAPL is slow to migrate.

Creosote compounds are typically very hydrophobic, they tend to sorb strongly to soils and rock. This strong tendency to sorb means creosote dissolved phase plumes may not migrate far beyond the extent of the DNAPL creosote. Naphthalene, anthracene and fluoranthene are generally the most soluble and least toxic of the PAHs in creosote and are the most commonly found in groundwater.

Creosote DNAPL actively migrates upon release either within the saturated or unsaturated zone. The movement of the product is primarily driven by the force of gravity along the least resistant path (coarser, more permeable strata). The migration of creosote may result in pooling on the surface of less permeable strata or can be left as residual DNAPL which occurs when the product is distributed in a discontinuous mass infiltrating weakness in the rock and is held within the pore spaces of geological materials. In either case, pooled or residual creosote DNAPL in the subsurface serves as a long-term continuing source for dissolved phase PAH and Phenol contamination in groundwater.

The lateral migration of creosote is dominantly governed by gravity. The slope of a low permeability horizon and the groundwater flow direction control the movement of the pooled DNAPL. The vertical migration of creosote occurs when the product reaches a critical height of DNAPL that is when the thickness of the product exceeds what is necessary to overcome the pore entry pressure of the underlying unit or strata.

4 GROUNDWATER EXCLUSION

During the construction phase of this SDZ commercial development, excavation of the proposed basement will extend below the water table within the subsoils to a current proposed depth of -12mOD. Given the site investigation boreholes were drilled to 17mBGL (-13mOD) with no bedrock encountered is it assumed that groundwater within the underlying calp limestone aquifer of the Lucan Formation will not be encountered during the excavation works.

4.1 Environmental Receptors

The site is not located within or directly adjacent to a protected site. There area a number of European sites in the vicinity of the proposed development, as previously mentioned in section 3.3.

- Grand Canal Proposed Natural Heritage Area

  The closest protected area to the site is the proposed natural heritage area of the Grand Canal located approximately 330m to the south of the site.

- Royal Canal Proposed Natural Heritage Area

  The proposed natural heritage area of the Royal Canal located approximately 500m to the east of the site.

- South Dublin Bay and River Tolka Special Protection Area

  The boundary of this area is located approximately 2.8km to the east of the project area; along the Liffey Estuary. This SPA occupies a substantial part of Dublin Bay and comprises extensive intertidal flats which support wintering waterfowl which are part of the overall Dublin Bay population.

The River Liffey is located approximately 30m to the south of the proposed site boundary. North Wall Quay defines the boundary of the Lower Liffey Estuary. This transitional water body connects the River Liffey to the Liffey Estuary and the wider Dublin Bay area; roughly 2-3km to the east. Across the Liffey Estuary, 360m to the southeast of the site, the Dodder River enters the Liffey Estuary from the south.

The underlying Locally Important groundwater aquifer is also an environmental receptor with known groundwater wells in the area and their uses undefined. The shallow groundwater in the sand and gravel subsoils beneath the site is restricted from vertical migration to the underlying bedrock aquifer by the low permeability boulder clay.

4.2 Existing Basement Structures

There are existing basement structures in the adjacent buildings to the proposed City Block 9 development on North Wall Quay. Theses building include the Landings Building to the west of the proposed development, which has a two-storey basement, and the Block 10A building to the east, which has a single basement development.

As part of this Basement Impact Assessment a 3-D conceptual ground model has been prepared, as presented in Figure 4 with plan view in Figure 5. This conceptual ground model is recommended in the Dublin City Council Basement Development Guidance Document in relation to the scoping process for a basement development. Figures 4 & 5 include a representation of available groundwater flow pathways around and below the existing and proposed basement structures.

The main aspects of the conceptual ground model include;

- The existing adjacent building basement and proposed building basements are not directly adjoining and therefore provide groundwater flow access corridors between the buildings which minimises groundwater flow pathways from extending around multiple basement structures.
- There is potential for localised mounding of groundwater on the upgradient northern side of the buildings which will not accumulate to a combined groundwater mound due to the presence of natural access corridors of natural ground between the buildings, as presented in Figures 4 and 5.
- There are no buildings or basement structures in the area of north quay wall road in the area between the building basements and the River Liffey Quay Wall. This area of ground where there is an element of groundwater flow parallel to the River Liffey Quay wall will not be affected by the City Block 9 development.
- Site investigation monitoring well information on the City Block 9 development has shown a minimal tidal influence of between 0.1 to 0.3m variations while the tidal variation in the adjoining River Liffey is in the region of up to 4m. There is therefore seen to be no direct hydraulic connection between groundwater level and the adjoining River Liffey due to the present of the quay wall.
- In the adjoining building basements of a double basement in the Landings Building and single basement in the Block 10A building groundwater flow can migrate within the underlying gravel deposits. In the City Block 9 development the proposed 2-storey basement structure will extend into the underlying lower permeability boulder clay deposits. The presence of natural gravels around the basement structure will allow for groundwater flow to migrate around the structure.
- As part of the proposed dewatering and monitoring infrastructure proposed for the City Block 9 development a series of groundwater monitoring wells are to be installed outside the secant pile wall of the proposed basement to monitor groundwater levels prior to, during and post construction works.

4.3 Protected Structures

A desktop survey to identify Protected Structures within a 500 m radius of the site was carried out. The Record of Protected Structures (Volume 3 of the 2016-2022 Dublin City Development Plan) and the National Monument Database were consulted. There are a number of protected structures within 150m of the site boundary.

- The first is located approximately 120m to the east of the site and is the façade of the current Three Arena. This structure is dated to approximately 1878 and used to be a train depot;

- The next is located approximately 52m to the east which is described as a detached two-storey industrial building constructed in approximately 1880;
- Another is located approximately 7m to the west of the site and is named Richford Motors this façade dates back to the 1860s.
- There are two protected structures approximately 35m to the west of the site, first is a three-story house with a shopfront rendering on the ground floor dating to the 1880s and second is a three-storey former warehouse building dating back to the early 1900s.

4.4 Site Specific Groundwater Investigation

From the available site investigations undertaken at the site in relation to the geological strata variation and associated soil and shallow groundwater contamination the following items need to be considered in the required dewatering programme for the proposed development.

1. Shallow groundwater contamination associated with historical site activities is mainly concentrated along the northern boundary of site and will require water treatment prior to discharging off-site.
2. There is an estimated 35,500m^3 of groundwater stored within gravel/sand strata onsite based on an upper estimate of 20% effective porosity (excluding all inflows under and through installed barriers).
3. Without any contamination, Verde's experience of similar sites in Dublin would have pumping flow rates in the region of 8-10litres/second for a period of six weeks to surface water, which would lower the groundwater to formation level. Post initial pumping of stored waters pumping will be required of any leakage from the installed secant wall, rainfall and water upwelling from beneath site. The degree of leakage through the secant wall is generally the most important figure regarding ongoing dewatering.
4. Due to the known presence of contamination in the groundwater on-site in order for activated carbon in the on-site site treatment plant to be effective, all water will need to have appropriate retention time within the vessels in order for dissolved phase hydrocarbons to be scrubbed from the water prior discharge off site. This flow rate is usually restricted to about 2 litres/sec per vessel.
5. If two activated carbon units were installed on-site it is estimated that the pumping of stored water would take upwards of 16 weeks to complete or two weeks for every 1m depth of saturated strata i.e. gravel layers. Treatment of contaminated groundwater needs appropriately low flow rates in order to ensure effective groundwater quality treatment. Flows rates as dependant on the concentration and type of groundwater contamination present.
6. Due to the presence of elevated ammoniacal nitrogen contamination on-site and metals, the treatment plant may also need to cater for treatment of these parameters to appropriate levels in the discharge licence.
7. The on-site water treatment system will require ongoing water monitoring and maintenance to ensure efficient operation.

4.5 DCC Basement Development Policy Requirements

The following is a list of Dublin City Council (DCC) basement policy requirements as outlined in the Basement Development Policy Document, September 2019 together with a response to each item;

1. **Protects and enhances where possible the groundwater quality, quantity and classification (groundwater environment).**

The secant pile wall extends around the perimeter of the site and is embedded into the black boulder clay layer at depth on the site. This wall will provide a waterproof seal around the site and cuts off the groundwater within the site from the groundwater in the docklands area. The contaminated soil will be removed, and any dewatering required during the works will be carried out by appropriate on-site water treatment prior to discharge under licence from Dublin City Council. Therefore, the groundwater is protected from contamination and the groundwater is enhanced by the removal of the contaminated soil which the groundwater is currently exposed to. Therefore, the proposed basement structure is seen to meet this requirement.

2. **Provides evidence that the construction of basements shall not place the groundwater at undue risk.**

As noted above the basement construction will involve the removal of soil and groundwater contamination and therefore does not place the groundwater at undue risk but removes that potential risk.

3. **Provides evidence that the structural stability of adjoining or neighbouring buildings is not put at risk. The Developer should also identify the risk to land stability of the site and adjacent areas and provides appropriate mitigation, as required.**

The secant pile wall embedded into the boulder clay ensures that any dewatering required is confined to the site within the secant pile wall of the site without any drawdown of the groundwater outside the site that may affect the structural stability of any neighbouring buildings. Monitoring wells outside the secant pile wall shall be provided to ensure that it is confirmed that there is no excessive drawdown of groundwater outside the site. As part of the monitoring works also, condition surveys of neighbouring buildings shall be carried out prior to commencement of the works and shall be monitored during the works.

4. **Provides an in-depth management plan for any demolition works and for the construction of a basement. The Developer is required to adhere to this plan ("Construction Management Plan") if the application is deemed successful.**

A full in-depth construction management plan shall be submitted for agreement with Dublin City Council prior to commencement of the works to ensure all issues are covered during construction.

5. **Is in accordance with the proper development of the area with a high quality design.**

The design engineers confirm that the design is of high quality and in accordance with the proper development of the area.

6. **Does not cause harm or undue nuisance to neighborhoods and adjoining buildings where development is to occur, during and after construction.**

Once the basement excavation is complete a reinforced water-tight concrete basement and floors shall be constructed. Therefore, the development both during construction and after construction shall not cause harm or undue nuisance to neighbourhoods. The use of strict noise, vibration and dust monitoring during construction shall be implemented throughout the construction.

7. **Ensures adequate consideration is given to traffic planning during construction and thereafter.**

Traffic planning during construction shall be included in detail in the construction management plan to be agreed with DCC prior to commencement of construction.

8. **Does not have an adverse effect on existing patterns of surface water drainage, including infiltration into groundwater and is consistent with DCC's Policy on Sustainable Urban Drainage Systems (SUDS).**

The site was covered with hardstanding prior to demolition. Therefore, there is no increase in surface water being generated with the proposed development. A full engineering services report has been provided indicating that the surface water drainage is designed to DCC's policy on sustainable urban drainage systems.

9. **Does not increase groundwater infiltration into existing sewers and drains beyond permitted restrictions.**

Surface water drainage in the area is under groundwater levels and the proposed development shall not affect the infiltration into existing systems.

10. **Shall not significantly impact on groundwater or surface water flows to the extent that this is likely to increase the risk of flooding. This flood risk is to be evaluated, in accordance with the OPW 2009 Guidelines, during and post construction with appropriate mitigation provided.**

A full flood risk assessment report has been carried out. The proposed development does not increase the risk of flooding. This risk has been evaluated for both during and post construction.

11. **Does not include basement development for residential use, below the estimated flood levels in flood zone areas Zone A or Zone B (see DCC Development Plan for Zone locations).**

The flood risk assessment provides an assessment relating to ramp access to the basements provided to ensure that the flood levels equal to flood zone A and B are prevented from entering the basement. Therefore, the proposed meets with this requirement.

12. **Accounts for the impact of the future planting and mature development of trees on site. A thickness of at least 1m of soil on the "roof" of a basement is required to mitigate against and minimise surface water runoff, with various SUDS measures incorporated.**

A full landscape plan is provided to meet the requirements of the SDZ planning scheme for the area and the drainage has been designed to DCC's SuDS requirements.

13. **Ensures that, all basement developments shall account for and accommodate the existing groundwater contained within and flowing through their site. As a minimum standard there is to be at least 0.5m wide of clear space provided between the site/property boundary and the outer extent of a basement. This 0.5m wide space and shall extend over the full height and around the perimeter of the basement and shall be filled with suitable, highly permeable material (with appropriate wrapping).**

We refer to the cross sections provided through the site where there are naturally occurring sands and gravel layers to significant depths. Therefore, there is no impediment to the flow of groundwater by the proposed basement as the groundwater is free to flow around the site, as presented in Figure 4 & 5. Therefore, the installation of permeable material is not required.

14. **Accounts for the characteristic of the site. In the case of a domestic basement development to the rear of a property (garden) generally should not exceed the footprint of the original building and be no deeper than one full storey below ground level. Domestic basement development should generally not extend to more than 50% of the amenity/garden space.**

This does not apply to this site.

15. **Provide appropriate evidence for larger schemes, including those consisting of more than one storey in depth or extending beyond the footprint of the above ground building, to demonstrate to the Planning Authority`s satisfaction that the development does not harm the built and natural environment or local amenity.**

As the development complies with the planning scheme for the area it is clear that the development does not harm the built and natural environment or local amenity.

16. **Takes account of the content of the "Dublin City Development Plan 2016 – 2022" for construction and development related matters. This policy is to be read in conjunction with this document and all other current DCC policies.**

As per the planning submission the development takes full account of the Dublin City Development Plan 2016 to 2022.

17. **Conserves and where possible enhances the biodiversity value of the site.**

This does not apply to this site as it is a brownfield docklands development.

18. **Ensures appropriate handling and dealing with waste removal, including contaminated/hazardous ground arising during construction – details to be included in the "Construction Management Plan".**

As per the submitted documents all contaminated ground shall be dealt with in accordance with statutory legislation and shall be shipped to appropriately licensed landfills.

19. **Ensures that the impact of the proposed construction methodologies and temporary works and ground anchors are fully assessed and any necessary mitigation measures put in place.**

All ground anchors under roads shall be of glass fibre as per the requirements of Dublin City Council and therefore can easily be removed during any future road excavation requirements.

20. Does not impact negatively on the surrounding areas, both private and public.

The proposed development as noted above does not impact negatively on the surrounding areas both private and public.

5 CONCEPTUAL SITE MODEL

The available existing information was utilised to estimate the baseline conditions for the site and all available information was compiled into a preliminary Conceptual Site Model (CSM). As presented below and represented graphically in Figures 3, 4 and 5.

5.1 Existing Conditions

The site is underlain by Calp Limestone, which is classified as a Locally Important Aquifer, bedrock which is moderately productive only in local zones (Ll). The sands and gravels in the area have not been classified as aquifers by the GSI in the vicinity of the site but contain shallow groundwater as seen in the site investigations.

The site is classed as having Low groundwater vulnerability indicating that the overburden in the area will be greater than 10m in thickness. The site is underlain by low permeability subsoils according to the GSI. This was confirmed by extensive site investigation inside the site boundary. The investigation found that the site is underlain by a layer of made ground to a maximum depth of 9mBGL. The natural subsoils consist of a silt layer, which in turn is underlain by a thick sequence of gravels & sands overlying a Boulder Clay layer of unknown thickness. It appears that this gravel/sand layer varies onsite from 3-8m in thickness with the lowest recorded level being at approximately 11mBGL. Boreholes were drilled to a depth of 17mBGL in the boulder clay with no bedrock encountered to this depth.

Results of a groundwater monitoring exercise undertaken on the existing monitoring wells on-site by RSK in June 2019 concluded that there is unlikely to be a continuous shallow groundwater table within the overburden soils encountered beneath the site. Of the 13 shallow wells installed within the made ground only five had groundwater present.

Groundwater monitoring undertaken on the deep wells installed in the natural gravel subsoils indicated the presence of a continuous groundwater body within the gravels with a depth range between -0.081mAOD (metres above ordinance datum) (BH110a) and -0.195 mAOD (BH229). The RSK monitoring report stated that it was not possible to determine a groundwater flow direction as it is likely that there is a degree of tidal influence on the groundwater underlying the site. It is assumed however, that groundwater in the shallow gravel aquifer is likely to flow in a south to south easterly direction towards the River Liffey.

