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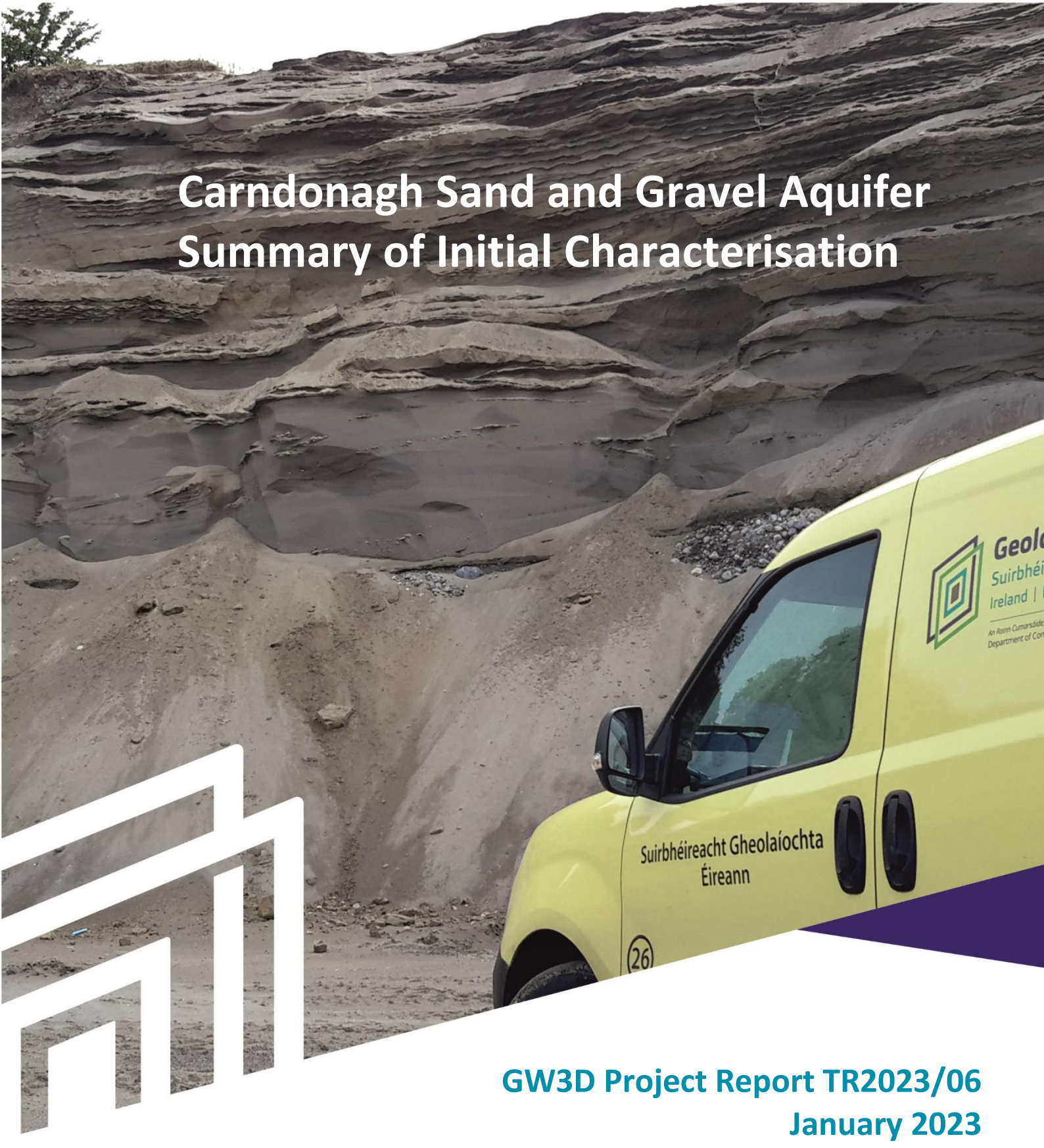

Carndonagh Sand and Gravel Aquifer
Summary of Initial Characterisation

GW3D Project Report TR2023/06
January 2023

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

Carndonagh Sand and Gravel Aquifer Description January 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
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- James McAteer, Gavin and Doherty Geosolutions

