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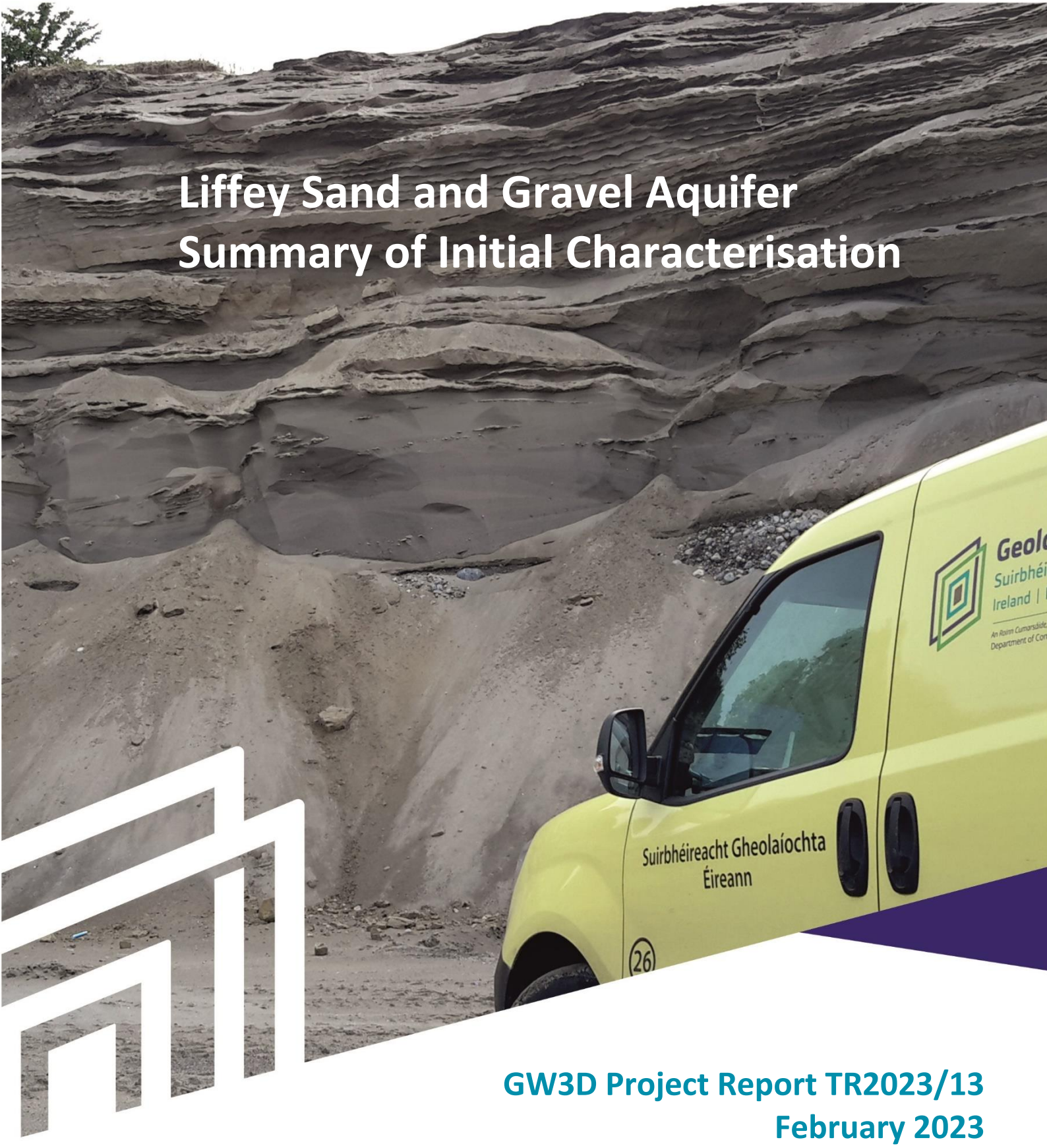

Liffey Sand and Gravel Aquifer
Summary of Initial Characterisation

GW3D Project Report TR2023/13
February 2023

Geological Survey Ireland is a division of the Department of the Environment, Climate and Communications

Liffey Sand and Gravel Aquifer Description February 2023

This sand and gravel report forms part of a series representing the output of a body of work undertaken to re-evaluate previously mapped sand and gravel aquifers and to identify new sand and gravel aquifers. This study resulted in the refinement of existing sand and gravel aquifer mapped extents, the modification of some sand and gravel aquifer categories, and the removal of some previously mapped sand and gravel aquifers, as well as identification of new aquifers. In addition to mapping the extent and depths of the sand and gravel aquifers, the investigations consider the hydraulic properties.

The study, undertaken as part of the GW3D project (2015-2019), comprised three parts:

1) Desk study and fieldwork preparation

Sand and gravel bodies above a minimum size criterion were extracted from the GSI Quaternary Sediments 1:50,000 map. Where it was known that the surface expression of the sands and gravels was only a small portion of the subsurface body, such areas were retained. This process left several hundred sand and gravel bodies remaining as a starting point for field work.

2) Fieldwork including mapping and data collection

Field work included a visit to each of the areas which had the potential to be (at least) a Locally Important Sand and Gravel Aquifer owing to its area. In such areas, gravel pits and sand pits were visited and depth and type of sediment recorded, other exposures into the subsurface were visited and logged, wells (whether Public Supply, Group Scheme or private farm or domestic) were dipped and any information on depths recorded, and data was collected where geological and hydrogeological data existed for the area.

3) Data collation, analysis and reporting.

All field data, and information from earlier reports and studies, were compiled and analysed. Where a sand and gravel body had qualifying aquifer properties (either 10 m depth sand and gravel, or 5 m depth saturated sediments), these areas were digitised in a GIS. The aquifer area was then ascertained and drawn up. Such areas formed the basic building blocks for the sand and gravel aquifer map, which included details on the aquifer name, area, aquifer resource value (Rg or Lg), confidence level, county, and any important aspects to note for each body.