The groundwater aquifer in the calp limestone bedrock is expected to be confined by the overlying low permeability boulder clay. It is expected that large volumes of shallow groundwater will be stored in the thick sand and gravel layer. Vertical migration of groundwater in the sand and gravel subsoils is considered restricted by the low permeability boulder clay beneath the site.

During the site investigation a buried pit was discovered to the north of the site which was likely to have been used for the treatment of timber by soaking the wood in creosote.

The GQRA report prepared by RSK in July 2019 established the contamination status of the soil and groundwater underlying the site and identified any potentially significant risks to human health and / or the water environment. The soil assessment identified areas of elevated contamination in the fill and underlying subsoils with contaminants of concern (COC) consisting of PAHs, hydrocarbons and metals (arsenic and lead) together with asbestos in shallow fill material. In a preliminary site assessment report undertaken by Arup in August 2018 reported high concentrations and flow of ground gases.

Similarly, the COC in the shallow groundwater beneath the site included elevated PAHs, hydrocarbons and metals (arsenic), ammoniacal Nitrogen, phenols and vinyl chloride.

Surface water samples taken from the River Liffey upstream, downstream and adjacent to the site had no detection of contamination from potential COC from the site indicating no pollutant linkage from the site to the River Liffey receptor.

5.2 Construction Phase

The proposed maximum depth of excavation is approximately 16mBGL (to -12mOD). The presence of the secant pile walls may result in a diversion of regular groundwater flow paths with groundwater mounding upgradient of the pile walls and lowering downgradient of the pile walls, as presented in Figure 3. It is unlikely that significant diversion of groundwater flow paths will occur.

As the permeability of the underlying sand and gravel strata is expected to be moderate to high it is anticipated that water will flow freely around the proposed secant pile walls through these permeable layers. It is considered unlikely that significant mounding will occur. In addition, the area in which groundwater will be excluded is significantly less than that of the water bearing sand and gravel layer that is anticipated to be present in the area. Therefore, the structure is not expected to have the potential to significantly impede normal groundwater flow patterns as the shallow water should flow around the structure.

The RSK site investigation works shows minor tidal variation influence on the shallow groundwater levels on-site of approximately 0.1 to 0.3m. This shows the tidal variation of up to 4m in the adjacent River Liffey has little influence on the shallow groundwater levels due to the presence of the quay wall.

5.3 Operational Phase

The removal of subsoils within the footprint of the excavated basement and its replacement with a tanked structure will result in localised diversion of shallow groundwater flow paths around the structure. There is a possibility of groundwater mounding as a result of this potential diversion to groundwater flow patterns. However, given the groundwater in the sand and gravel subsoils is not a significant groundwater body with no direct hydraulic connection with the underlying bedrock aquifer any significant diversion of groundwater flow paths is not expected. Immediately downgradient of this localised flow diversion there is the potential for lowering groundwater levels before the normal groundwater flow patterns converge again, as presented in Figure 3.

6 PROPOSED BASEMENT – GROUNDWATER IMPACT ASSESSMENT

The potential impacts during the construction phase of the proposed development on the hydrogeological environment are outlined below. The proposed dewatering programme for the site considers the hydrogeological impact that the proposed development and basement may have on the hydrogeology of the site and surrounding area including environmental receptors in term of groundwater quality and groundwater flow.

6.1 Construction Phase Impacts

6.1.1 Soils and Geology

The expected excavation depth is likely to be 16mBGL (or -12mOD). Site investigations on the site show that this depth is expected to be hosted in Boulder Clay. The lower layers of boulder clay will be exposed for a short period of time during the construction phase in which time the known creosote related contamination could migrate to the lower strata and possibly into the bedrock aquifer.

6.1.2 Groundwater Quality

- Surface Contaminants

There are known areas of elevated hydrocarbons, PAHs and metals contamination with the fill material and underlying subsoils which are to be excavated. The excavation of these contaminated zones has the potential to release contamination into the shallow groundwater. Removal of lower permeability boulder clay in the deeper excavation increases the vulnerability risk of the underlying bedrock aquifer to known contamination within the shallow groundwater. This would provide a direct pathway for contaminants or surface runoff to enter the underlying bedrock aquifer and could result in a negative impact on groundwater quality.

Poorly designed and installed monitoring and pumping wells can inadvertently allow contamination of deeper strata by providing a downward pathway for migration of the known contamination of the buried pit and made ground in the north of the site. The excavations have the potential to create pathways for the migration of contaminants. Linear horizontal underground feature such as pipelines and secant pile walls have the potential to act as horizontal and vertical pathways for groundwater flows. The introduction of these pathways could have a negative short-term impact on shallow groundwater quality.

Possible groundwater contamination could be introduced during construction works by leakage from machinery and associated equipment if not adequate managed and controlled. An accidental hydrocarbon spillage would have a negative impact on shallow groundwater quality.

- Foundation Pouring

Spillages of cement and/or runoff from fresh concrete can impact the pH to shallow groundwater. The entry of cement washwater into groundwater would have a negative short-term impact on groundwater quality.

6.1.3 Groundwater Quantity

As presented in Figure 3 the installation of secant piling to allow dewatering and construction works will potentially raise groundwater levels upgradient of the site and lower groundwater levels downgradient potentially impacting nearby buildings and groundwater users, however significant impacts are not likely.

6.1.4 Groundwater Flow

The maximum depth of excavation is 16mBGL (to -12mOD) and it is assumed that the secant pile walls will extend to this depth also. This may result in localised diversion of regular groundwater flow paths as outlined previously. Groundwater flow diversion my impact neighbouring properties, especially listed buildings which would have more vulnerable foundations which can be more sensitive to changes in groundwater level. Ground settlement can occur in areas of groundwater lowering such as the downgradient region of the proposed basement structure. The quay wall is a listed structure which is located approximately 30m in the downgraident region of the proposed development site. Although the effective stress in the ground as a results of lowering groundwater levels and pore water pressures is unlikely to damage nearby buildings/structures a preconstruction assessment of the surrounding building structures is recommended. A survey of potential buildings at risk of settlement should be monitored over the construction period.

The potential raising of shallow groundwater levels in the upgradient region of the proposed development could impact on services in the area such as groundwater becoming in contact and causing ingress to sewers etc, causing a negative long-term impact.

6.2 Operational Phase Impacts

6.2.1 Soils and Geology

The operation of the proposed development is not expected to have a direct impact on the underlying soil or geological environment. Removal of the contaminated fill and subsoil material will improve the environmental impact of this current contamination on-site. The area will be largely permanently covered with an impermeable surface which will minimise the potential for surface contaminants such as spill and leak from vehicles.

6.2.2 Groundwater Quality

The proposed dewatering works required for the construction operation will involve water treatment as part of the operation and therefore lead to an improvement in the groundwater quality to the current condition. Operational

activities on the site will allow for storm water runoff to collect in dedicated interceptors prior to appropriate discharge off-site. There will be no direct discharge to groundwater from operational activities.

6.2.3 Groundwater Dependant Features

There are no groundwater dependant features in the immediate vicinity of the site. The shallow groundwater flow in the subsoils to the River Liffey is currently impeded by the quay wall.

6.2.4 Groundwater Flow

Groundwater flow paths in the shallow groundwater within the permeable subsoils above the bedrock aquifer will be diverted around the basement structure. It is anticipated that the shallow groundwater will flow freely around the structure in the higher permeability sand and gravel subsoils without causing significant mounding of groundwater upgradient. These sand and gravel deposits are likely to extend along the River Liffey channel and therefore localised flow impedance around the basement structure is predicted over this wider shallow aquifer. The main groundwater body for this area is within the underlying limestone bedrock aquifer which will not be impacted by the building development or operational phase of works.

7 MITIGATION MEASURES

Construction of the proposed basement has the potential to cause negative short term to long term impacts to the hydrogeology of the site and its surrounds. A number of planned mitigation measures details below will reduce the impacts significantly.

7.1 Construction Phase (Soils)

From the detailed site investigation and sampling works, the fill material and subsoils have been classified into different waste categories and will be disposed of accordingly to appropriate waste facilities off-site.

7.2 Construction Phase (Groundwater)

Groundwater on-site will need to be continually pumped during the construction phase, to allow site construction to proceed to install base structures (floor slab and deep structures) in dry conditions and to avoid the risk of hydrostatic uplift.

Initially the stored shallow groundwater will be removed from the sand and gravels underlying the site through dewatering wells that will be drilled in suitable locations on-site. Groundwater will be treated using an on-site waste treatment plant and then discharged to a combined sewer off-site in accordance with a discharge licence application.

7.2.1 Discharge Licence Application

Prior to undertaking the proposed dewatering works a discharge licence application to Dublin City Council (DCC) will be required for discharge of trade effluent to a surface water sewer. This will require:

- Baseline sampling of water quality from existing groundwater installations onsite.
- Laboratory analysis of water samples for set parameters as outlined by discharge licence conditions.
- Discharge volume calculations based on site hydrogeology, construction details, average rainfall, workforce populations, etc.
- Advertisement of proposed discharge to surface water in a local newspaper
- Submission of discharge licence application to Dublin City Council.
- Administration fee payable to Dublin City Council for discharge licence applications.
- Correspondence with Dublin City Council regarding the status of the licence and any further information they require.

7.2.2 Dewatering Design

A suitable dewatering design for the above site based on several criteria, namely site hydrogeology, average rainfall, construction details, discharge licence limits, available space on site, groundwater storage volumes, groundwater inflow calculations, etc. The dewatering design stage will include:

- Conceptual hydrogeology cross sections based on previous site investigations.
- Site comparisons with other dewatering operations undertaken locally.
- Required water treatment plant on-site in order to treat the identified contaminants of concern prior to discharge off-site.

In order to limit the risk of spreading identified metals and creosote related groundwater contamination across the site pumping will be limited to the northern side of the site thus keeping any groundwater contamination present localised. The sand and gravel present across the site is expected to have high permeability which will allow groundwater to flow towards installed wells from all areas of site. Further dewatering wells will be installed on-site as required in order to fully dewater the site for construction works. Pumping from the southern side of site will be monitored during the dewatering stage to determine if the contamination risk has been reduced based on laboratory results from raw water entering the proposed on-site water treatment system.

7.2.3 On-site water treatment plant

The on-site water treatment system will be setup so that water will initially be pumped into a settlement tank, which will primarily treat the water for suspended solids present. The settlement tank has an additional function of preventing the migration of potential LNAPL via a series of internal baffle walls and a weir facility to siphon off potential product into an adjacent IBC for safe disposal. Likewise the treatment system will cater for DNAPL if present in the groundwater and will be prevented from migrating to the outlet of the tank via a second baffle wall in the treatment plant where is will settle on the base of the tank where it can removed later via vacuum tanker as required.

Once water exits the settlement tank, it will then be pumped into a series of activated carbon vessels where activated carbon will adsorb the dissolved hydrocarbon present and prevent its migration onwards towards a flowmeter and sewer outfall. The dewatering well placement on-site will be modelled and planned with a focus on using the most effective dewatering method in advance of the general dig site commencement works. Additional activated carbon vessels can be added to this system if a faster rate of groundwater level decline is required.

Treated for other parameters such as ammoniacal nitrogen and metals will be undertaken as required to satisfy the requirement of the discharge licence.

7.2.4 Dewatering Infrastructure Installation

Site specific dewatering infrastructure design will need to include:

- Organising materials and equipment to site.
- Installation of a sufficient number of dewatering wells using the existing piling rig onsite.
- Purging of installed wells to waste.
- Installation settlement tank, hosing, pumps, flow meters, etc.
- Installation of remote water quality monitoring telemetry system inclusive of rainfall, flow monitoring, water levels, etc.
- Installing of external monitoring wells outside of the secant wall perimeter to monitor groundwater levels during the dewatering process.

Once the initial storage water has been pumped, treated and discharged off site, there will be continued pumping and treating of groundwater based from three sources, namely:

1) rainfall landing on-site;
2) upwelling groundwater from the underlying strata and;
3) the lateral inflows from potential leaks through the secant pile wall.

The third factor is generally very difficult to model and therefore it is proposed that these leaks be should be sealed up as quickly as possible when identified in order to reduce the risk of excessive drawdown in groundwater levels outside of the site.

Regular monitoring of the groundwater quality of the on-site treatment plant will be undertaken to ensure the discharge water quality is being adequately treated prior to discharge.

Dewatering will be stopped once a structural assessment (provided by the Client) concludes the risk of hydrostatic uplift is no longer present and all joints and wellheads are sealed out; at this stage the dewatering infrastructure will be removed from the site. All wells will need to be decommissioned appropriately in accordance with best practice guidelines such as “Decommissioning abandoned boreholes and wells’, Environment Agency 2004.

8 CONCLUSIONS

The site of the proposed development of the SDZ commercial scheme and adjoining 1005 No. unit SHD housing scheme with multiple basement levels is located along North Wall Quay and is contained in an area known as City Block 9 as described by the North Lotts and Grand Canal Dock Strategic Development Zone (SDZ) Planning Scheme. The proposed development and associated basement structure are expected to extend to 16mBGL (to -12mOD). A progress report for the site in November 2020 outlined that at the time over half the pile wall is installed around the full City Block 9.

Historical maps indicate the site was used for various industrial uses including a Vitriol Works, bathhouses and glassworks in the early 1800s. In the early 1900s the site was occupied by a large sawmill and timber yard. These historical site operations have caused contamination of the subsurface fill material and underlying subsoils together with the shallow groundwater within the subsoils. The identified contaminants of concern include creosote related parameters (PAHs, and hydrocarbons), metals and ammoniacal nitrogen. Creosote impacted groundwaters were not found in the sand and gravel layer beyond 75m downgradient of the buried treatment timber pit located in the north of the site, within the site boundary.

Approximately 30m to the south of the proposed site boundary, North Wall Quay defines the boundary of the Lower Liffey Estuary. The river water quality status for the River Liffey at this location is classified by the EPA as “unpolluted”. Surface water samples retrieved from three locations along the River Liffey near the site did not identify a pollutant linkage to the site. The boundary of the Dublin Bay SPA is located approximately 2.8km to the east of the project area; along the Liffey Estuary. The site is not recorded as being at risk of fluvial or coastal flooding.

Ground investigations conducted by IGSL, ARUP and RSK, show that the site is underlain by a layer of made ground overlying a silt layer, which in turn is underlain by a thick sequence of gravels & sands overlying a boulder clay layer. Site investigation information from the site shows bedrock in excess of 17mBGL and therefore the basement excavation it not anticipated to encounter bedrock.

Groundwater on-site will need to be continually pumped during the construction phase, to allow site construction to proceed to install base structures in dry conditions and to avoid the risk of hydrostatic uplift.

The site is underlain by calp limestone of the Lucan Formation. Site investigation data shows that the site is underlain by a layer of made ground overlying a silt layer, which in turn is underlain by a thick sequence of gravels & sands overlying a low permeability boulder clay layer of unknown thickness. The thickness of the sand/gravel layer onsite varies from 3-8m across the site.

The subsoil permeability is reported as being low so it is expected that the boulder clay will act as a confining layer and will limit the vertical migration of groundwater to the locally important limestone aquifer beneath the site. The boulder clay layer of unknown thickness is also thought to create a shallow groundwater system hosted in the overlying sand and gravel layer which is the main geological unit that requires dewatering for the construction works.

A waste classification programme of works for the site will dispose of the fill material and subsoils according to their classification to appropriate disposal routes. Ground settlement can occur in areas of groundwater lowering such as the downgradient region of the proposed basement structure which needs to be examined by a structural assessment.

The dewatering design for the site will take into account the on-site known groundwater contamination by installing a sufficient number of dewatering wells on-site. Some well locations will target the area of contamination in order to allow adequate on-site water treatment prior to discharge off-site. Pumping rates will be designed to allow for sufficient retention time on the water treatment plant to allow adequate treatment.