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Carndonagh Sand and Gravel Aquifer: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
40 – Donagh - Moville Donegal County Council	**Rivers:** Glennagannon River, Donagh River, Ballywilly Brook **Streams:** Several, unnamed minor streams **Lakes:** None	North Inishowen Coast SAC and pNHA Trawbreaga Bay SPA	8.3

Topography	This sand and gravel aquifer is roughly square-shaped and lies to the north of Carndonagh, between the town centre and Trawbreaga Bay (Figure 1). The body comprises a series of flat-topped terraces, located in a flat, low-lying area, and ranges in elevation from sea level to about 30 m AOD. The terraces abut higher ground to the west, south and southeast. In the east and north, much of the ground is very flat and low-lying. The sea bounds the aquifer body to the north. Two north flowing rivers traverse the centre of the sand and gravel body, where they flow into Trawbreaga Bay, and north flowing streams cross to the east and the west of this also.	
Geology and Aquifers	**Aquifer categories**	The sands and gravels are considered to continue underneath the locally mapped peat in pockets throughout the body. However, the sand and gravel aquifer is mapped as the area that is interpreted to have at least 5 m saturated thickness (Lee and Fitzsimons, 2004). Drilling data show that the sorted sediment thickness ranges from 4.5 m to >8.0 m, so despite the relatively extensive areal extent, these deposits are classified as a **Locally Important Sand and Gravel Aquifer (Lg)** (DELG/EPA/GSI, 1999; GSI, 2017).
	Main aquifer lithologies	The aquifer body has four main components: alluvium deposited by river water along the Donagh and Glennagannon Rivers; low level, Atlantic-type blanket peat which has developed above the sands and gravels owing to the presence of iron pans; raised beaches; and the adjacent, glaciofluvial sand and gravel terraces. Drilling records show SILT with bands of gravel over sandy SILT (K.T. Cullen and Co. Ltd., 1992). Particle size analyses indicate 70% - 90% sand and gravel or larger sized clasts (Solmec, 1974; Farrell, 1989). The glaciofluvial terraces are composed of sands and gravels derived chiefly from metamorphic rocks (GSI, 2023).
	Key structures	The majority of the sands and gravels are interpreted to have been deposited in a glaciofluvial outwash fan or delta (McCarron, 2002), with the result that the material is likely to grade from coarser sand and gravel near Carndonagh Town to finer material (which is exposed at low tide) along the coast. Borehole logs show the variability of the aquifer material, which consists largely of sands and gravels, with occasional low permeability horizons. The underlying bedrock includes Precambrian Quartzites, Gneisses and Schists (GSI, 2023) which is are classed as 'Poor' Bedrock Aquifers (GSI, 2023), which are generally unproductive except for local zones (Pl).
	Key properties	Estimated transmissivity is 350 - 600 m^2/d with a bulk permeability of 80 m/d computed (Lee, 2004). Storativity is also expected to be high (20%) (Lee and Fitzsimons, 2004). Groundwater levels rest at about 1.5 mbgl, but will be closer to ground surface near the rivers and streams and in the north of the body, where ground elevations are lower. Groundwater is generally unconfined, but may become slightly confined where low permeability deposits (clays, or more particularly peat) overlie the sands and gravels. Groundwater gradients are likely to be around 0.007 to 0.01 (Lee, 2004, and map estimates).
	Thickness	Borehole records indicate that the Quiaternary sediments are at least 8 m thick in places, with an average saturated thickness of at least 5 m proven within the alluvium (Lee, 2004). Further work is needed to confirm the thickness and saturation of the gravel deposits beneath the peat material.
Overlying Strata	**Lithologies**	The gravel terraces are partially overlain by peat deposits, as well as alluvium along the two major rivers. Historical, 6 inch scale, GSI bedrock and Quaternary mapping indicates the presence of raised beach deposits, beneath the peat, near the coast. Based on topographic analysis, it is assumed that the raised beach deposits beneath the peat also connect to the main body of the glaciofluvial sand and gravel aquifer.