The updated mapped sand and gravel aquifers are found on the Geological Survey Ireland site https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Aquifers

The GW3D Mapping Team involved in the current revision of delineated sand and gravel aquifers were:

Geological Survey Ireland staff:

- Dr. Sophie O'Connor, Groundwater Programme / Land Mapping Unit
- Dr. Sarah Blake, Groundwater Programme

Consultant support:

- Dr. Robbie Meehan, Talamh Ireland
- Coran Kelly, Tobin Consulting Engineers
- Damien Doherty, independent Consultant Geologist/ Tobin Consulting Engineers
- Natalie Duncan, independent Consultant Geologist
- Sara Raymond, independent Consultant Geologist
- James McAteer, Gavin and Doherty Geosolutions

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Liffey Sand and Gravel Aquifer: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
09 - Liffey and Dublin Bay Dublin City Council	**Rivers:** River Liffey, River Dodde, Tolka River, Camac River, Poddle River, Stein River, Bradoge River **Streams:** Creosote Stream, Glib Water, City Wall Ditch, Colman's Brook, Gallows Stream, Magazine Stream, Oxmanstown Stream, Viceregal Stream, Grace Park Stream, and several unnamed streams **Lakes:** Salmon Pool (at Islandbridge)	North Dublin Bay pNHA Grand Canal pNHA Royal Canal pNHA	7

Topography	The lower portion of the River Liffey valley is covered for the most part by 'Made' ground which masks the natural surface topography and soils/subsoils geology of the area. Borehole logs have largely been used to map the distribution of Quaternary sediments around and beneath Dublin City (GSI, 2023c). This desk study shows that there is an extensive and deep glaciofluvial sand and gravel deposit within the valley itself, along the lower reaches of the river's course. The main sand and gravel deposit is set within a pre-glacial river channel (Farrington, 1929), and the modern River Liffey flows through the centre of this. Elevations range from sea level to 20 m AOD.	
)Geology and Aquifers	**Aquifer categories**	The sand and gravel deposit is confirmed as greater than 10 m in thickness and has a saturated thickness greater than 5 m, over an area of at least 5.5 km^2 (GSI, 2023c). Based on this areal extent, the thickness and the degree of saturation, this deposit is therefore classified as a **Locally Important Sand and Gravel Aquifer (Lg)** (DELG/EPA/GSI, 1999; GSI, 2017).
	Main deposit lithologies	The deposit is comprised of glaciofluvial sands and gravels derived chiefly from limestones (GLs), a strip of alluvium (A) along the river itself, and some areas of marine beach sands (Mbs) and windblown sands (Ws) near Irishtown/Ringsend, and Fairview (GSI, 2023a).
	Key structures	The main deposit is a glaciofluvial channel infill, however thinner sand and gravel deposits thought to be connected to this main body are also known and mapped, along either side of the main channel. Borehole logs show the variability of the deposit material, which consists largely of sands and gravels, with occasional low permeability horizons. The sand and gravel is underlain by discontinuous stretches of till; however, the sands and gravels are also in contact intermittently with the underlying bedrock. This bedrock is of Dinantian Upper Impure Limestones ('Calp' limestone) which are classified a Locally Important Bedrock Aquifer (GSI, 2023a). According to the available geotechnical data, as well as Farrington (1929) and Kealy (2017), the glaciofluvial channel begins at Islandbridge and runs to St. James Gate Brewery, where it crosses to the north of the River Liffey. The channel then runs in a southwest to northeast direction, towards East Wall Road, where it then turns southwards over the North Dock and Pembroke Street Lower. Depth to bedrock reaches a maximum of about 45 m below ground level at the mouth of the river (GSI, 2023c). Along the northern flank of the deep channel, through the length of O' Connell Street in the City Centre, the bedrock surface falls from about 10 m BGL to 25 m BGL over a distance of some 0.5 km (Long et al., 2012).
	Key properties	The groundwater in the Liffey sand and gravel body is considered to be generally unconfined; however, where clay layers are present within and above the sand and gravel deposits, the groundwater may be locally confined. Variability in the deposit material influences the hydrogeological behaviour, and therefore yields are expected to vary throughout the area of the body. Borehole logging data indicate that coarse material predominates, and therefore permeability and storativity are expected to be high. Groundwater storage has been estimated, based on an average 5 m saturated thickness over 7 km^2, and a specific yield of 0.1, to be 3.5 x 10^6 m^3.