It is assumed however, that groundwater in the shallow gravel aquifer is likely to flow in a south to south easterly direction towards the River Liffey with minimal tidal influence (<0.3m) reported on the water table. Shallow groundwater flow from the sand and gravels is currently restricted by the present of the quay wall at the River Liffey which has a 4m tidal range. There are no groundwater dependant features in the immediate vicinity of the site.

The presence of the secant walls around the entire City Block 9 site will result in a localised diversion of regular groundwater flow paths with localised groundwater mounding upgradient of the pile walls and lowering downgradient of the pile walls. It is unlikely that significant diversion of groundwater flow paths will occur. Installation of monitoring well/wells outside the pile wall will provide information on any potential groundwater mounding/lowering. The main groundwater body for this area is within the underlying limestone bedrock aquifer which will not be impacted by the building development or operational phase of works.

A review of the combined basements in the neighbouring building to the east and west was undertaken and presented in a conceptual ground model as recommended in the DCC Basement Development Guidance Document. The existing and proposed basements are not directly adjoining and therefore provide groundwater flow access corridors between the buildings which minimises groundwater flow pathways from extending around multiple basement structures.

A review of Dublin City Council (DCC) basement development policy requirements was undertaken for each item in relation to the proposed development with appropriate environmental monitoring, traffic planning, construction management plan, drainage, landscape, flood risk and engineering responses provided with no impact predicted once the appropriate mitigation measures outlined are adhered to.

There are possible short term impacts to groundwater quality from the vertical migration of contaminants with the excavation of the protective soil layers. In order to prevent the spread of contamination from a known contamination zone on the site pumping of groundwater will be limited to the northern section of the site, treated and discharged to a combined sewer off-site subject to conditions of the discharge licence.

The on-site water treatment plant will be designed to cater for the known contaminants of concern that are known to be on-site within the shallow groundwater. Although the detection of free phase product was not reported to be present on-site the water treatment system proposed will cater for LNAPL and DNAPL if present. Treatment design well cater for all contaminants of concern which will be verified by further baseline groundwater monitoring on-site prior to dewatering works.

Other mitigation measures during the operational dewatering phase of works will allow for continuous monitoring of the pumping operation flows and water quality (pH) via a telemetry system with alarms to allow for efficient and continuous dewatering operations to proceed during the construction phase of works.

Regular monitoring of the groundwater quality of the on-site treatment plant will be undertaken to ensure the discharge water quality is being adequately treated prior to discharge.

Dewatering will be stopped once a structural assessment (provided by the Client) concludes the risk of hydrostatic uplift is no longer present and all joints and wellheads are sealed out; at this stage the dewatering infrastructure will be removed from the site. All wells will need to be decommissioned appropriately in accordance with best practice guidelines.

Overall the removal of contaminated fill material, subsoils and treatment of the contaminated groundwater during the dewatering construction works will improve the environmental quality of the area. There is not anticipated to be a direct negative environmental impact of the construction works on the soil/geological or groundwater on-site or on surrounding off-site environmental receptors (including Designated Sites) as long at the detailed dewatering plan and associated mitigation measures are implemented.

9 REFERENCES

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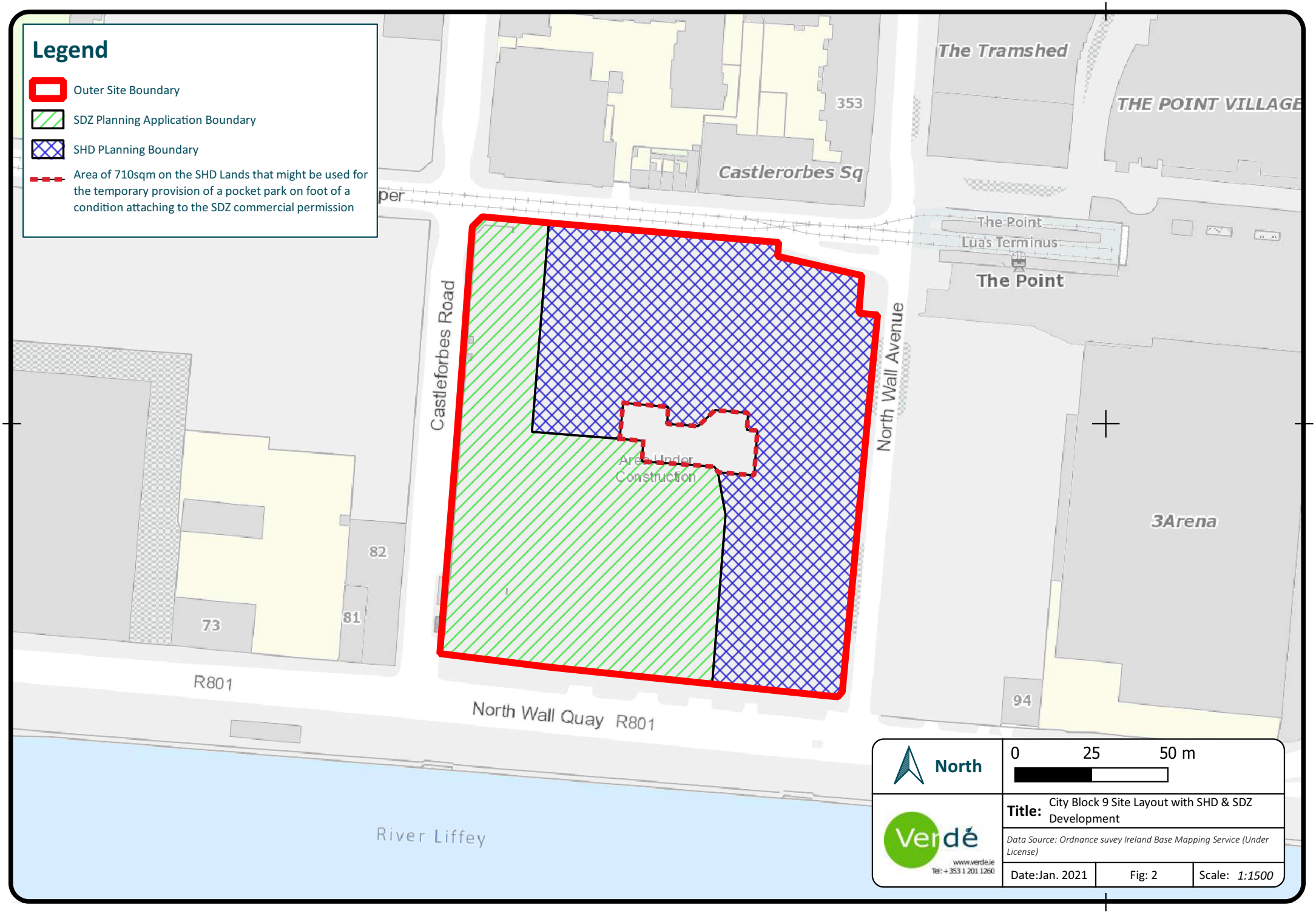
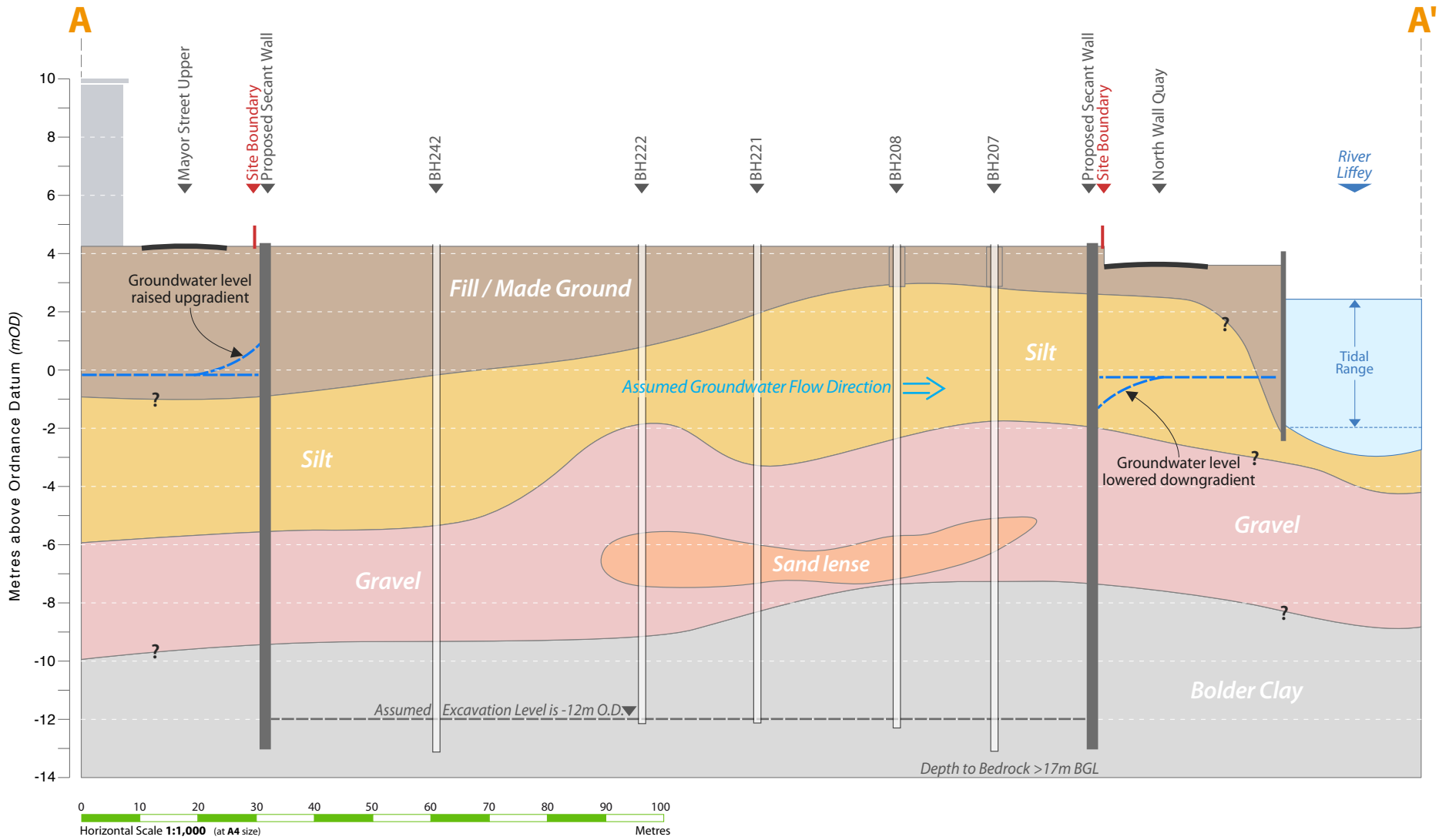
- Environment Agency 2007. Hydrogeological Impact Appraisal for Dewatering Abstractions.
- Ciria C515 (2000). Groundwater control - Design and Practice
- Decommissioning abandoned boreholes and wells, Environment Agency 2004
- Basement Development Guidance Document, Version 1.0, Dublin City Council , September 2019
- Basement Development Policy Document, Version 1.0, Dublin City Council , September 2019
- Roadbridge. Progress Report No. 6. Project Waterfront – City Block 9, 5th November 2020.

FIGURES


Site Boundary
0
750
1500 m
N
Figure 1: Site Location Map
Data Source: ESRI World Topo
Scale: 1:25000
Date: 29 - Aug - 2019
Verdé
Drumcondra
Marino
Fairview
Ballybough
Phibsborough
Clontarf
East Wall
Dublin Port
DUBLIN
Dublin 1
Dublin 7
Smithfield
Temple Bar
Ringsend
Dublin 4
Dublin 6
Ballsbridge
Dublin Harbour
Botanic Road
Clonliffe Road
North Strand Road
East Wall Road
Howth Road
Clontarf Road
Sheriff Street Upper
North Wall Quay
Pearse Street
Haddington Road
Pembroke Road
Mespil Road
Bath Avenue
Amiens Street
Seville Place
Tolka Quay Road
Promenade Road
Alexandra Road
Pigeon House Road
Irishtown Stadium
Aviva Stadium
Croke Park
Holy Cross College
Trinity College
Griffith College
Mount Prospect Avenue
Seafield Road East
Vernon Avenue
Castle Avenue
The Stiles Road
Griffith Court
Philipsburgh Avenue
Richmond Road
Whitworth Road
Alfie Byrne Road
Fairview Park
East Point Business Park
Haulage Depots
Ida Small Industries Centre
Oil Storage Area
Alexandra Dock Storage Area
North Wall Power Station
Spencer Dock
Liffey Enterprise Centre
P & O European Ferries Terminal
DFT Lolo Freight Terminal
Irish Ferries Terminal
Benson Street Enterprise Centre
South Quays Container Terminal
Irish Cement
Dublin Port South
Dublin Bay Power Station
Ringsend Park
Sean Moore Park
Ymca Sports Ground
Royal Dublin Society Showgrounds
Herbert Park
Clyde Lane
Merrion Square
St Stephens Green
Iveagh Gardens
Grand Canal
South Circular Road
Cork Street
King Street North
Jervis Street
Dublin-Holyhead
Dublin-Liverpool
Dublin-Douglas
River Dodder
Shelbourne Road
Ever Ton
5 m
9 m
7 m


318000.000
234500.000
234500.000
318000.000
Legend
Outer Site Boundary
SDZ Planning Application Boundary
SHD PLanning Boundary
Area of 710sqm on the SHD Lands that might be used for the temporary provision of a pocket park on foot of a condition attaching to the SDZ commercial permission
The Tramshed
THE POINT VILLAGE
353
Castlerorbes Sq
The Point
Luas Terminus
The Point
Castleforbes Road
North Wall Avenue
Area Under Construction
3Arena
82
73
81
R801
North Wall Quay R801
94
River Liffey
North
0 25 50 m
Title: City Block 9 Site Layout with SHD & SDZ Development
Data Source: Ordnance suvey Ireland Base Mapping Service (Under License)
Verdé
www.verde.ie
Tel: +353 1 201 1260
Date:Jan. 2021
Fig: 2
Scale: 1:1500