	Thickness	The overlying alluvial clay along the rivers is thin, ranging from 0.7 m to 0.8 m in thickness (Lee, 2004). The thickness of the blanket peat is not known but is considered to be originally relatively thin, then cut and/or drained (Meehan pers comm., in Lee, 2004).
	% area aquifer near surface	Approximately 65%.
	Vulnerability	As the majority of the aquifer area is at the surface it is vulnerable; consequently pollutants can easily infiltrate the aquifer. Sand and gravel aquifers are categorised as having either 'High or 'Extreme' vulnerability (DELG/EPA/GSI, 1999), with the vulnerability classification determined by the depth to the water table from ground level. In such areas, where the water table is less than 3 m below ground level, the aquifer vulnerability is mapped as 'Extreme'. Water level records within the alluvium at Carndonagh (K.T. Cullen and Co., 1992) suggest that the water table is less than 3 m below ground level across the majority of the delineated aquifer body area. Much of the area of the aquifer covered with peat is classified as being of 'High' vulnerability though, as the peat is considered to provide some protection to the sand and gravel aquifer beneath.
Recharge	**Main recharge mechanisms**	Diffuse recharge occurs *via* rainfall percolating through the unsaturated sands and gravels. Due to the high permeability of sands and gravels, a high proportion of the available recharge will percolate down to the water table, particularly in the south of the deposit where groundwater is at deeper levels. Typically, the proportion of recharge that infiltrates to groundwater in sands and gravels is around 85% (Hunter Williams *et al*., 2011). In the north of the body, higher rates of runoff are suggested by drainage channels. Rejected recharge from the surrounding hills will also increase the amount of available recharge to this aquifer, set in a low, coastal embayment. The rivers flowing across the aquifer also provide additional recharge. Recharge is induced from a surface drainage channel to the pumping well at Carndonagh Public Water Supply (Lee, 2004). During the dry summer of 1995, the flow in the Donagh River sank into the underlying sands and gravels (Lee, 2004).
	Est. recharge rates	In southern part of the aquifer body, estimated recharge (90% of effective rainfall) is 595 mm (Lee, 2004). Closer to the coast, where drainage is poorer due the water table being at a shallower depth, recharge will be lower. The average rainfall in the area of the Carndonagh sands and gravels is 1,236 mm (Walsh, 2012), and the estimated recharge rate to the aquifer from direct recharge is an average of 483 mm/yr. The minimum groundwater throughput in the aquifer is estimated to be 4,960 m^3/d, with a significant portion of this volume coming from rejected recharge from the surrounding hills.
Discharge	**Large springs and large known abstractions (m^3/d)**	The Carndonagh Public Water Supply, which abstracts groundwater from this aquifer, has an 'Excellent' yield of 1,680 m^3/day in winter, and 1,440 m^3/day in summer. The scheme abstracts from infiltration galleries set into the groundwater, which are augmented by boreholes in summer.
	Main discharge mechanisms	The main discharges are likely to be to the rivers which flow through the aquifer. Where the water table is sufficiently close to the surface such that the river bed elevation is lower than it is, the aquifer will contribute groundwater to the baseflow of the river. There is also groundwater seepage from the extremities of the gravel body at lower elevations at the north, which appear as seeps at surface along the coast at Trawbreaga Bay.
	Hydrochemical Signature	There are raw water samples available for this public water supply (Lee, 2004; EPA Drinking Water Returns, 2002, 2005), which indicate that the water quality within this aquifer is generally good (K.T. Cullllen and Co. Ltd., 1992). Data available for the infiltration gallery at Carndonagh Water Supply indicate that the aquifer body has a calcium bicarbonate signature. Groundwater analyses indicate a hard (251-350 mg/l $CaCO_3$) groundwater, with conductivity ranging from 650-700 µS/cm (Lee, 2004). Alkalinity ranges from 174 to 400 mg/l as $CaCO_3$, and chloride concentrations average 29 mg/l (range 15-35 mg/l; Lee, 2004).