	Thickness	The thickness of the sand and gravel is extremely variable, ranging from approximately 1 m to 45 m in thickness. The saturated thickness has been shown to reach up to 25 m (Ball, 2017, 2018).
Overlying Strata	**Lithologies**	Almost the entirety of the deposit area is overlain by 'Made' ground, with the aquifer at surface only along the channel where alluvium lies, and in pockets in some parks and gardens.
	Thickness	The thickness of the concrete cover generally varies from 0.5 m to 6 m depth (GSI, 2023c).
	% area aquifer near surface	Less than 5%
	Vulnerability	Sand and gravel aquifers are categorised as having either 'High or 'Extreme' vulnerability (DELG/EPA/GSI, 1999). The vulnerability classification of such a sand and gravel aquifer is determined by the depth to the water table from ground level. In areas where the water table is less than 3 m below ground surface, the aquifer vulnerability is mapped as 'Extreme', and where it is greater than 3 m below ground, the aquifer vulnerability is mapped as 'High'. Measured water levels in the Liffey sand and gravel aquifer body range from 0.5 m to 19 m below ground level, meaning that the water table within the sand and gravel deposit typically lies at an elevation between sea level and 6 m AOD (GSI, 2023c).
Recharge	**Main recharge mechanisms**	Minimal recharge is expected through infiltration due to the preponderance of overlying 'Made' ground. The glaciofluvial sands and gravels were deposited in an eroded channel in the bedrock (Farrington, 1929). Based on experience gained from drilling through the deposit, Ball (pers. comm., 2018) expects that the sands and gravels are recharged by the underlying limestone aquifer *via* rejected recharge. This theory is supported by "groundwater discharging where bedrock outcrops along the River Liffey bed between Capel Street and the Ha'penny Bridge" (Ball, pers. comm., 2018), and explains the relatively shallow level of the water table across the sand and gravel body. The hydrostatic pressure in the sand and gravel is lower than in the surrounding, fractured bedrock, because the soft sediments are more permeable. From this, Ball (pers. comm., 2018) suspects that the sand and gravel deposit body is recharged as groundwater flows from the relatively high fractured rock elevations on either side of the channel, where it is under higher pressure than in the gravel. According to Ball (pers. comm., 2018) though the bedrock aquifer is classified as Locally Important, high yielding fractures have been encountered providing >1,000 m^3/day from the bedrock. Thus, as the sand and gravel is in contact with the bedrock over such an extensive distance, it is likely there are a number of high yielding fractures feeding into the sands and gravels.
	Est. recharge rates	The rainfall in the area of the Liffey sands and gravels is 722 mm (Walsh, 2012), and the estimated recharge rate to the aquifer from direct recharge is 60 mm/yr. The minimum groundwater throughput in the aquifer is estimated to be at least 1,152 m^3/d, with a significant additional volume coming from rejected recharge from the higher ground on either side of the channel.
Discharge	**Large springs and large known abstractions (m^3/d)**	Two borehole wells dug within the Guinness Brewery complex are dug several centuries ago into and through sand and gravel deposits of the former (glaciofluvial) River Liffey Channel, and into underlying 'Calp' Limestone bedrock. The first, 'Cooperage well' is of historic construction and has been reused to supply high volumes of water for processing needs, rather than for brewing needs. Plans seen in the 1980s showed that this was a significant piece of early Victorian engineering, and cross-section sketches provided by Guinness show that the well was very deep, reaching 1,531.5 feet (466 m). The high volumes of extraction suggest that it is taking water from the gravels in the channel of the former River Liffey, rather than from bedrock. An additional well is known, but it has not yet been located, other than it was around Market Street, which is where the current Guinness Storehouse for public visitors is situated. Ball (2017) has also recorded high yields in the sands and gravels in boreholes at both Pigeon House and Trinity College.
	Main discharge mechanisms	Groundwater discharges to the River Liffey, as well as along the coast.

	Hydrochemical Signature	Historically, dredged material from the bay was used to reclaim the (often marshy) land across the city. Groundwater hydrochemical analyses indicate that there are areas within Dublin City in which the groundwater is saline. This is thought to be due to the reclamation of the City, rather than sea water intrusion (Ball, 2017). As there are a limited groundwater chemistry analyses available within the city zone, it is difficult determine in which areas the groundwater is saline versus non-saline. Groundwater analyses from a number of reports indicate that the groundwater is polluted by sewage and/or industrial waste in various localities also.
Groundwater Flow Paths		Groundwater flow path lengths depend on the extent of the sand and gravel deposit, and also upon the spacing of internal groundwater divides and the distance between streams. It is assumed within the Liffey sand and gravel body that, generally, the surface water and groundwater flow directions coincide. The principal groundwater flow directions are thus considered to be from north to south or from south to north, on either side of the channel.
Groundwater & Surface water interactions		Hydraulic connection between the groundwater and surface water is expected to be high. According to Higgins and Mason (1989) the low permeability silt and clay along the river act as a barrier to groundwater flow, and therefore the bedrock aquifer is not affected by tidal fluctuations. It is uncertain whether this is the case in the sand and gravel deposits.
Conceptual modelCo		• There are four types of sand and gravel deposits along the lower Liffey channel (GSI, 2023a): alluvium along the river, which is gravelly in places; raised beach sands and gravels; marine beach sands, particularly along the coastal stretch; and glaciofluvial sand and gravels. • Delineation of a potential aquifer body area focussed on the glaciofluvial sands and gravels as they are the most substantial deposit body. These glaciofluvial sands and gravels associated with the Liffey are deposited in an eroded channel in the bedrock (Farrington, 1929). • The boundaries of the deposit were drawn based on the extent of the sand and gravel deposits, as indicated by geotechnical borehole logs. • Where cross sections have determined that these glaciofluvial materials are in hydraulic connectivity with adjacent alluvium and raised beaches, these areas have also been included as part of the aquifer. • The glaciofluvial channel begins at Islandbridge and runs to St. James Gate Brewery, where it crosses to the north of the River Liffey (Figure 1). • The channel then runs in a southwest to northeast direction, towards East Wall Road, where it then turns southwards over the North Dock and Pembroke Street Lower (Figure 1). • The boundaries of the aquifer are somewhat difficult to define die to the overlying 'Made' ground (Figure 1). • South of the Liffey, at Grand Canal Dock and towards Irishtown and Sandymount, beach sands are present beneath the 'Made' ground. • It is possible, if not probable, that this deposit is hydraulically connected to the glaciofluvial deposits (Meehan, pers. comm., 2020). • The beach sands and gravels are generally shallower, but there are areas where the 5 m depth of saturated material is reached. • In 1673 the shoreline at the mouth of the Liffey was mapped by the Dutch Engineer Bernard De Gomme, before the reclamation of the eastern portion of Dublin City. The shoreline ran from the junction of Annesley-Bridge Road and Fairview Strand, to O'Connell Bridge and then southeast along Grand Canal Street, and finally eastwards towards Sean Moore Park. • In the absence of groundwater chemistry data, this shoreline can be used as a proxy to determine areas which are likely to be saline, including along the quays and at the present-day coastline. • According to Higgins and Mason (1989) the low permeability silt and clay on the river act as a barrier to groundwater flow, and therefore bedrock aquifer is not affected by the tidal fluctuations. • The minimum direct throughput estimation of this deposit (510 m^3/d) is relatively low, owing to the minimal recharge expected to percolate through the overlying 'Made' ground. However it is thought that the sands and gravels are recharged by the underlying limestone aquifer *via* rejected recharge, increasing the potential minimum throughput to 1,152 m^3/d. This explains the relatively shallow water table across the majority of the area of the sands and gravels. • The idea that the bedrock is discharging to the gravels is supported groundwater discharging from rock