LEGEND

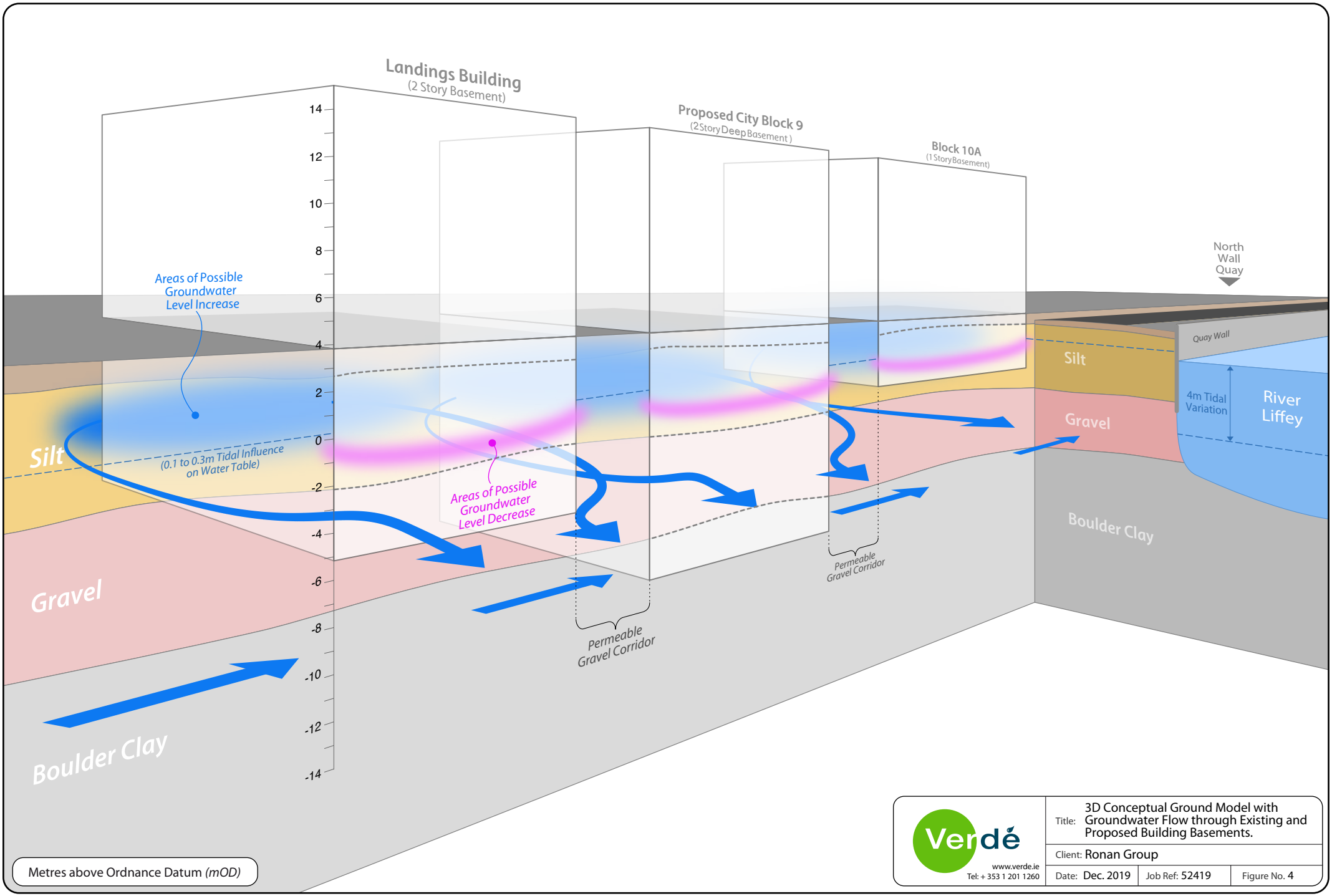
- Borehole
- ? Uncertainties
- Water Table

Verdé
www.verde.ie
Tel: + 353 1 201 1260

Title: Conceptual Site Model
North Wall Quay, Dublin

Client: Ronan Group

Date: Sept. 2019 | Job Ref: 52419 | Figure No. 3



Verdé
www.verde.ie
Tel: + 353 1 201 1260

Title: 3D Conceptual Ground Model with Groundwater Flow through Existing and Proposed Building Basements.

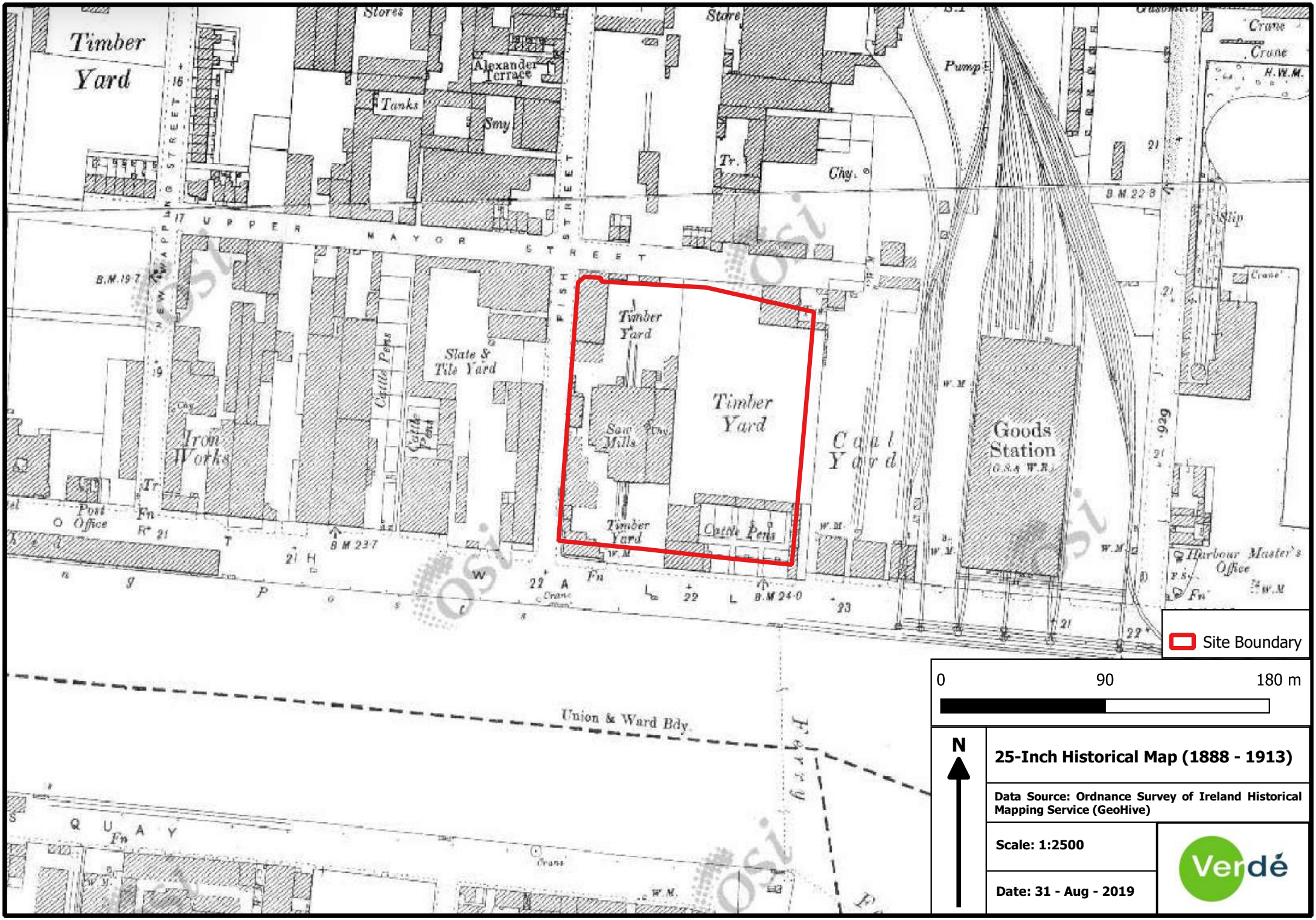
Client: Ronan Group

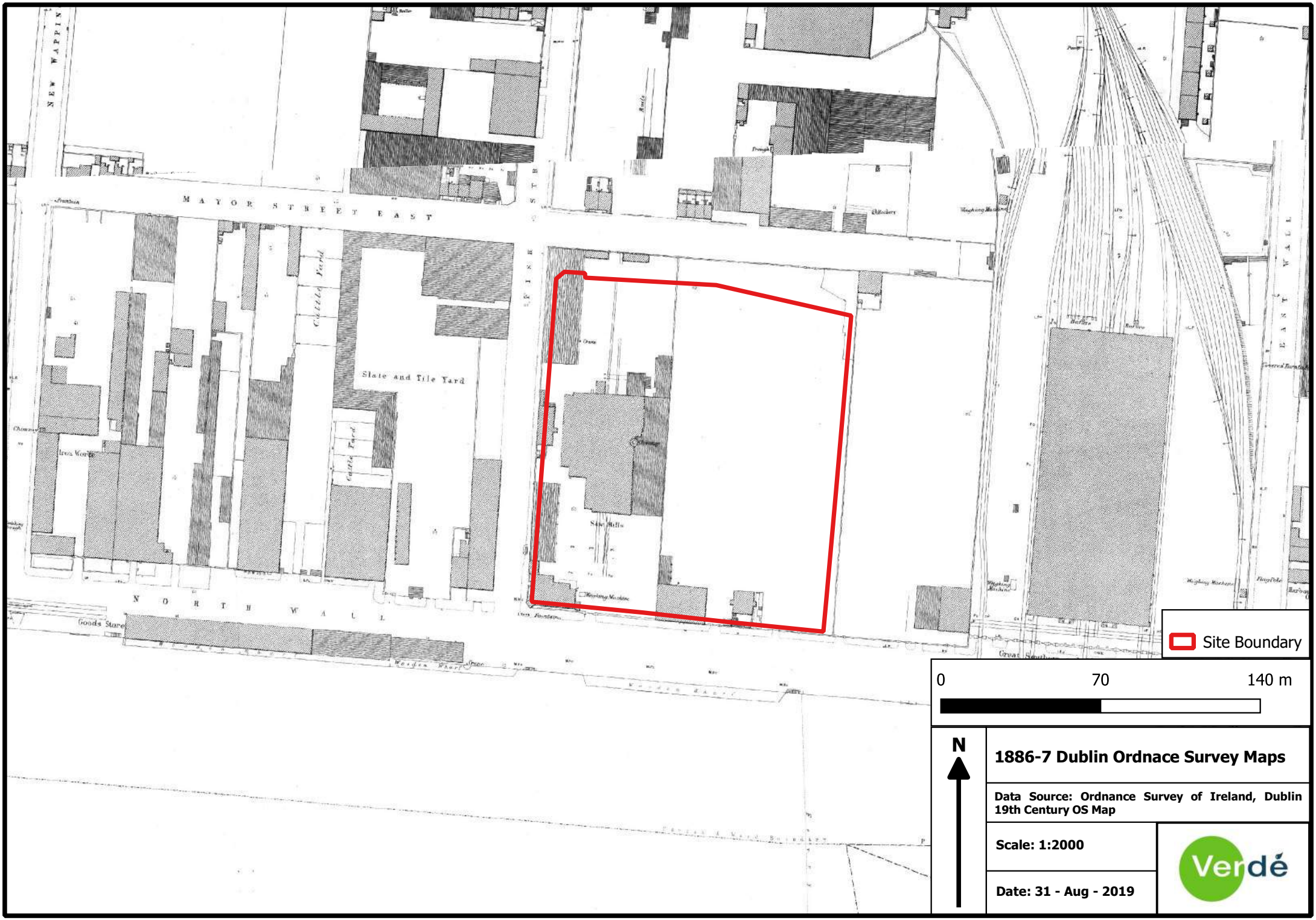
Date: Dec. 2019 | Job Ref: 52419 | Figure No. 4


Major Street Upper
Permeable Gravel Corridor
Permeable Gravel Corridor
Area of Possible Groundwater Level Increase
Area of Possible Groundwater Level Increase
Area of Possible Groundwater Level Increase
Landings Building
(2 Story Basement)
Proposed City Block 9
(2 Story Deep Basement)
Block 10A
(1 Story Basement)
Area of Possible Groundwater Level Decrease
Area of Possible Groundwater Level Decrease
Area of Possible Groundwater Level Decrease
North Wall Quay
River Liffey
LEGEND
Groundwater Flow Pathway
Verdé
www.verde.ie
Tel: + 353 1 201 1260
Title: Plan View of Cumulative Basement Effect on Groundwater Flow
Client: Ronan Group
Date: Dec. 2019
Job Ref: 52419
Figure No. 5

APPENDIX A

Desk Study Maps


Timber Yard
Stores
Store
Alexander Terrace
Tanks
Smy
Tr.
Chy.
Pump
Crane
H.W.M.
B.M 22·8
Slip
UPPER MAYOR STREET
NEW WAPPING STREET
B.M.19·7
Timber Yard
Slate & Tile Yard
Cattle Pens
Saw Mills
Iron Works
Post Office
Fn
B.M 23·7
B.M 24·0
Canal Yard
Goods Station
(G.S.& W.R.)
Harbour Master's Office
Union & Ward Bdy.
QUAY
Site Boundary
0
90
180 m
N
25-Inch Historical Map (1888 - 1913)
Data Source: Ordnance Survey of Ireland Historical Mapping Service (GeoHive)
Scale: 1:2500
Date: 31 - Aug - 2019
Verdé


MAYOR STREET EAST
NORTH WALL
EAST WALL
Slate and Tile Yard
Cattle Yard
Cattle Yard
Goods Store
Site Boundary
0
70
140 m
N
1886-7 Dublin Ordnace Survey Maps
Data Source: Ordnance Survey of Ireland, Dublin 19th Century OS Map
Scale: 1:2000
Date: 31 - Aug - 2019
Verdé


Site Boundary
0
180
360 m
N
1995 Aerial Imagery
Data Source: Ordnance Survey of Ireland Historical Mapping Service (GeoHive)
Scale: 1:5000
Date: 31 - Aug - 2019
Verdé


Site Boundary
0
180
360 m
N
2000 Aerial Imagery
Data Source: Ordnance Survey of Ireland Historical Mapping Service (GeoHive)
Scale: 1:5000
Date: 31 - Aug - 2019
Verdé

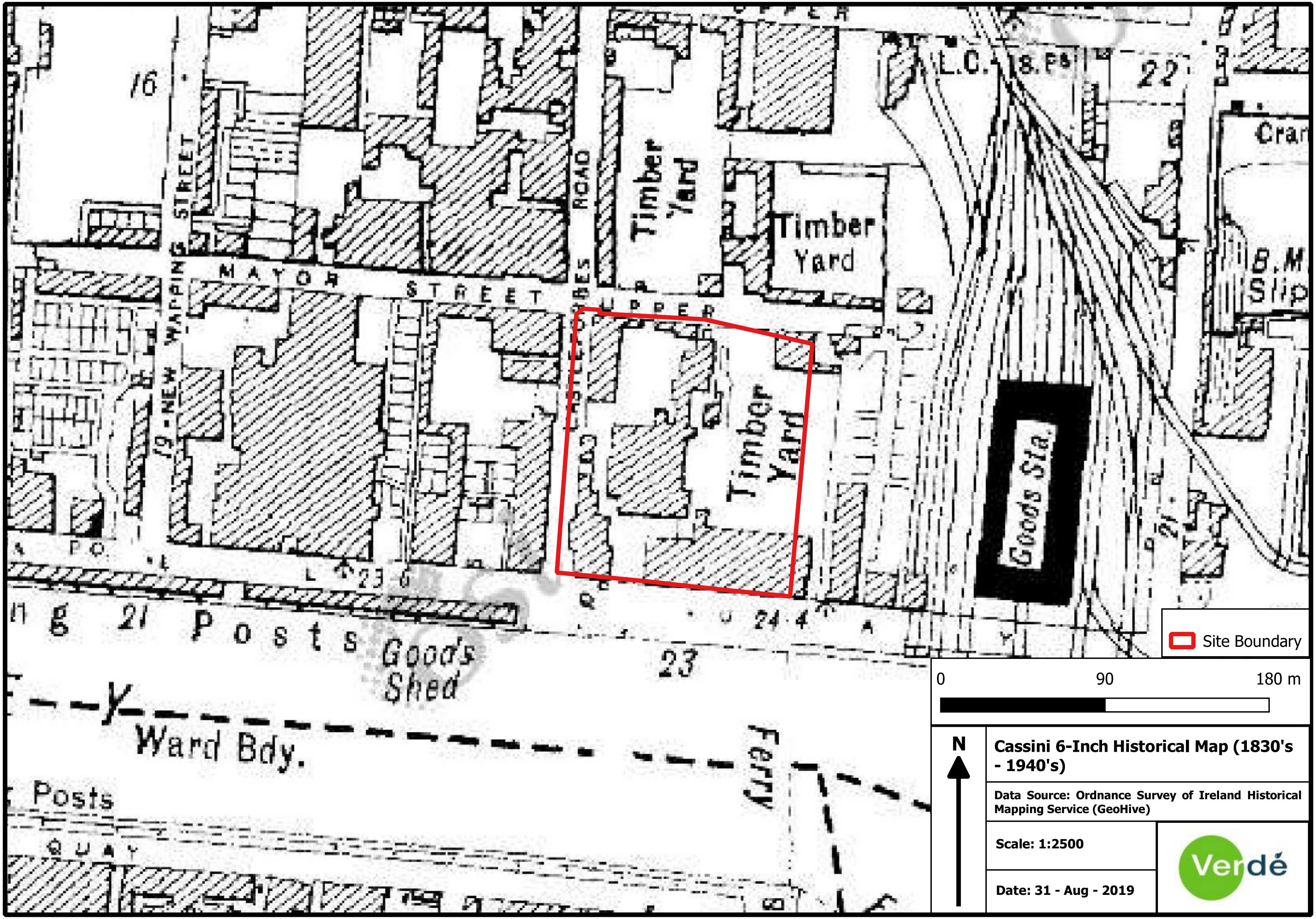
2005 Aerial Imagery

Data Source: Ordnance Survey of Ireland Historical Mapping Service (GeoHive)

Scale: 1:5000

Date: 31 - Aug - 2019

Verdé



Cassini 6-Inch Historical Map (1830's - 1940's)

Data Source: Ordnance Survey of Ireland Historical Mapping Service (GeoHive)

Scale: 1:2500

Date: 31 - Aug - 2019

Verdé

316600 316800 317000 317200 317400 317600 317800 318000

234800 234600 234400 234200 234000 233800 233600

Generalised Site boundary

Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 0.5% AEP	Flow (m³/s) 0.5% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
09LIFF00180	2.67	N/A	3.12	N/A	3.35	N/A
09LIFF00131	2.67	N/A	3.11	N/A	3.34	N/A
09LIFF00072	2.67	199.56	3.11	205.11	3.34	208.47

09LIFF00180

09LIFF00131

09LIFF00072

For river Dodder flood extents and depths refer to Dodder maps.

IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

- 10% Tidal AEP Event
- 0.5% Tidal AEP Event
- 0.1% Tidal AEP Event
- Modelled River Centreline
- AFA Extents
- Node Point
- Node ID Node Label

0 50 100 200 300 400 500 Metres

FINAL

REV:	NOTE:	DATE:
01	Amendments to Flood Extents.	05/12/16

EASTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

OPW
The Office of Public Works
Jonathan Swift Street
Trim
Co Meath

RPS
Elmwood House
74 Boucher Road
Belfast
BT12 6RZ
T +44(0) 28 90 667914
F +44(0) 28 90 668286
W www.rpsgroup.com
E ireland@rpsgroup.com

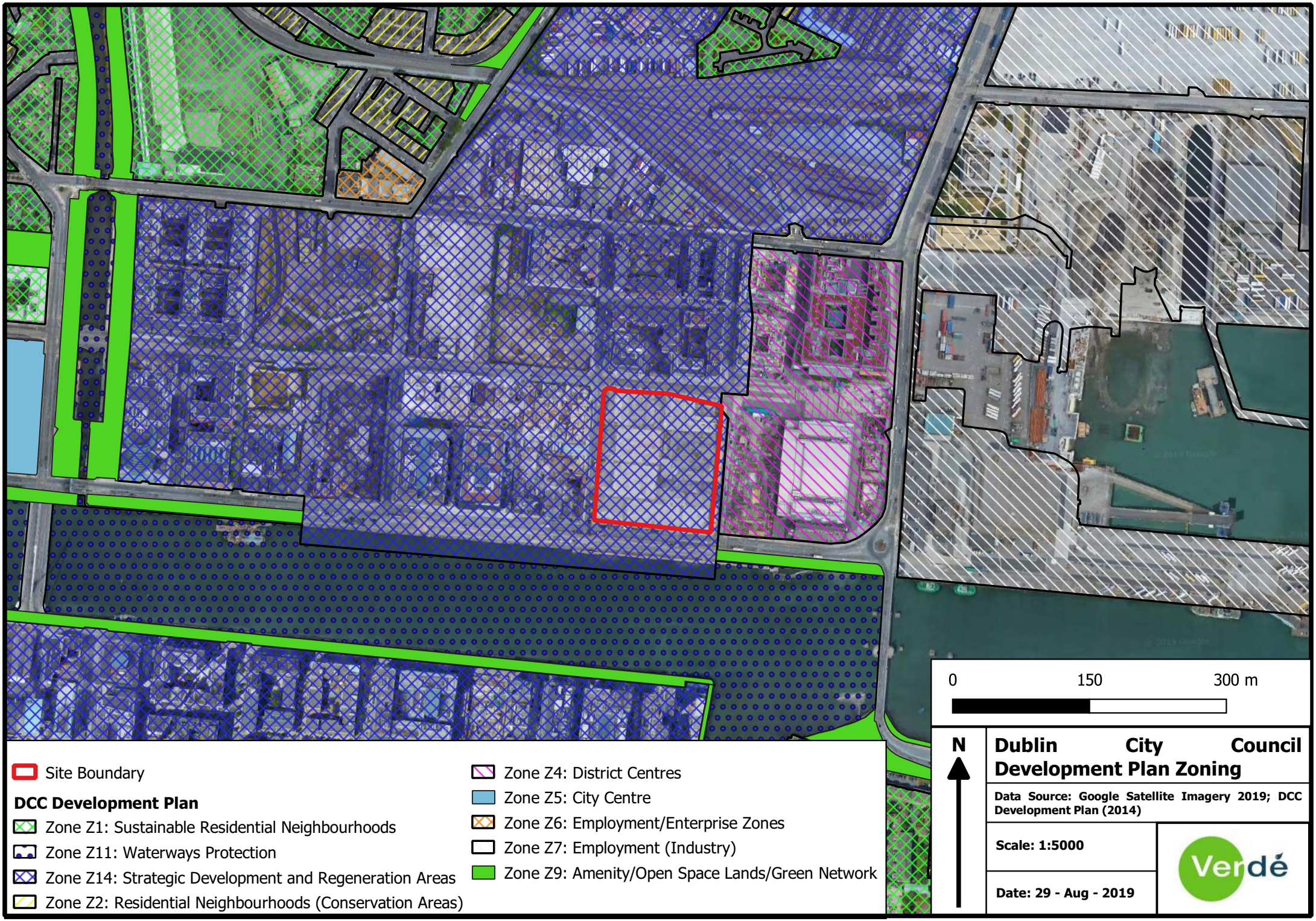
Map:
Liffey Tidal Flood Extents

Map Type:	EXTENT
Source:	TIDAL
Map Area:	COASTAL
Scenario:	CURRENT
Drawn By : C.C.	Date : 9 May 2017
Checked By : A.S.	Date : 9 May 2017
Approved By : S.P.	Date : 9 May 2017

Drawing No. :
E09LIF_EXCCD_F1_04

Map Series : Page 4 of 8

Drawing Scale : 1:5,000 @ A3


Site Boundary
DCC Development Plan
Zone Z1: Sustainable Residential Neighbourhoods
Zone Z11: Waterways Protection
Zone Z14: Strategic Development and Regeneration Areas
Zone Z2: Residential Neighbourhoods (Conservation Areas)
Zone Z4: District Centres
Zone Z5: City Centre
Zone Z6: Employment/Enterprise Zones
Zone Z7: Employment (Industry)
Zone Z9: Amenity/Open Space Lands/Green Network
0
150
300 m
N
Dublin City Council
Development Plan Zoning
Data Source: Google Satellite Imagery 2019; DCC Development Plan (2014)
Scale: 1:5000
Date: 29 - Aug - 2019
Verdé

Generalised Site boundary

316600 316800 317000 317200 317400 317600 317800 318000

234800 234600 234400 234200 234000 233800 233600

09LIFF00180

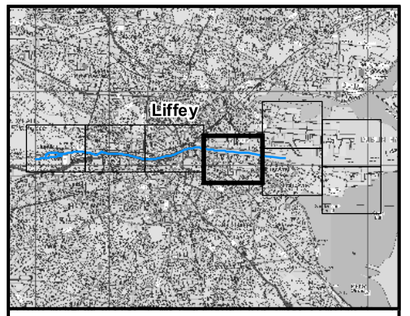
09LIFF00131

09LIFF00072

For river Dodder flood extents and depths Refer to Dodder maps.

Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 1% AEP	Flow (m³/s) 1% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
09LIFF00180	2,45	194,47	2,45	245,61	2,45	313,04
09LIFF00131	2,44	211,11	2,44	262,02	2,45	329,68
09LIFF00072	2,44	233,19	2,44	283,68	2,44	351,20

0 50 100 200 300 400 500 Metres



IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

- 10% Fluvial AEP Event
- 1% Fluvial AEP Event
- 0.1% Fluvial AEP Event
- Modelled River Centreline
- AFA Extents
- Node Point
- Node ID Node Label

FINAL

REV:	NOTE:	DATE:
01	Amendments to Flood Extents.	05/12/16

EASTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

OPW

RPS

The Office of Public Works
Jonathan Swift Street
Trim
Co Meath

Elmwood House
74 Boucher Road
Belfast
BT12 6RZ

T +44(0) 28 90 667914
F +44(0) 28 90 668286
W www.rpsgroup.com
E ireland@rpsgroup.com

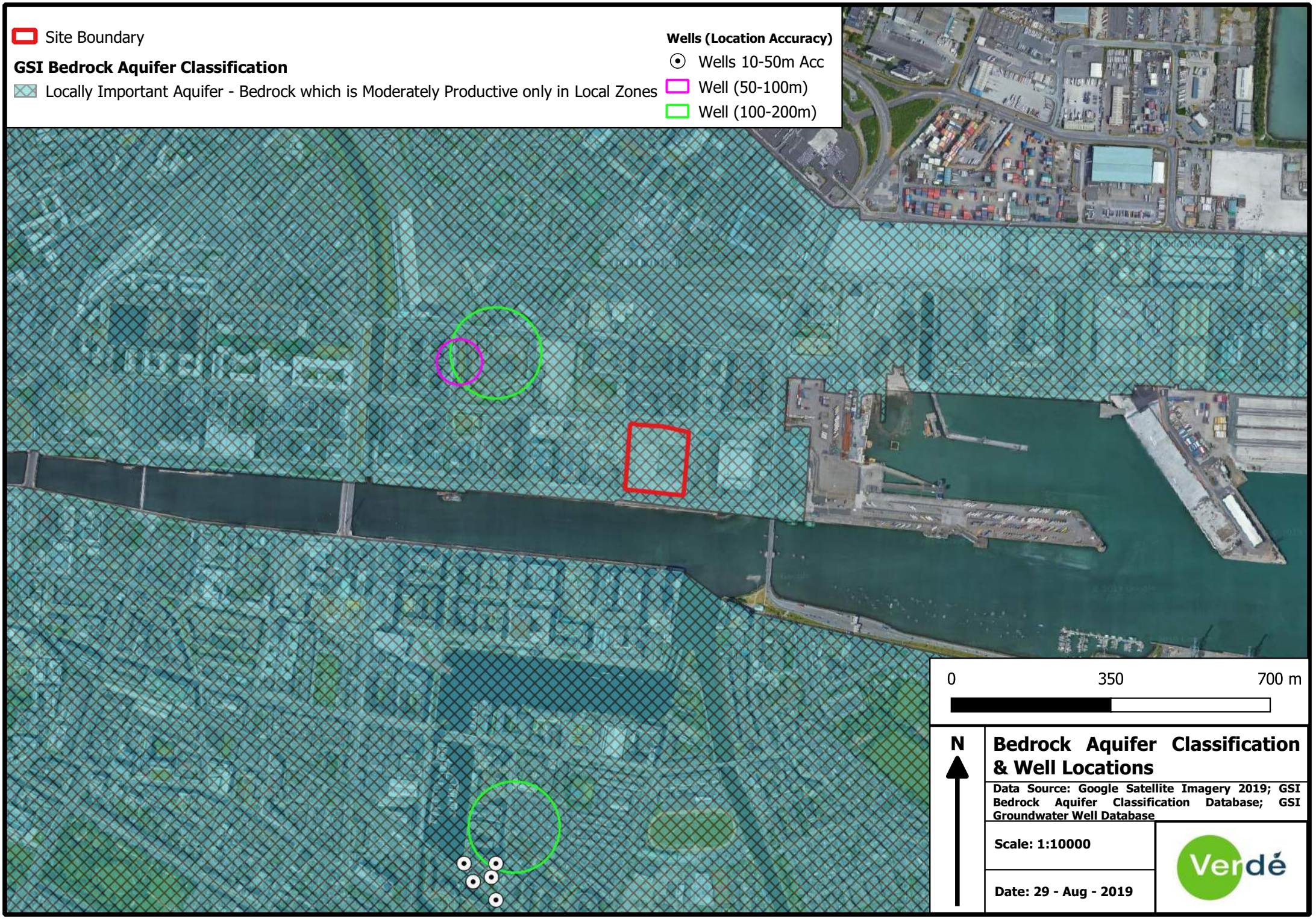
Map:
Liffey Fluvial Flood Extents

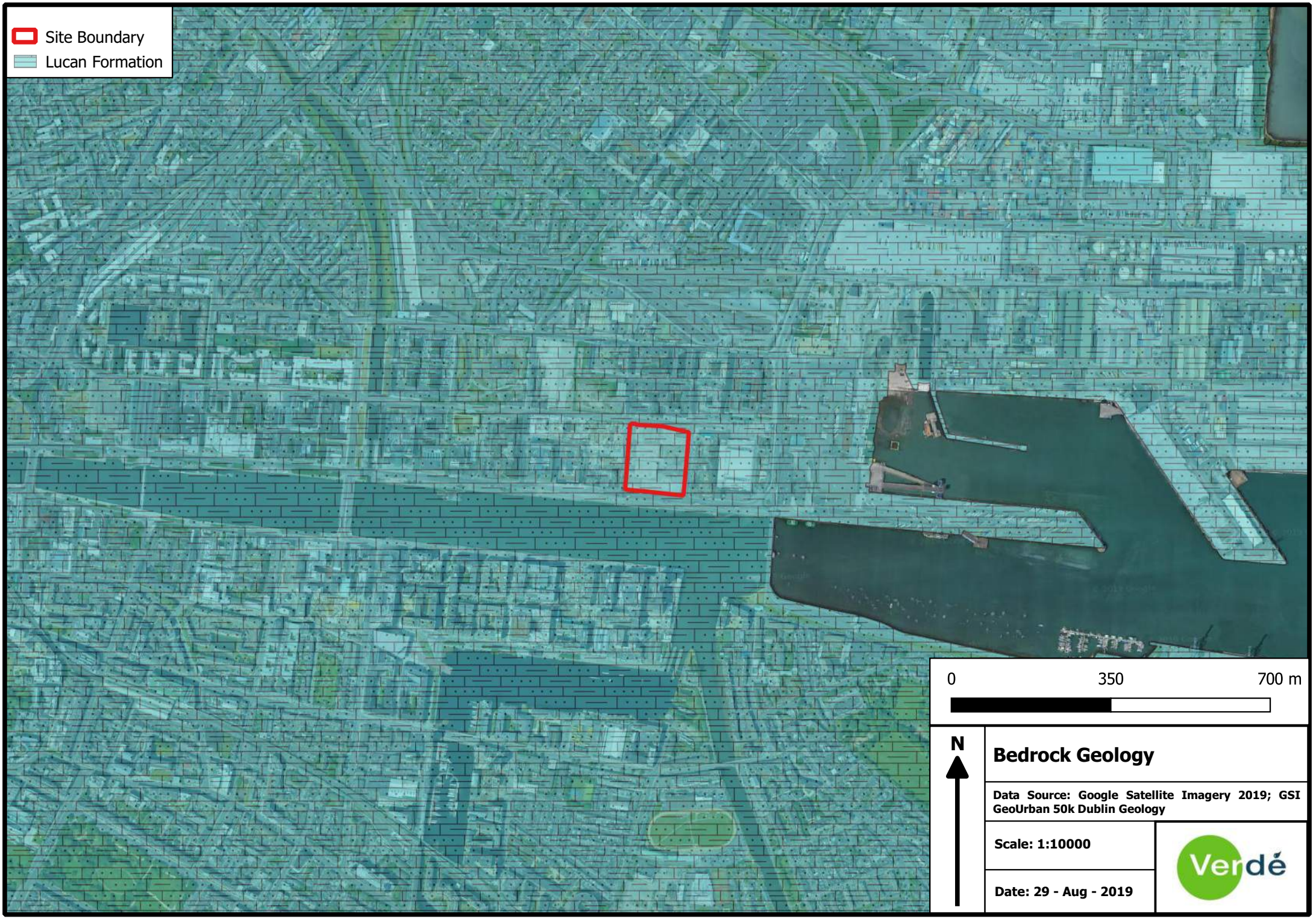
Map Type:	EXTENT	
Source:	FLUVIAL	
Map Area:	HPW	
Scenario:	CURRENT	
Drawn By :	C.C.	Date : 9 May 2017
Checked By :	A.S.	Date : 9 May 2017
Approved By :	S.P.	Date : 9 May 2017