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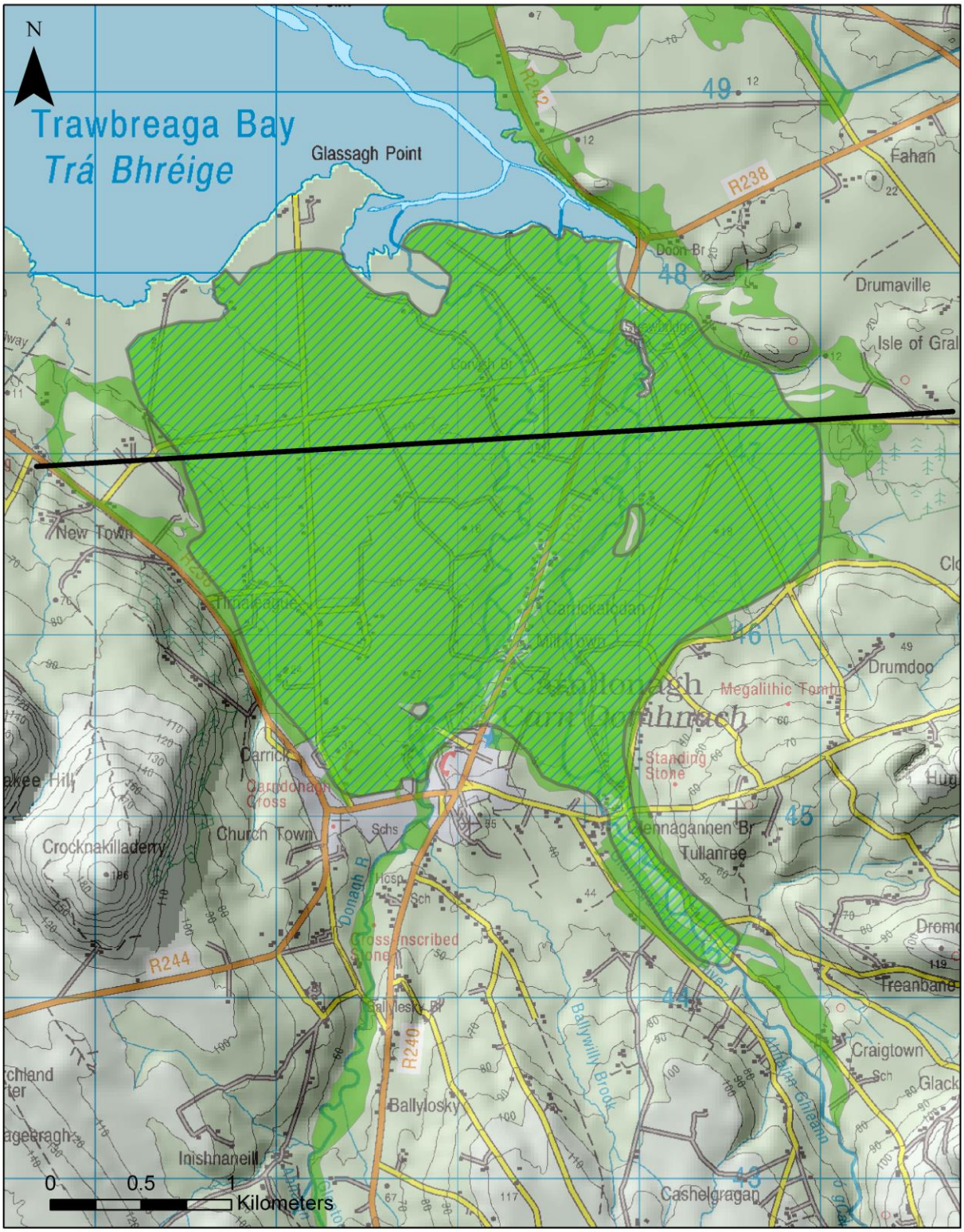
Groundwater Flow Paths	The length of flowpaths in sand and gravel aquifers depends on the areal extent of the deposit. In general, locally important sand and gravel aquifers are expected to have relatively short flow paths due to their relatively limited geographical extent *i.e*. up to several hundred metres. This is expected to be the case at Carndonagh, given the setting and geometry of the deposit; the longest flow paths are expected to be in the order of 1 km.
Groundwater & Surface Water interactions	Hydraulic connection between the groundwater in the aquifer and river water is expected to be high, thus water will be able move into and out of the aquifer depending on the river stage. Drainage works on the Donagh and Glennagannon River beds found the alluvium to be thin and underlain by gravel (Lee, 2004). Water level data indicate that recharge from a stream to the aquifer is induced by groundwater abstraction at Carndonagh Public Water Supply. Anecdotal evidence also suggests that during very dry weather, the Donagh River sinks into the aquifer. In the northern part of the body, groundwater discharges to streams, rivers and drainage channels, and as seeps to Trawbreaga Bay.
Conceptual model	• The sand and gravel deposits at Carndonagh are located in a relatively lowlying, gently undulating to flat area, at elevations between sea level and 30 m AOD, between Carndonagh Town and Trawbreaga Bay. • The deposits are bounded to the southwest and southeast by steeply rising ground, to the north by the coast, and to the northwest, northeast and south by till subsoil and/or bedrock. • The surface drainage is northwards to Trawbreaga Bay. Drainage is good in the southern area of the deposit, but poorer in the north and closer to the sea, where overlying peat is common. • The aquifer comprises glaciofluvial sand and gravel deposits deposited in an outwash fan or delta, as well as some raised beach material. • Estimated transmissivity of the sand and gravel body is 350 - 600 m^2/d. The saturated thickness of the sand and gravel aquifer is roughly 5 m, and bulk permeability is estimated as 80 m/d. • Overall, groundwater flows from south to north. Locally, groundwater will flow towards or away from the rivers and streams, depending on the relative water levels in the groundwater and surface water features. Groundwater gradients are estimated to be about 0.007 to 0.01. • Diffuse recharge occurs *via* rainfall percolating through the unsaturated sands and gravels. River water also recharges the aquifer in the south of the deposit during low groundwater conditions, and because of lowered water levels related to abstraction. • Groundwater discharges to the rivers and streams that flow across the deposits. In the north of the aquifer body, groundwater discharges to the drainage channels and to the sea at Trawbreaga Bay. • Relative water levels and hydrogeological observations indicate that the hydraulic connection between the groundwater in the aquifer and river water is high. • The lengths of the flow paths range from several hundred metres to around 1 km. • The groundwater has a calcium bicarbonate signature and is hard. Chloride concentrations are relatively high due to the aquifer's proximity to the sea. • The minimum groundwater throughput in the aquifer is estimated to be 4,960 m^3/d, with a significant portion of this volume coming from rejected recharge from the surrounding hills, particularly those to the west and southeast.
Attachments	Figure 1: Location and extent Figure 3: Cross sections Figure 4: Groundwater vulnerability