	outcrops along the river bed along the Liffey Channel between Capel Street and the Ha'penny Bridge. • The pressure in the sand and gravel is lower than in the fractured bedrock, because the soft sediments are more permeable. The water flows from the relatively high fractured rock elevations on either side of the channel, where it is under higher pressure than in the gravel. • The sands and gravels are in contact with the bedrock over such an extensive distance that it is likely there are a number of high yielding fractures feeding into them (Ball, pers. comm., 2018). • David Ball (2018) has recorded high yields in boreholes in the sands and gravels at Pigeon House and Trinity College. High yields have also been recognised historically at the Guinness Brewery Wells.	
Instrumentation	**Hydrometric gauges**: **National Water Monitoring Stations;** **River**:	09066 (O'More Bridge) RS09D011100 (Dodder - Lansdowne Rd Br) RS09D011200 (Dodder - Londonbridge Rd Br) RS09D011300 (Dodder - Ringsend Rd Br) TW07001014DB2001 (DB120 - Dodder / Grand Canal Basin) TW07001014DB2002 (DB210 - East Link Toll Bridge) RS09L013200 (Liffey Talbot Br) TW07001015DB1002 DB020 (Liffey at Matt Talbot Bridge) RS09L013100 (Liffey Butt Br) RS09L012500 (Liffey d/s Islandbridge Weir) RS09L012600 (Liffey - Islandbridge Flats) TW07001015DB1001 (DB010 - Liffey at Heuston Bridge) RS09L012700 (Liffey - Heuston Station (u/s Camac)) RS09C020700 (Camac - Liffey Outfall) TW07001015DB1004 (Liffey Estuary Upper - WFD Reporting Station) RS09L012800 (Liffey - Queen St Br) RS09P030800 (Poddle - Outfall to Liffey) TW07001015DB1003 (DB015 - Liffey at Wood Quay) RS09L012900 (Liffey - Winetavern St Br) RS09L013000 (Liffey - Chapel St Br.)
	Groundwater:	None present
Attachments	Figure 1: Location and extent Figures 2 and 3: Cross sections Figure 4: Area under which aquifer saturation criteria are expected to be met Figure 5: Area of potential aquifer connecting areas which satisfy aquifer saturation criteria Figure 6: Groundwater vulnerability	
Information Sources	• Atkins-McCarthy (2000). Dublin Light Rail: Sandyford to Ballymun Line. Report for Dublin City Council. • Ball, D. (2017). Groundwater, Groundwater Contamination and Planning in Dublin. Unpublished Report for Dublin City Council. • Ball, D. (2018). *Personal Communication, April 2018.* • Daly, E.P. (1985). Hydrogeology, In: Edwards, K.J. and Warren, W.P. (eds), "The Quaternary history of Ireland". Academic Press, London, pp. 331-343. • Dublin City Council (2018). Basement Development Guidance Document Draft. • Farrington, A. (1929). The pre-glacial topography of the Liffey Basin. Proceedings of the Royal Irish Academy, 38B, 148-170. • Geotech Specialists Ltd. (2007). Dublin Interconnector Feasibility Stage Ground Investigation Phase 1 and 2. Report for Fingal County Council. • GSI (2017). A description of Irish aquifer categories. 3 pp. Available from: https://www.gsi.ie/documents/GSI%20Aquifer%20Category%20Descriptions.pdf • GSI (2023a). Geological Survey Ireland Spatial Resources Viewer. https://www.gsi.ie/en-ie/data-	

Information Sources (contd.)	and-maps/Pages • GSI (2023b.) Geological Survey Ireland. Internal Groundwater Database • GSI (2023c). Geological Survey Ireland. Internal Geotechnical Database • Higgins, J. and Mason, S. (1989). The geotechnical aspects of the redevelopment of the Custom House docks. First presentation to a joint meeting of the Geotechnical Society of Ireland and Construction Section, Dublin City Council. • Hoare, P. G. (1976). Glacial Meltwater Channels in County Dublin. Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science, 76, 173-185. • Iarnrod Eireann (2010). Level Crossings Project, Environment Impact Statement Main EIS Report. • IGSL (2010). Dart Underground Factual Report Ground Investigation Report. Report for Dublin City Council. • IGSL (2012). Geotechnical Ground Investigation Report Luas Broombridge Volume 1. Report for Dublin City Council. • Kealy, S. (2017). The Gravel Deposits in the Pre-Glacial Trench in Central Dublin. Unpublished BSc Geotechnical Study, School of Civil Engineering, UCD. • Long, M., Daynes, P, Donohue, S. and Looby, M. (2012). Retaining wall behaviour in Dublin's fluvio-glacial gravel, Ireland. Proceedings of the Institution of Civil Engineers - Geotechnical Engineering, 165:5, 289-307. • Map: The environs of Dublin. Drawn & engraved by B.R. Davies, 16 George Street, Euston Square. Published under the superintendence of the Society for the Diffusion of Useful Knowledge. By Baldwin and Cradock, 47 Paternoster Row, Octr. 1st. 1837. (London: Chapman & Hall, 1844). • Walsh S. (2012). A Summary of Climate Averages 1981-2010 for Ireland, Climatological Note No.14, Met Éireann, Dublin.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations and assumptions based on the information sources described above and established hydrogeological formulae. Figures 2, 3, 5 and 6 are used for illustrative purposes only.