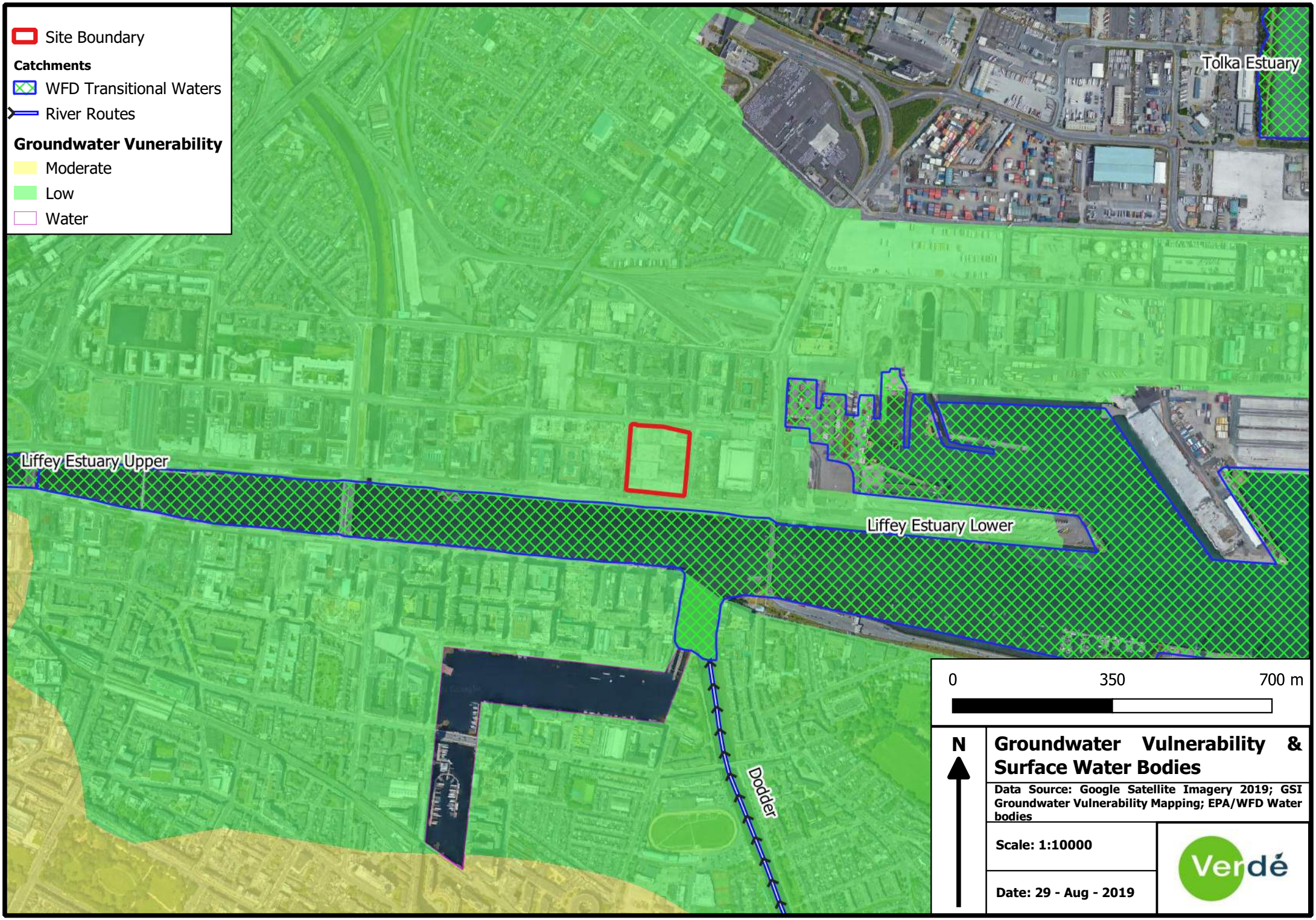
Drawing No. :
E09LIF_EXFCD_F1_04

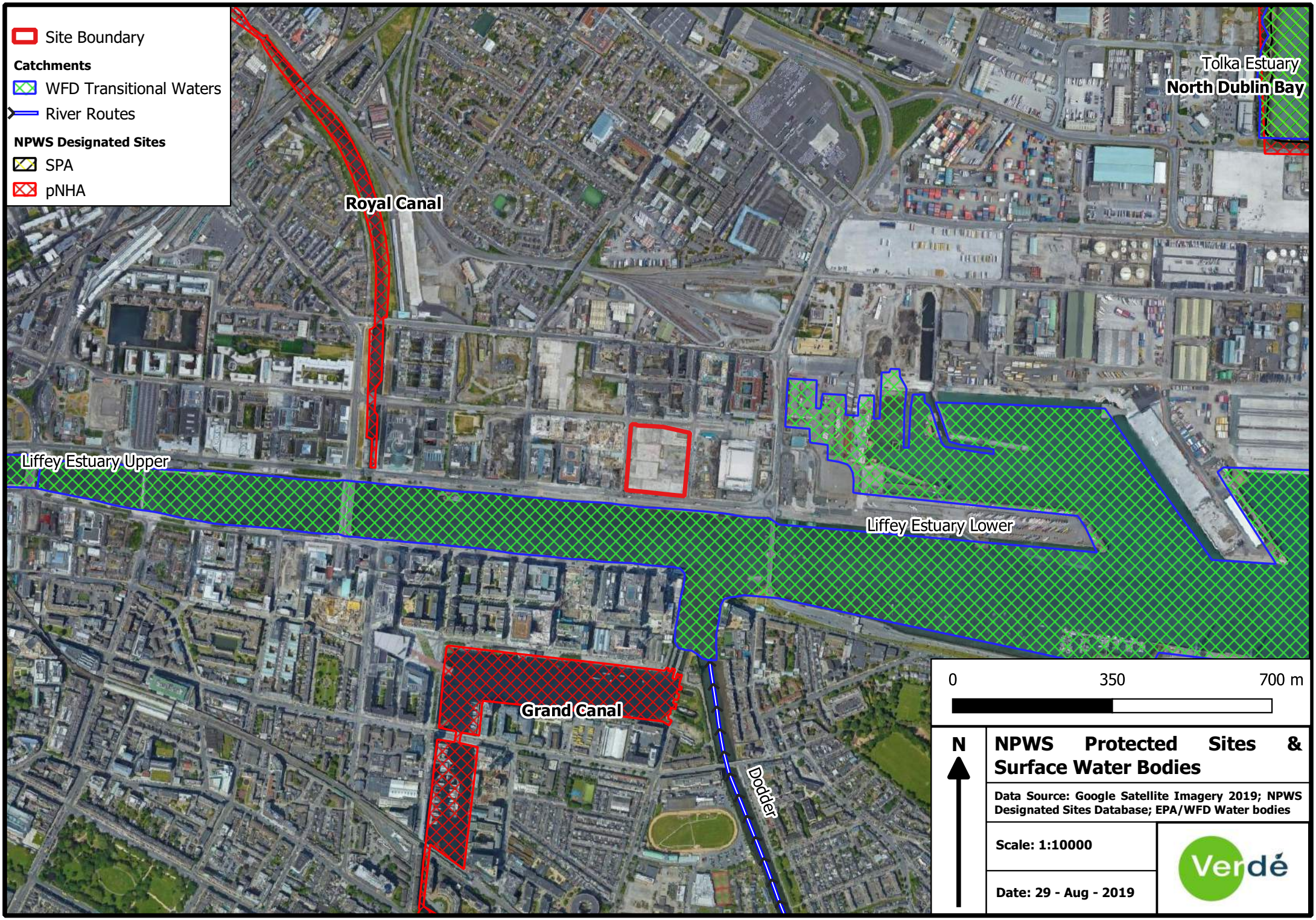
Map Series : Page 4 of 8

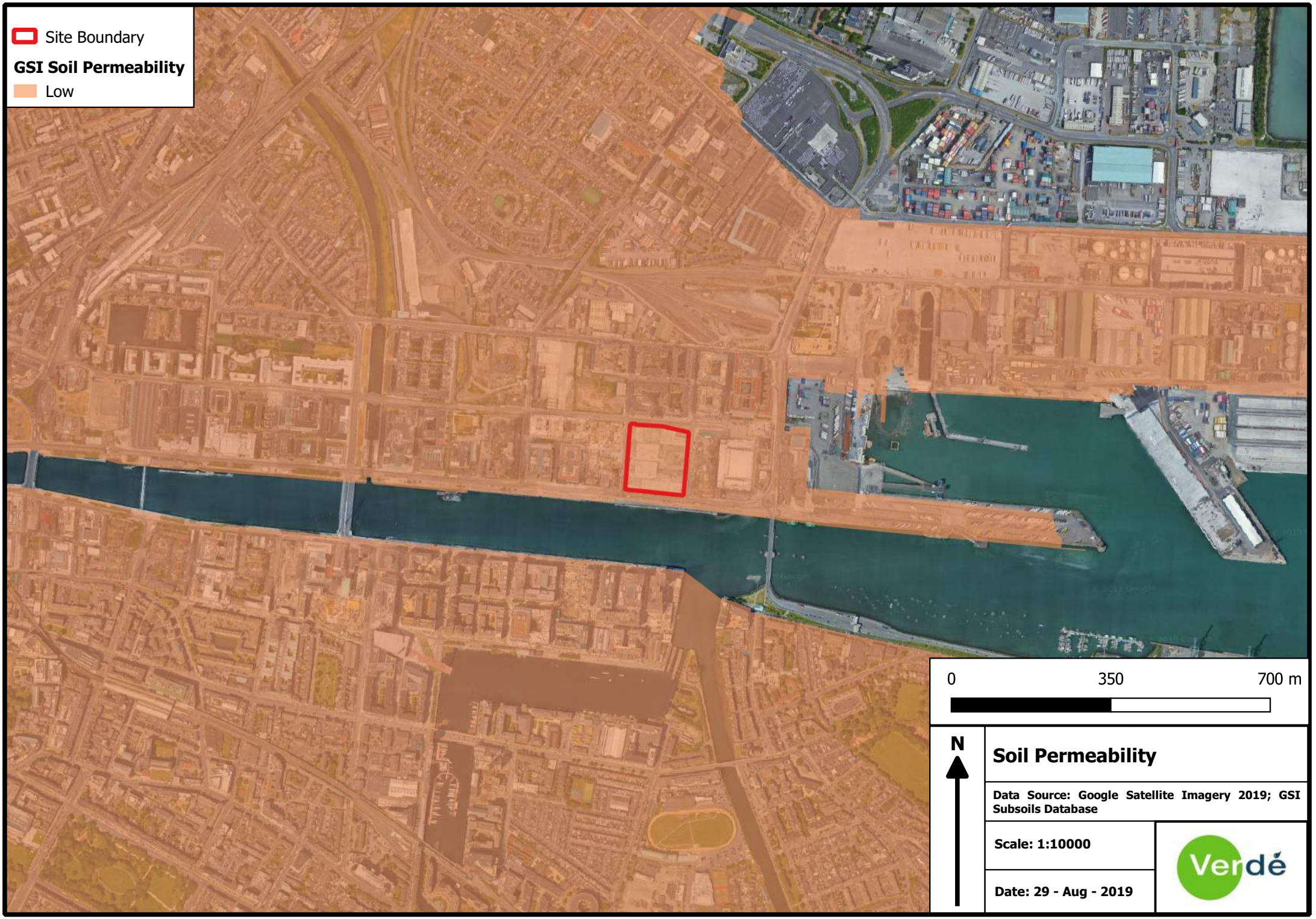
Drawing Scale : 1:5,000 @ A3

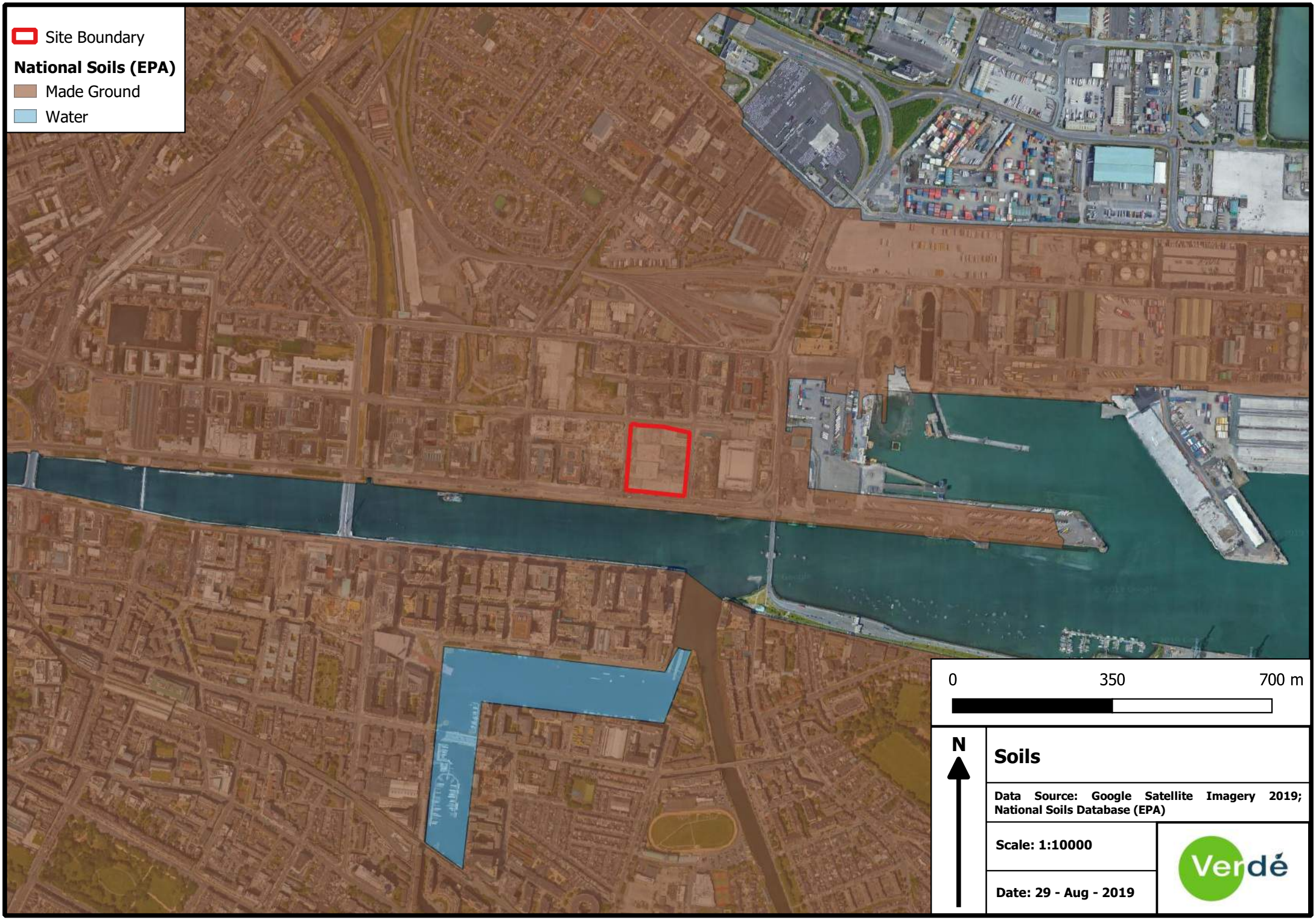

Site Boundary
GSI Bedrock Aquifer Classification
Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
Wells (Location Accuracy)
Wells 10-50m Acc
Well (50-100m)
Well (100-200m)
0
350
700 m
N
Bedrock Aquifer Classification & Well Locations
Data Source: Google Satellite Imagery 2019; GSI Bedrock Aquifer Classification Database; GSI Groundwater Well Database
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé

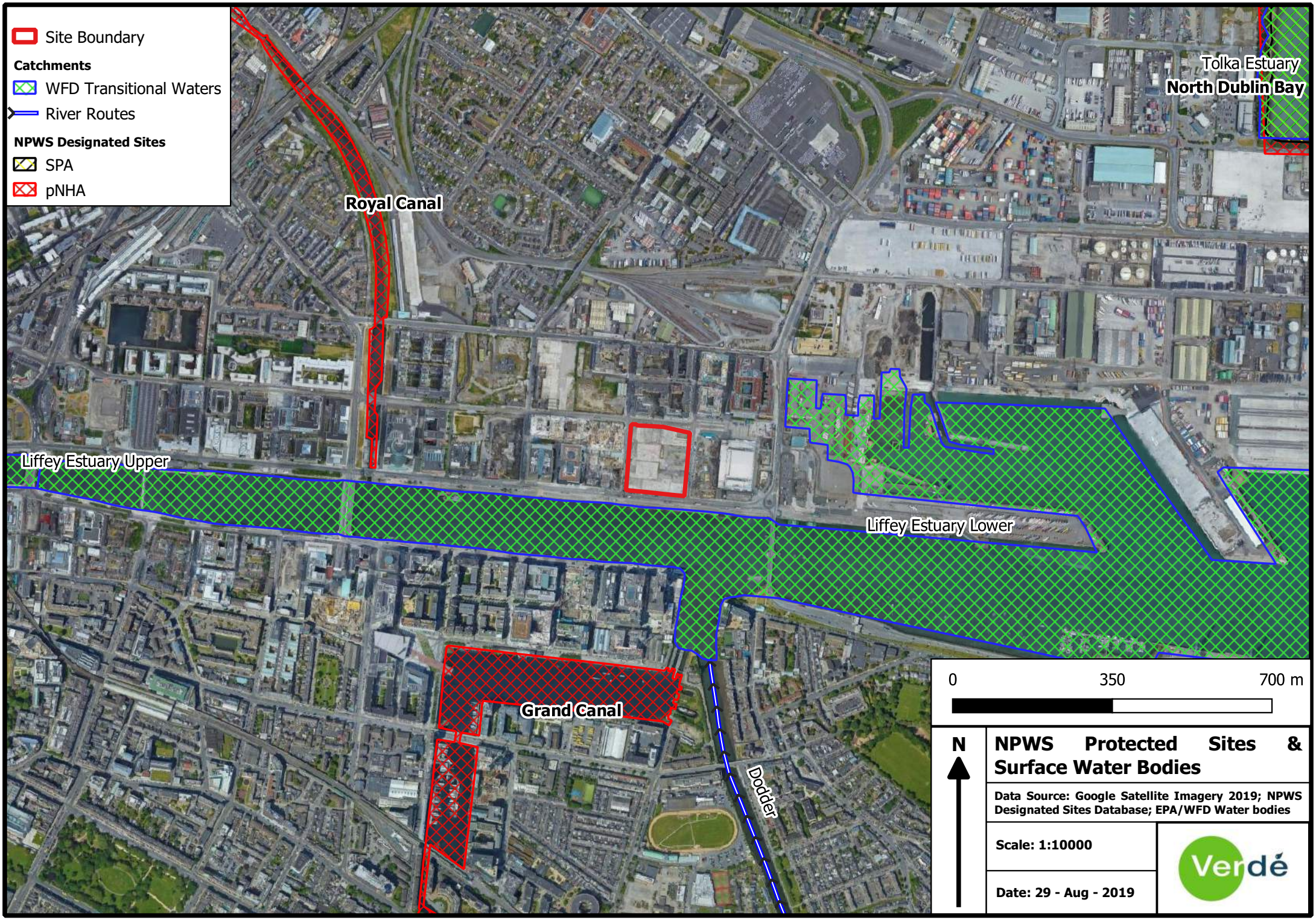

Site Boundary
Lucan Formation
0
350
700 m
N
Bedrock Geology
Data Source: Google Satellite Imagery 2019; GSI GeoUrban 50k Dublin Geology
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé


Site Boundary
Catchments
WFD Transitional Waters
River Routes
Groundwater Vunerability
Moderate
Low
Water
Tolka Estuary
Liffey Estuary Upper
Liffey Estuary Lower
Dodder
0
350
700 m
N
Groundwater Vulnerability & Surface Water Bodies
Data Source: Google Satellite Imagery 2019; GSI Groundwater Vulnerability Mapping; EPA/WFD Water bodies
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé


Site Boundary
Catchments
WFD Transitional Waters
River Routes
NPWS Designated Sites
SPA
pNHA
Royal Canal
Tolka Estuary
North Dublin Bay
Liffey Estuary Upper
Liffey Estuary Lower
Grand Canal
Dodder
0
350
700 m
N
NPWS Protected Sites & Surface Water Bodies
Data Source: Google Satellite Imagery 2019; NPWS Designated Sites Database; EPA/WFD Water bodies
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé


Site Boundary
GSI Soil Permeability
Low
0
350
700 m
N
Soil Permeability
Data Source: Google Satellite Imagery 2019; GSI Subsoils Database
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé

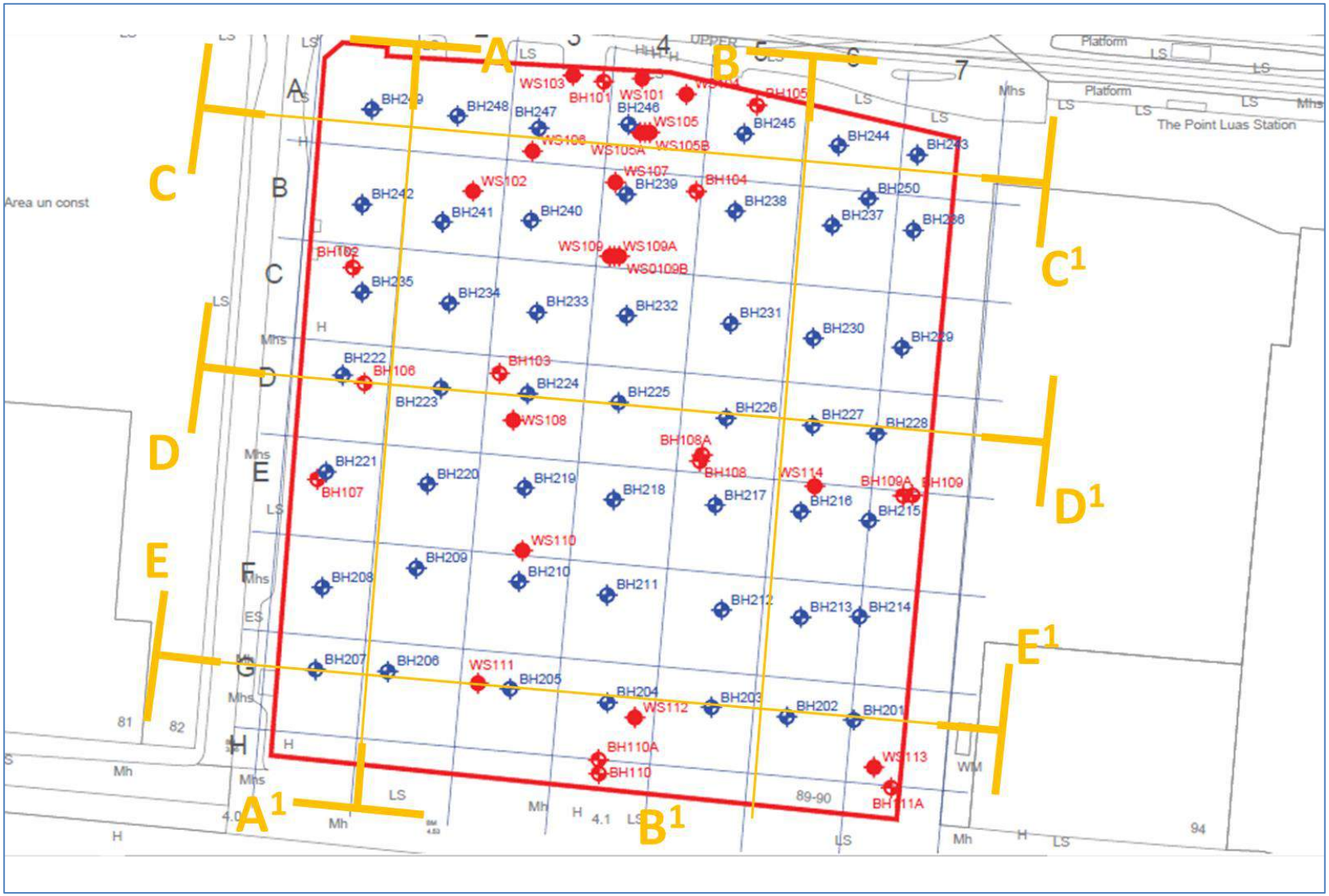

Site Boundary
National Soils (EPA)
Made Ground
Water
0
350
700 m
N
Soils
Data Source: Google Satellite Imagery 2019; National Soils Database (EPA)
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé


Site Boundary
Catchments
WFD Transitional Waters
River Routes
NPWS Designated Sites
SPA
pNHA
Royal Canal
Tolka Estuary
North Dublin Bay
Liffey Estuary Upper
Liffey Estuary Lower
Grand Canal
Dodder
0
350
700 m
N
NPWS Protected Sites & Surface Water Bodies
Data Source: Google Satellite Imagery 2019; NPWS Designated Sites Database; EPA/WFD Water bodies
Scale: 1:10000
Date: 29 - Aug - 2019
Verdé

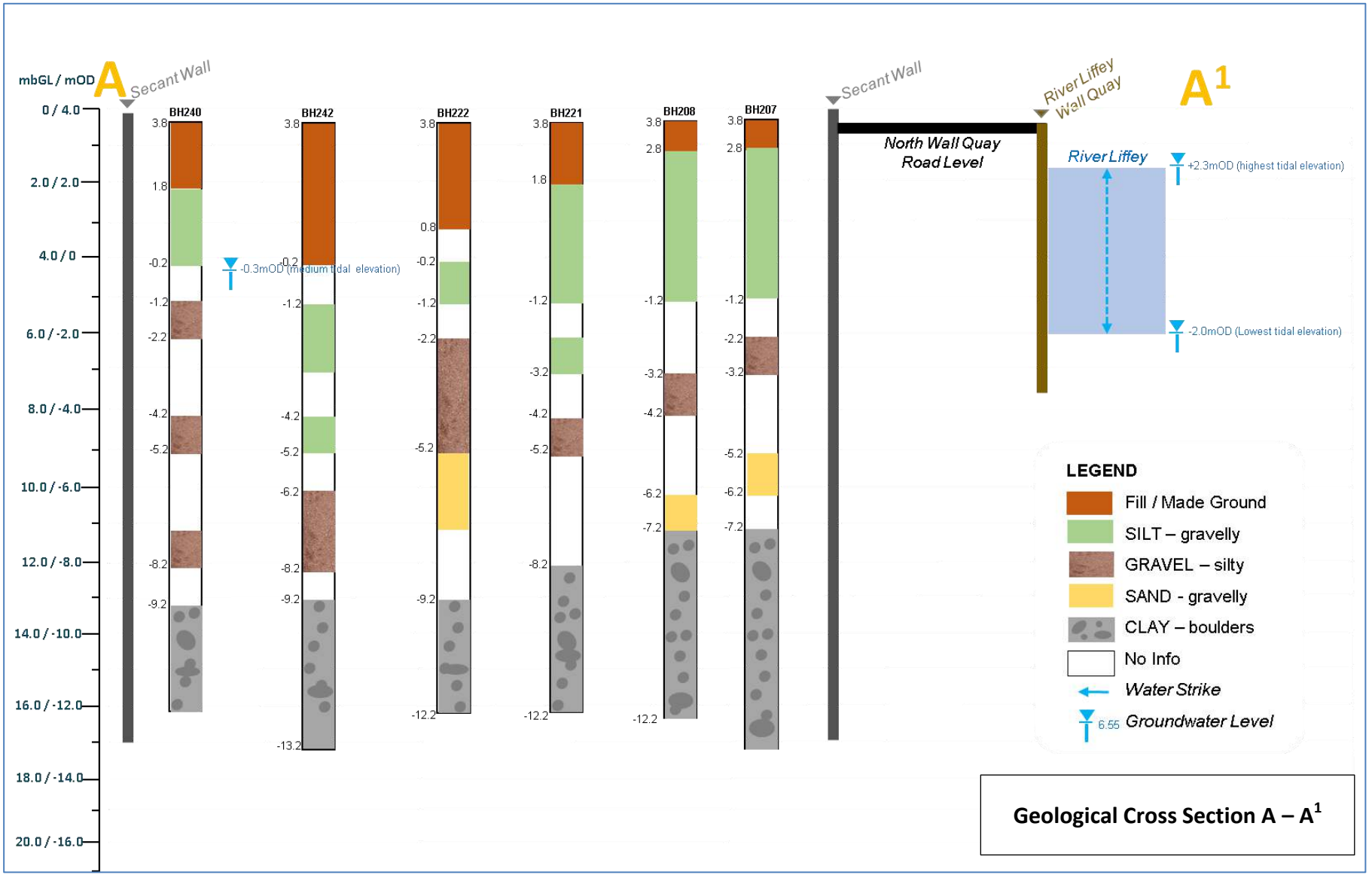

Site Boundary
0
180
360 m
N
Current Aerial Imagery
Data Source: Google Satellite Imagery (2019)
Scale: 1:5000
Date: 31 - Aug - 2019
Verdé