Instrumentation	**Hydrometric gauges:** **National Water Monitoring Stations;** **River:** **Groundwater:**	None present RS40D010220 Br W of Old Mill (E. Channel) 40006 Carndonagh RS40G012000 Strawbridge Bridge RS40D010640 Carndonagh WWTP Downstream RS40G01200 Strawbridge Br. 40003 Glennagannon RS40D010500 1km d/s Corvish Br (u/s STW) (Tidal) 40007 Corvish Br. RS40D010310 Millrace Str nr St 0300 None present
Information Sources	• DELG/EPA/GSI (1999). Groundwater Protection Schemes. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. • EPA Drinking water returns (2002 and 2005): http://erc.epa.ie/safer/dataAndResources/publiclyAvailableDatasets. • EPA Website: http://gis.epa.ie/Envision/ • Farrell, E. (1989). Site investigation information including borehole and PSA information. • GSI (2017). A description of Irish aquifer categories. 3 pp. Available from: • https://www.gsi.ie/documents/GSI%20Aquifer%20Category%20Descriptions.pdf • GSI (2023). Geological Survey Ireland Spatial Resources Viewer. https://www.gsi.ie/en-ie/data-and-maps/Pages • Hunter Williams, N., Misstear, B., Daly, G., Johnston, P., Lee, M., Cooney, P. and, Hickey, C. (2011). National Groundwater Recharge Map for Ireland. Geological Survey Ireland and Department of Civil, Structural and Environmental Engineering, Trinity College Dublin. • K.T. Cullen and Co. Ltd. (1992). Proposed Groundwater Protection Policy for the Carndonagh Gravel Aquifer. Report for Donegal County Council. • Lee, M. (2004). Carndonagh Water Supply Groundwater Protection Zones, 19 pp. Geological Survey of Ireland. • Lee, M. and Fitzsimons, V. (2004). County Donegal, Groundwater Protection Scheme Volume I: Main Report. Geological Survey of Ireland. • McCarron, S. (2002). Aggregate Potential Mapping of County Donegal. Geological Survey of Ireland. Report for Donegal County Council. Geological Survey of Ireland. • Meehan, R.T. (2006). Subsoils Map for County Donegal. Map produced as part of EPA Soil and Subsoil Mapping Project (formerly FIPS-IFS). Teagasc, Kinsealy. • Ó' Riain, G. (2004). Water Dependent Ecosystems and Subtypes Draft Report. WFD Support Projects. Compass Informatics in association with National Wildlife and Parks Service (DEHLG). • Ó'Súilleabháin, C. (2000). Assessing the boundary between high and moderately permeable subsoils. Unpublished MSc., University of Dublin. Department of Civil, Structural and Environmental Engineering, Trinity College Dublin. • Solmec (1974). Lough Inn Regional Water Supply Scheme Carndonagh Section – Trial Boreholes Logs and PSA. • Walsh S. (2012). A Summary of Climate Averages 1981-2010 for Ireland, Climatological Note No.14, Met Éireann, Dublin. • Wright, G.R., Aldwell, C.R., Daly, D. and Daly, E.P. (1982). Groundwater resources in the Republic of Ireland, vol 6. In: European community's Atlas of groundwater resources, SDG, Hannover, Germany.
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 1, 2 and 3 are used for illustrative purposes only.