Liffey Sand and Gravel Aquifer

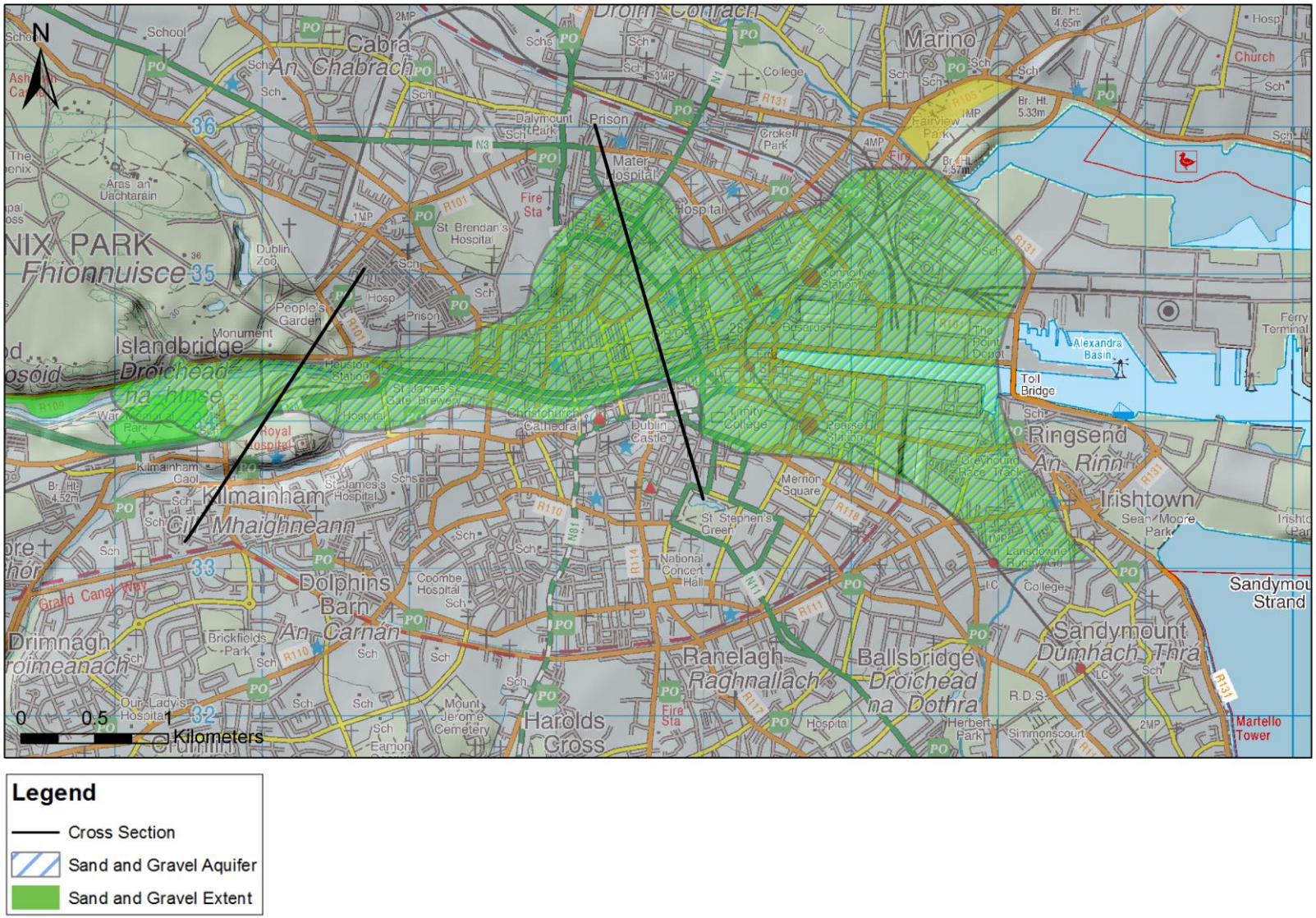

Figure 1. Liffey Sand and Gravel Aquifer extent with cross section locations.