APPENDIX B

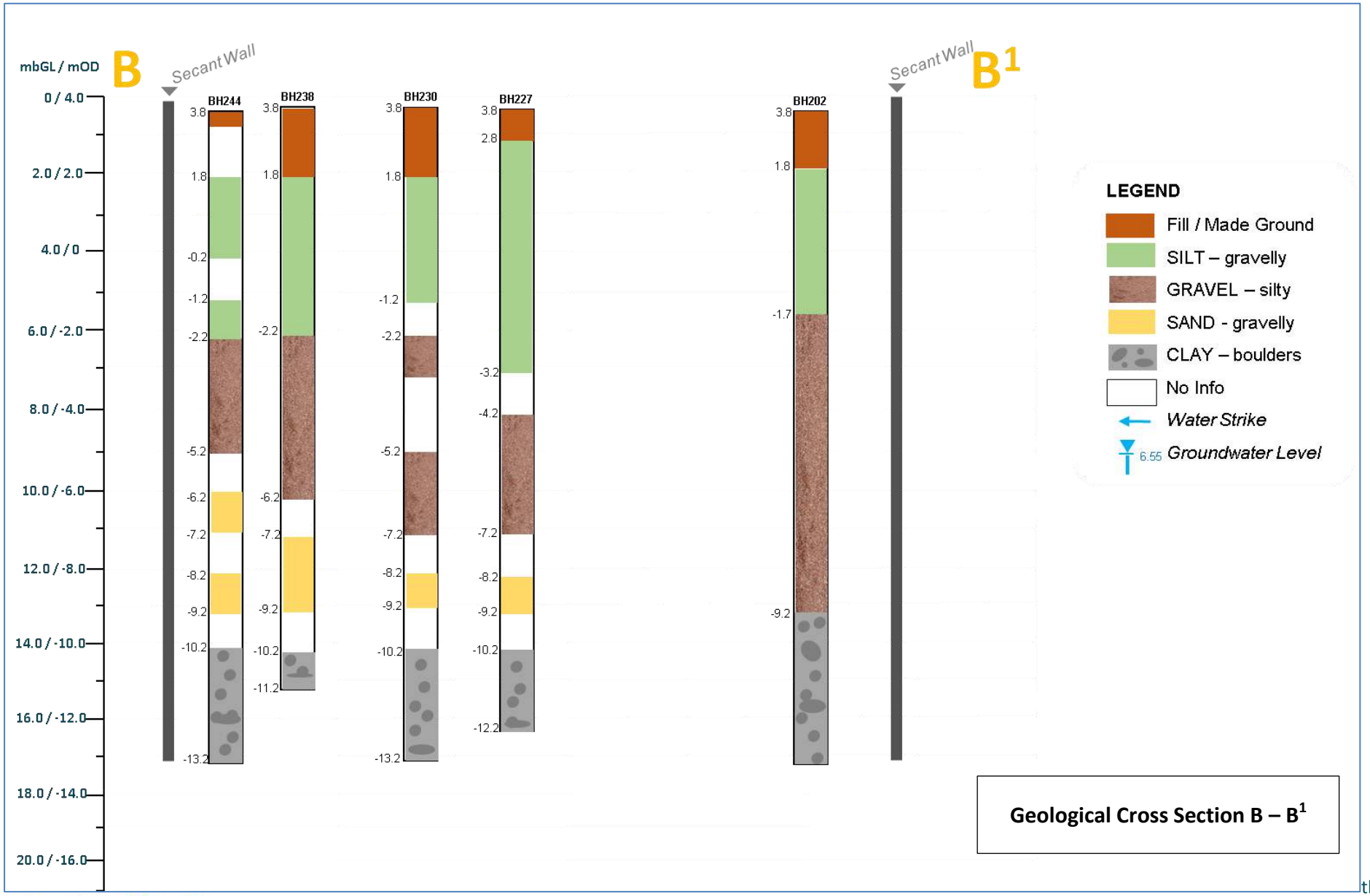
GEOLOGICAL CROSS SECTIONS

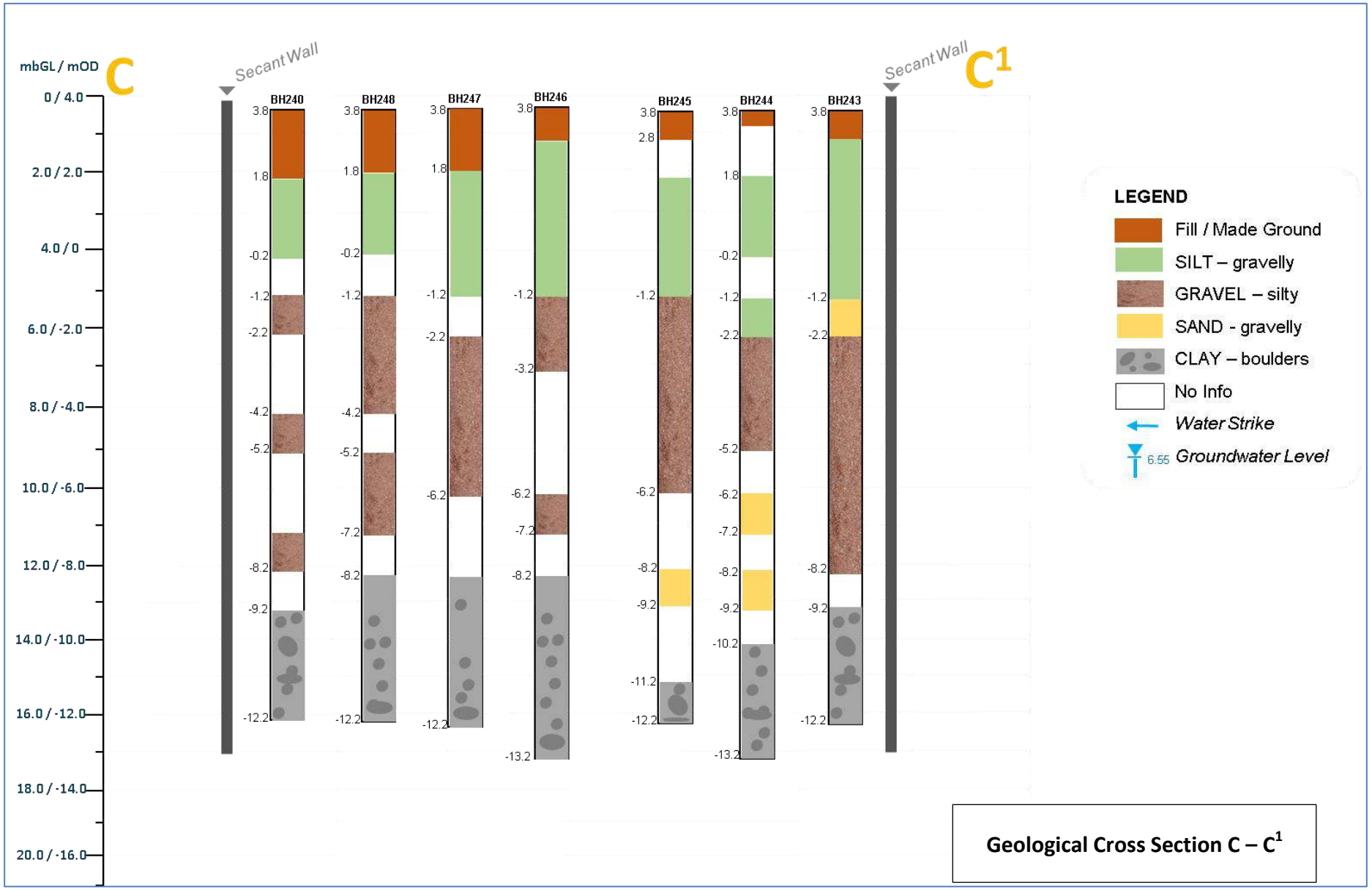


Site Map with Borehole Locations and Cross Section Lines

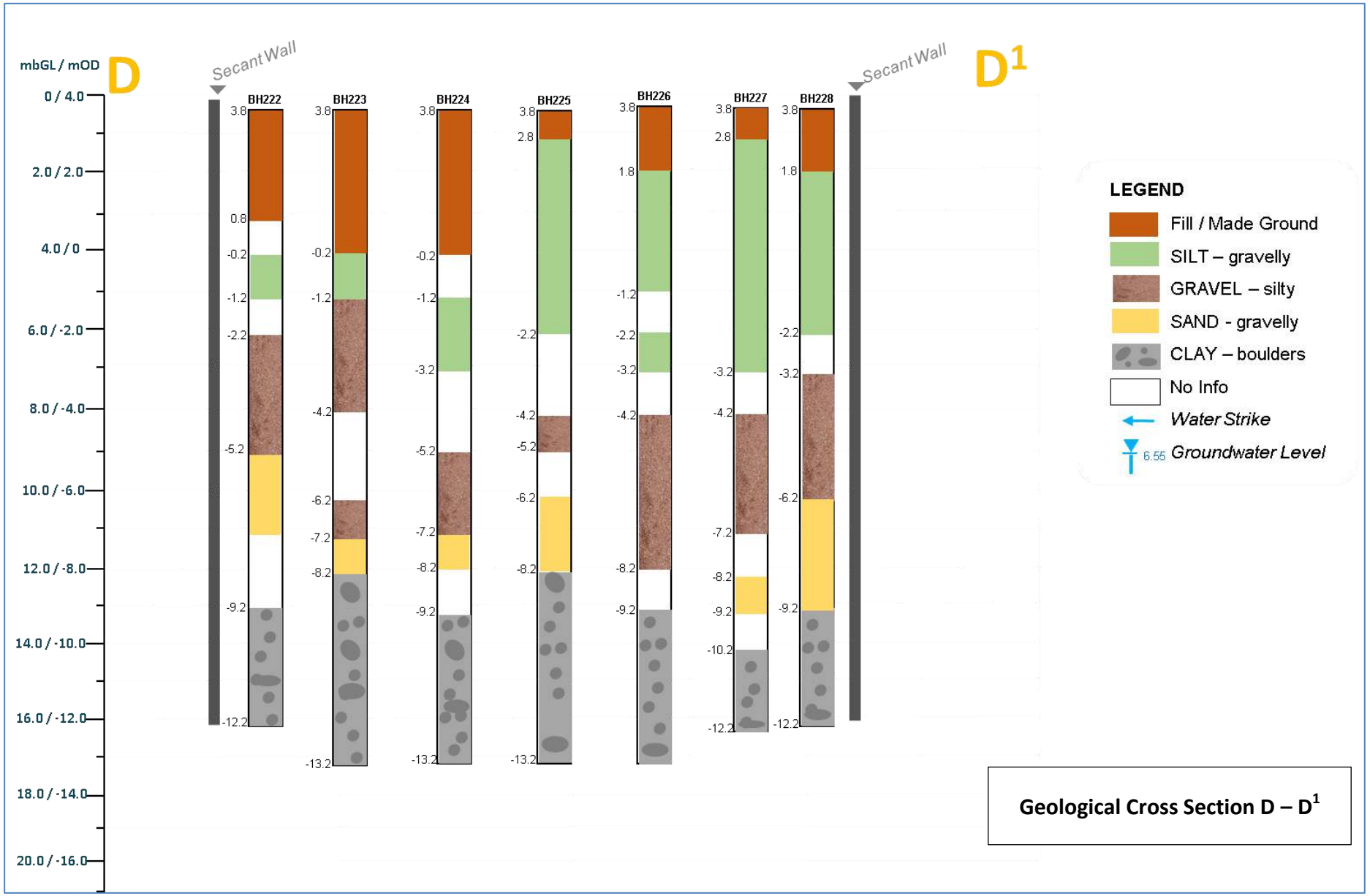


Geological Cross Section A – A^1

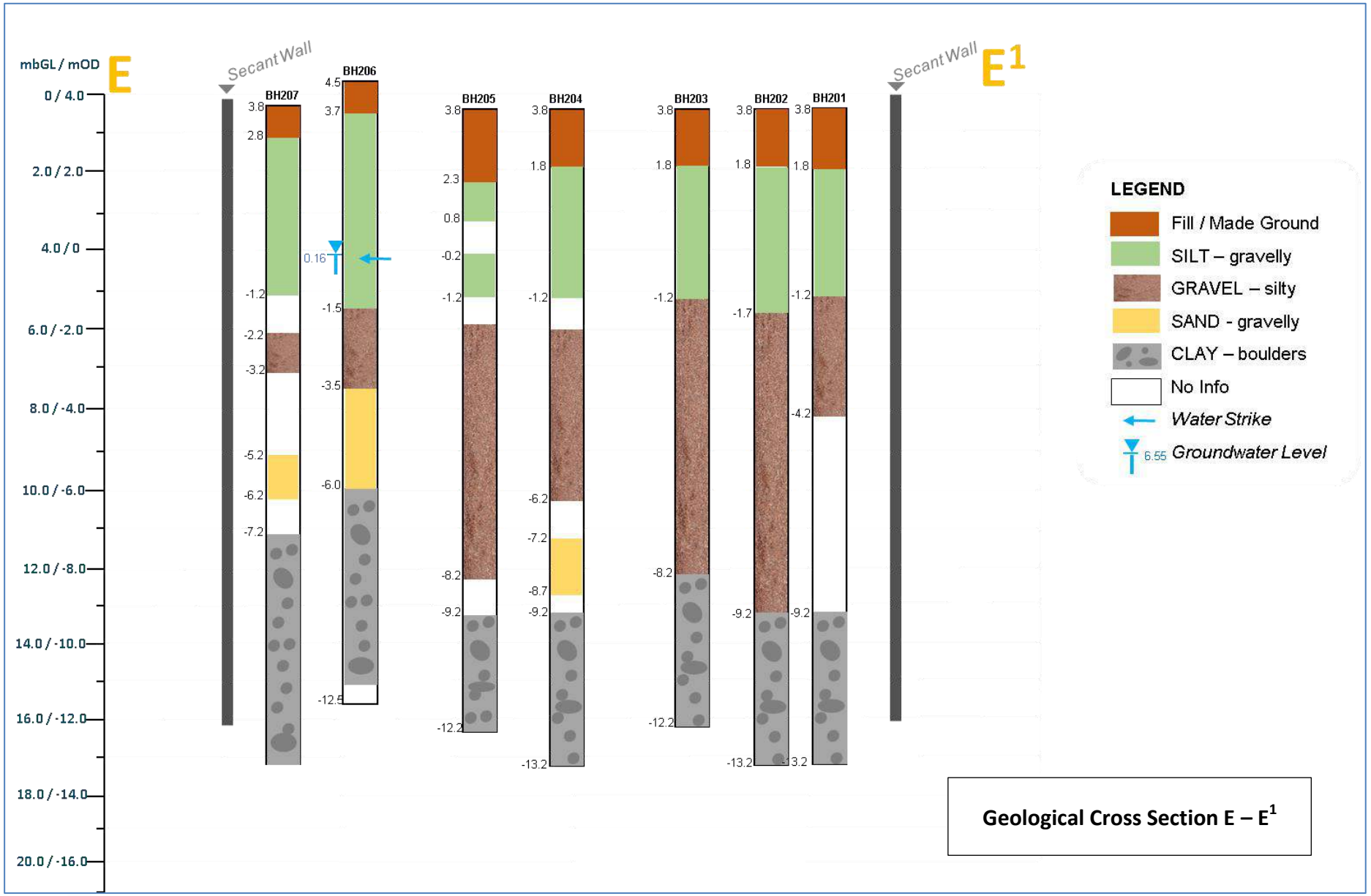

mbGL / mOD
B
Secant Wall
B1
Secant Wall
0 / 4.0
2.0 / 2.0
4.0 / 0
6.0 / -2.0
8.0 / -4.0
10.0 / -6.0
12.0 / -8.0
14.0 / -10.0
16.0 / -12.0
18.0 / -14.0
20.0 / -16.0
BH244
3.8
1.8
-0.2
-1.2
-2.2
-5.2
-6.2
-7.2
-8.2
-9.2
-10.2
-13.2
BH238
3.8
1.8
-2.2
-6.2
-7.2
-9.2
-10.2
-11.2
BH230
3.8
1.8
-1.2
-2.2
-5.2
-7.2
-8.2
-9.2
-10.2
-13.2
BH227
3.8
2.8
-3.2
-4.2
-7.2
-8.2
-9.2
-10.2
-12.2
BH202
3.8
1.8
-1.7
-9.2
LEGEND
Fill / Made Ground
SILT – gravelly
GRAVEL – silty
SAND - gravelly
CLAY – boulders
No Info
Water Strike
6.55 Groundwater Level
Geological Cross Section B – B1



Geological Cross Section C – C[1]



Geological Cross Section D – D[1]


mbGL / mOD
E
E1
Secant Wall
Secant Wall
0 / 4.0
2.0 / 2.0
4.0 / 0
6.0 / -2.0
8.0 / -4.0
10.0 / -6.0
12.0 / -8.0
14.0 / -10.0
16.0 / -12.0
18.0 / -14.0
20.0 / -16.0
BH207
BH206
BH205
BH204
BH203
BH202
BH201
3.8
2.8
-1.2
-2.2
-3.2
-5.2
-6.2
-7.2
4.5
3.7
0.16
-1.5
-3.5
-6.0
-12.5
3.8
2.3
0.8
-0.2
-1.2
-8.2
-9.2
-12.2
3.8
1.8
-1.2
-6.2
-7.2
-8.7
-9.2
-13.2
3.8
1.8
-1.2
-8.2
-12.2
3.8
1.8
-1.7
-9.2
-13.2
3.8
1.8
-1.2
-4.2
-9.2
-13.2
LEGEND
Fill / Made Ground
SILT – gravelly
GRAVEL – silty
SAND - gravelly
CLAY – boulders
No Info
Water Strike
6.55 Groundwater Level
Geological Cross Section E – E1