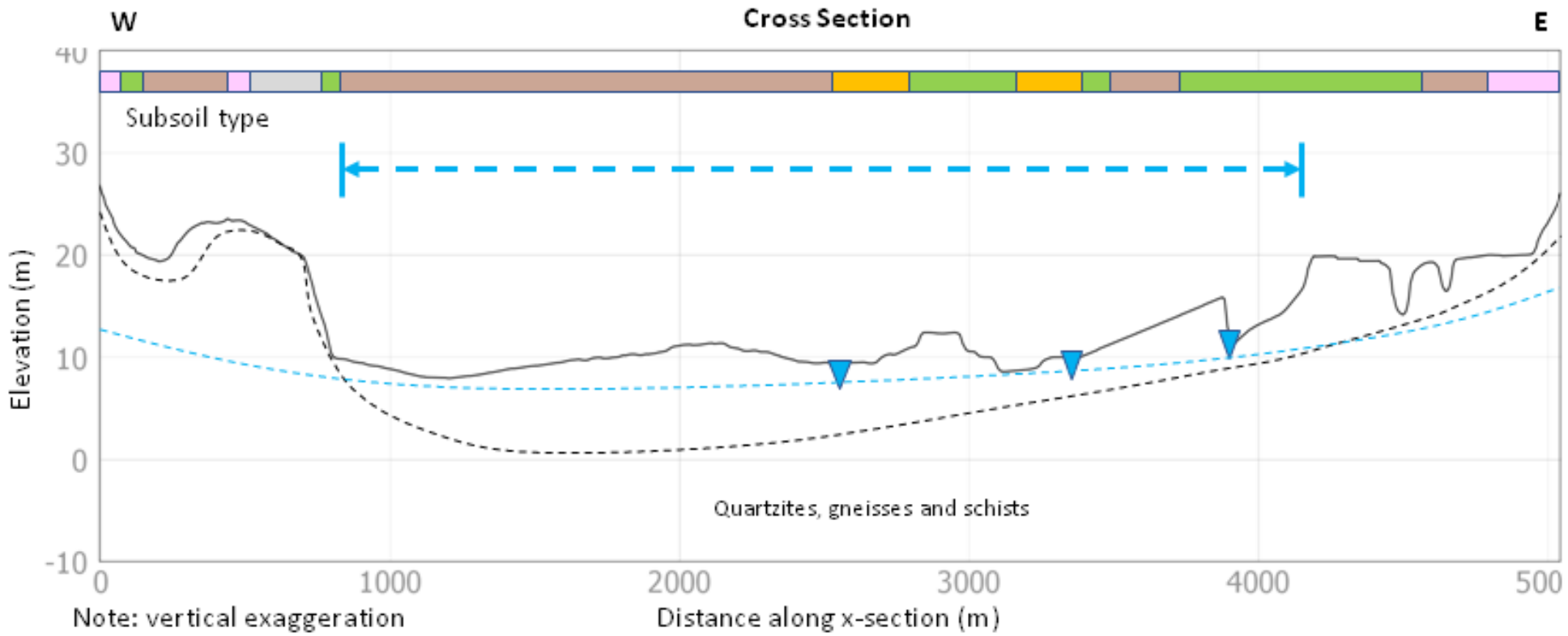
Carndonagh Sand and Gravel Aquifer



Legend

- Cross Section
- Sand and Gravel Aquifer
- Sand and Gravel Extent

Figure 1. Carndonagh Sand and Gravel Aquifer extent with cross section location.