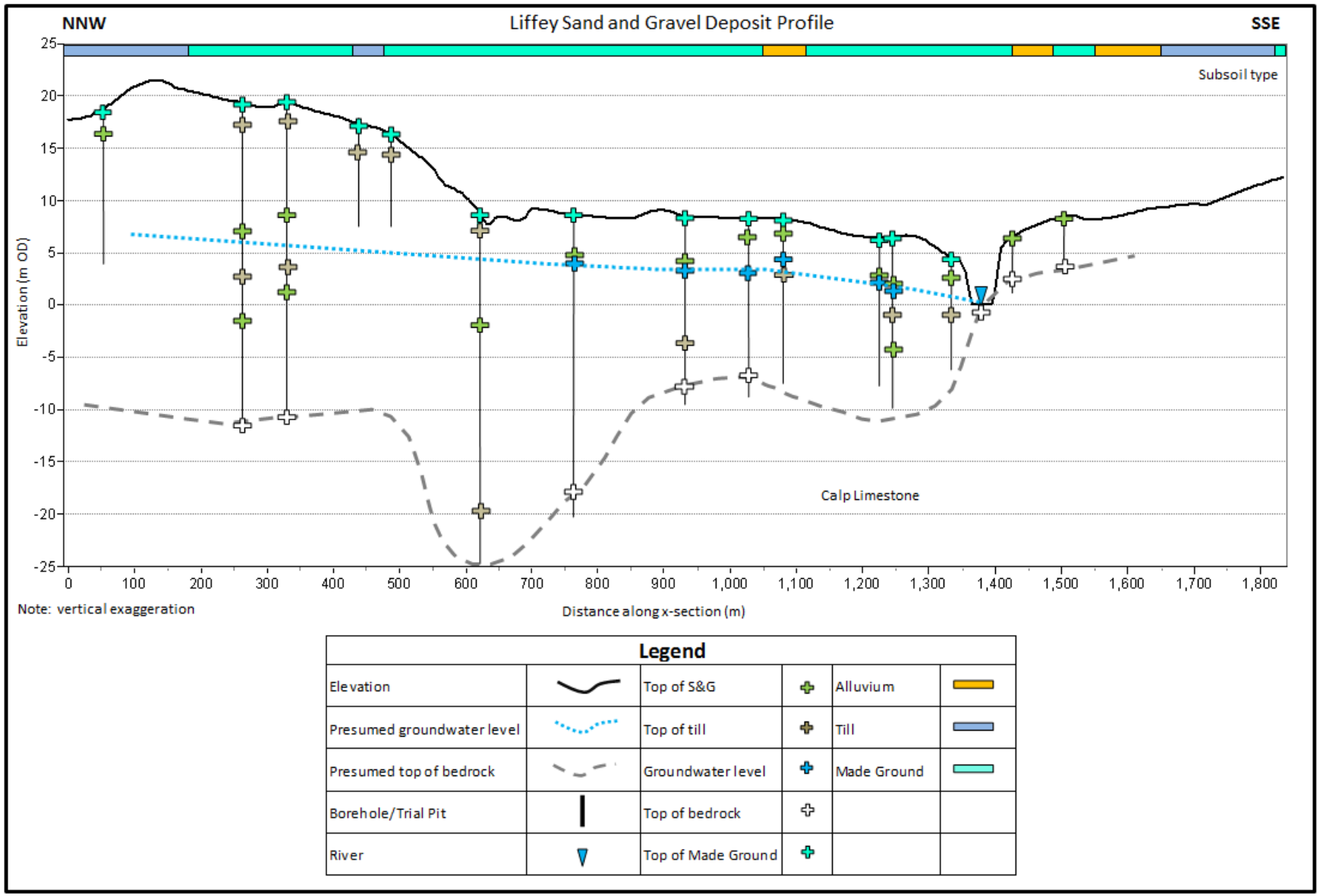

Figure 2. Cross section 1 through the Liffey Sand and Gravel Aquifer body.

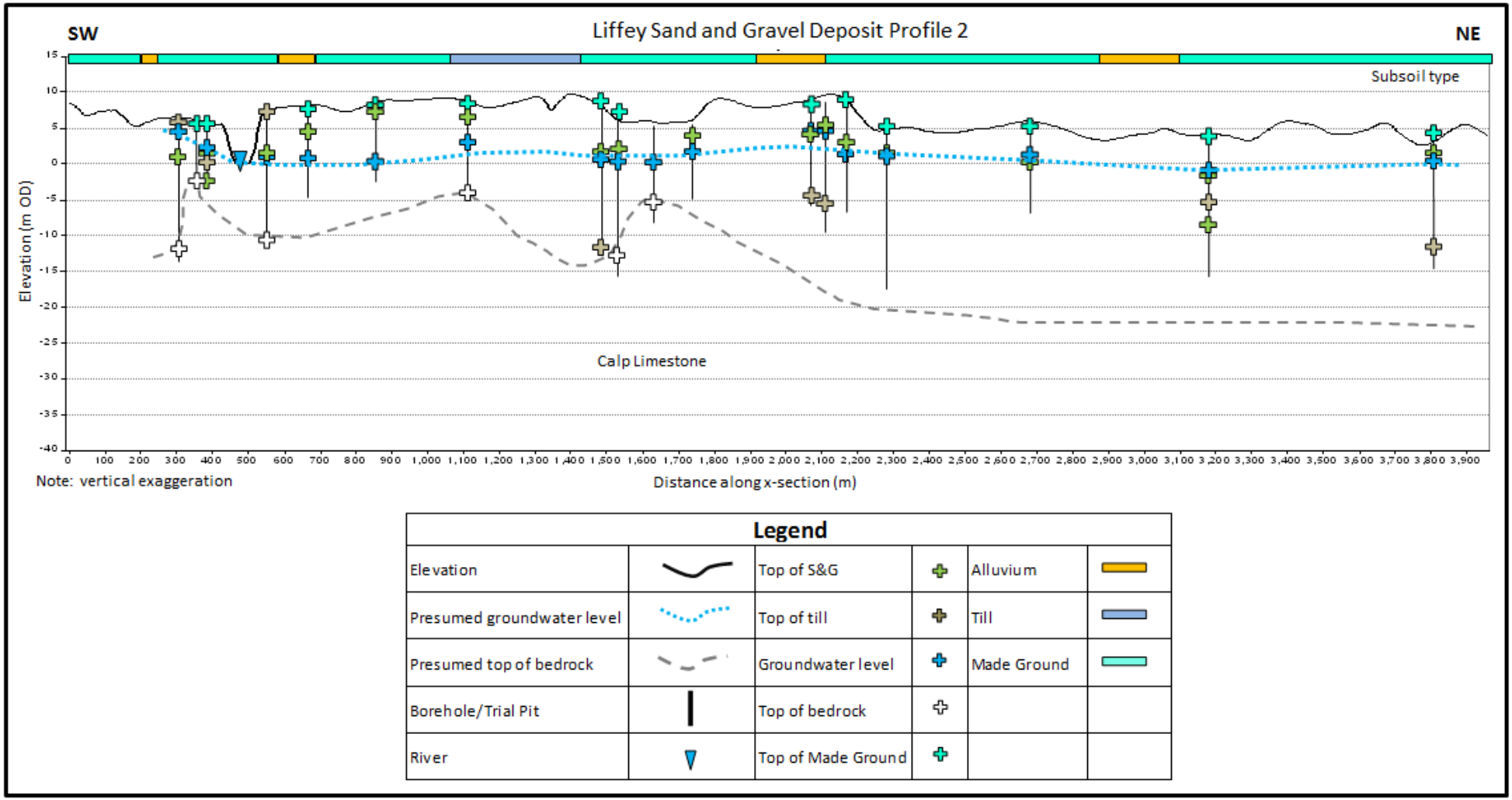

Figure 3. Cross section 2 through the Liffey Sand and Gravel Aquifer body.

Liffey Sand and Gravel Aquifer

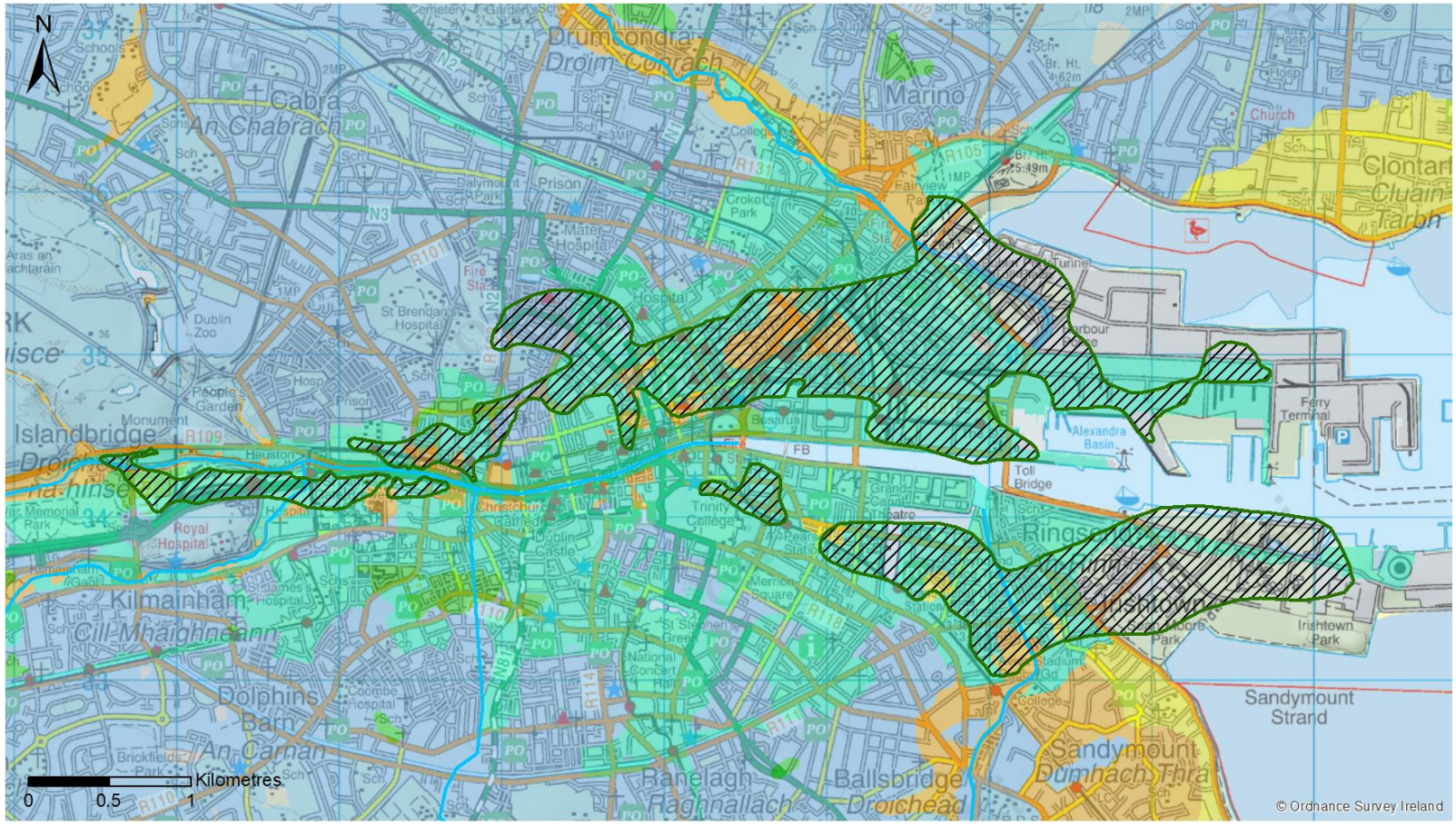

Figure 4. Estimated area under which aquifer saturation criteria are expected to be reached in the Liffey Sand and Gravel Aquifer body.