Elevation		Presumed Groundwater Level		Sand and Gravel	
Groundwater level		Presumed Top of Bedrock		Till	
Top of bedrock		Presumed Top of Till		Alluvium	
River		Borehole/Trial Pit		Rock	
Aquifer				Peat	

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

Carndonagh Sand and Gravel Aquifer Vulnerability

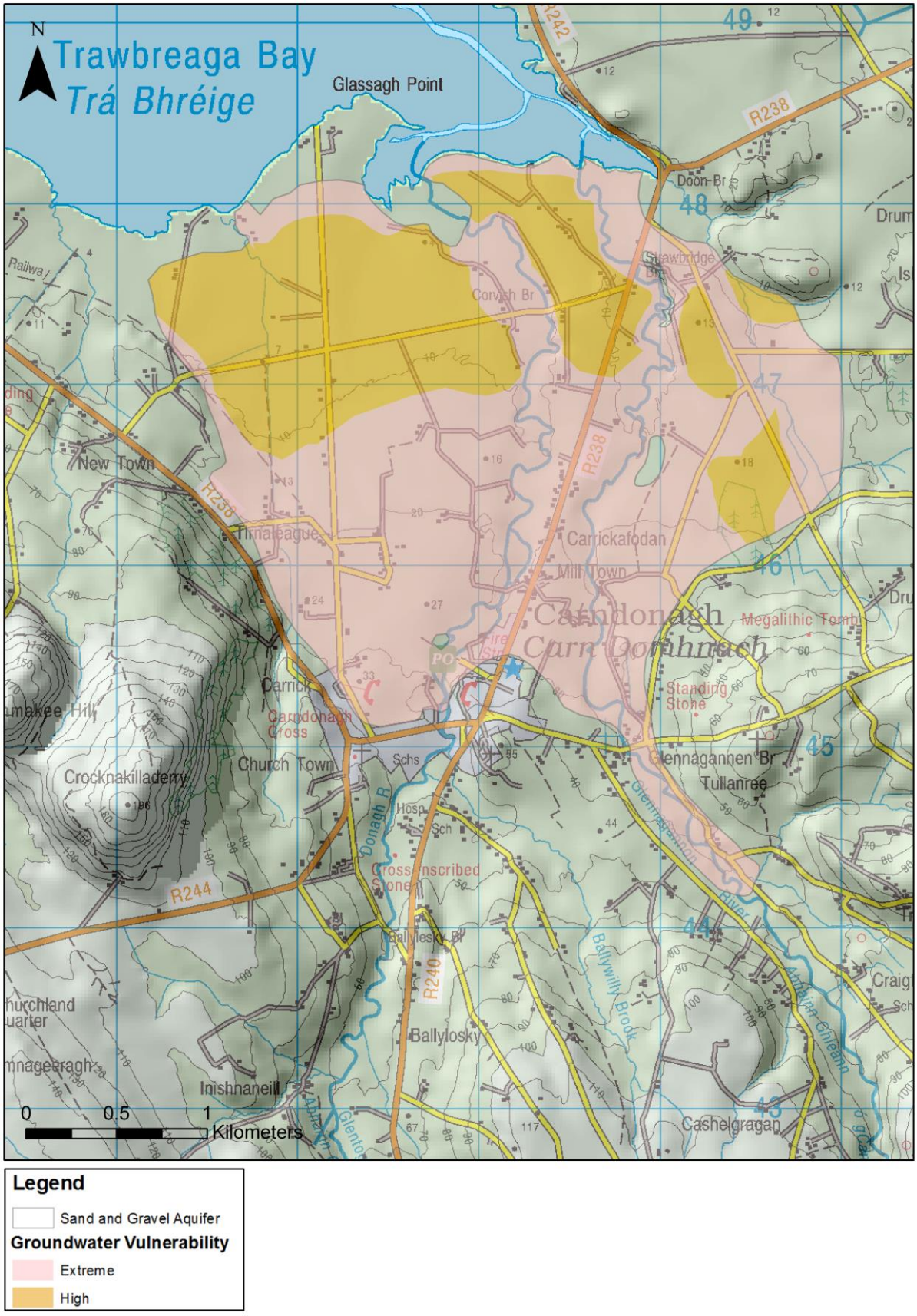


Figure 3. Groundwater vulnerability across the Carndonagh Sand and Gravel Aquifer.