Liffey Sand and Gravel Aquifer

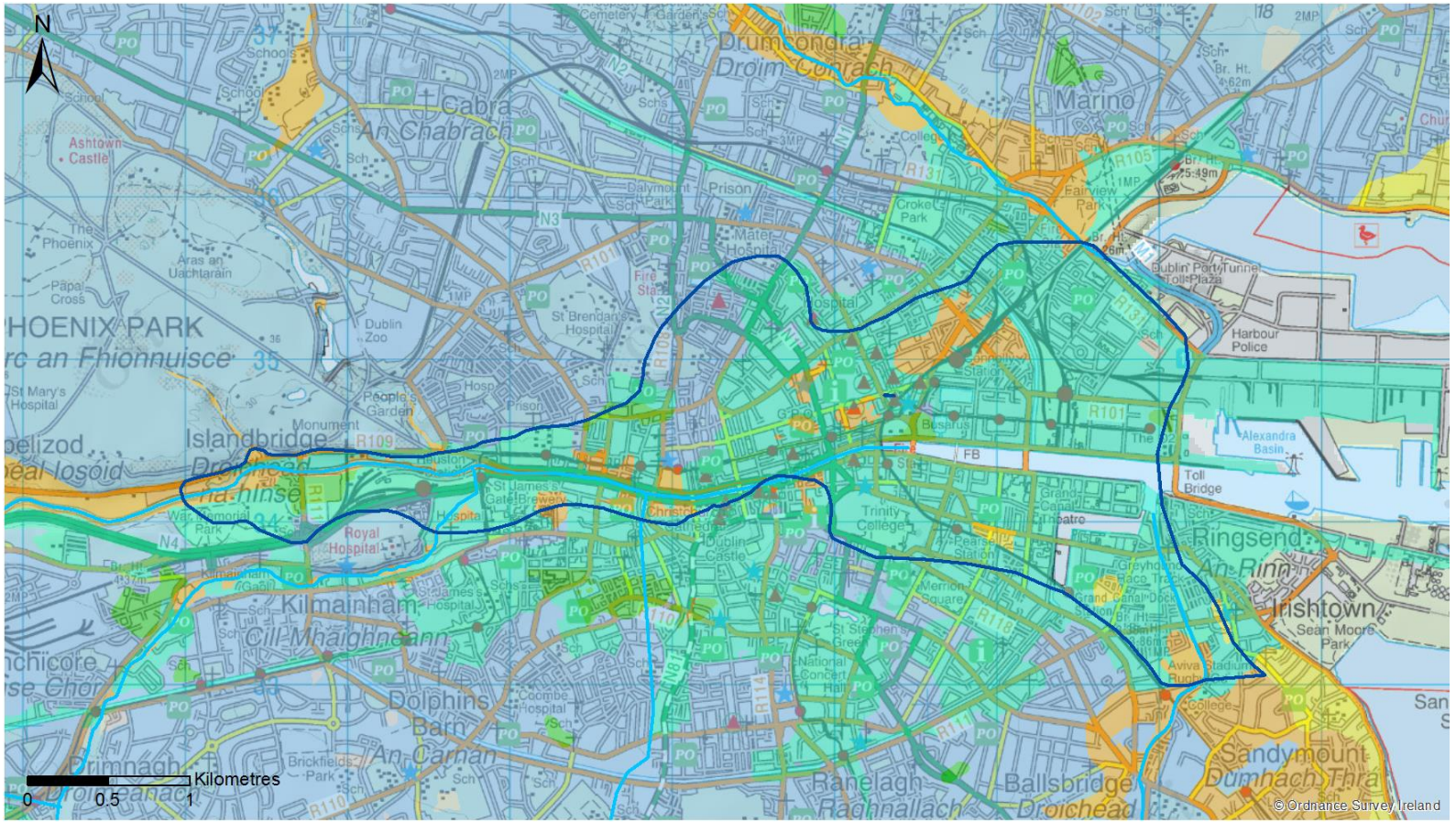

Figure 5. Area of potential aquifer connecting areas which satisfy aquifer saturation criteria.

Liffey Sand and Gravel Aquifer

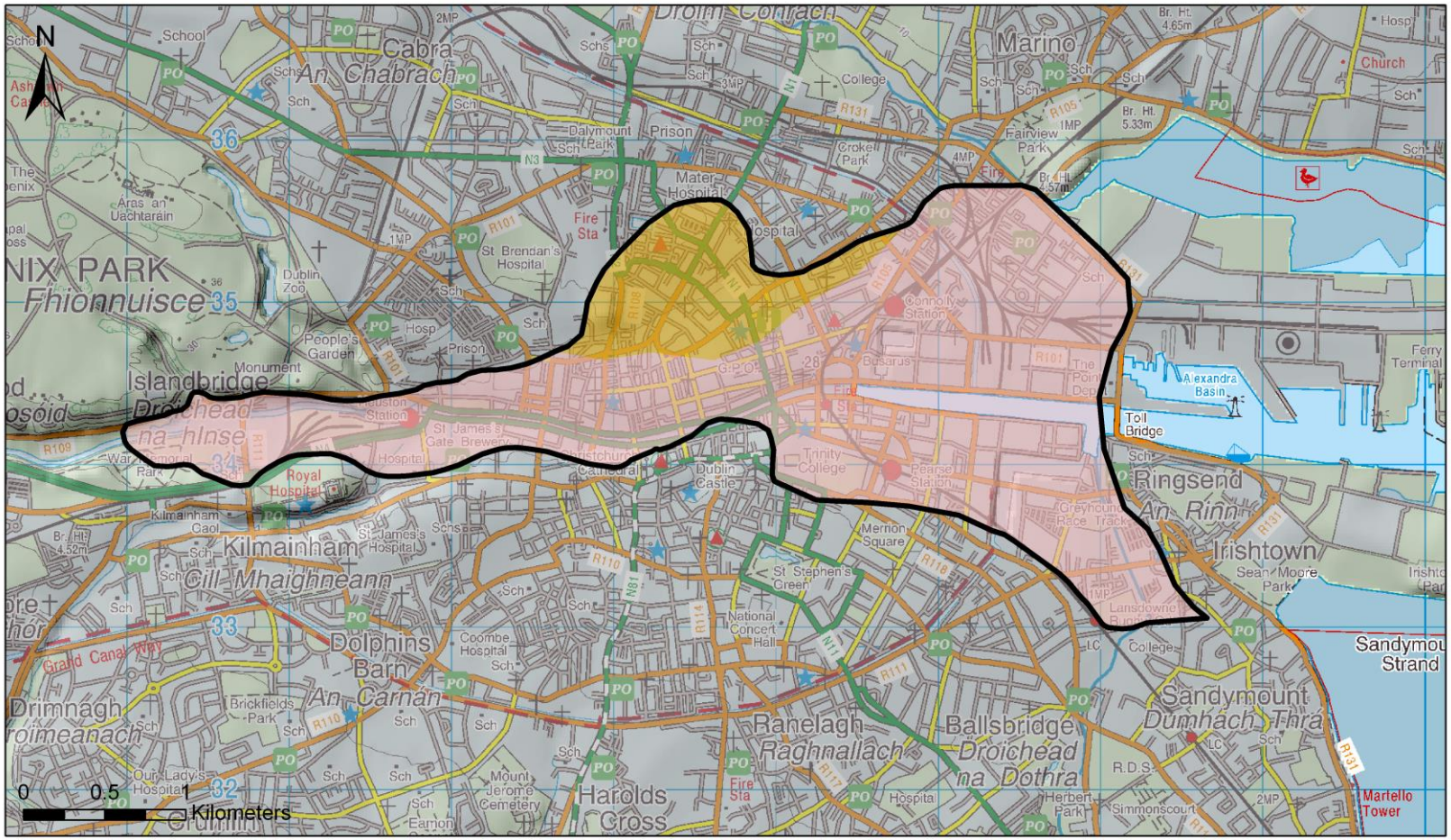

Figure 6. Groundwater vulnerability across the Liffey Sand and Gravel Aquifer.