HYDROGEOLOGICAL ASSESSMENT OF SUBSOILS FOR PROPOSED NEW BURIAL GROUND AT GORMANSTON TOWNLAND, STAMULLEN, COUNTY MEATH

FINAL REPORT

Prepared for:
MEATH COUNTY COUNCIL,
BUVINDA HOUSE,
DUBLIN ROAD,
NAVAN,
COUNY MEATH,
C15 Y291.

Prepared by:
EurGeol. Dr. Robert T. Meehan, PGeo.
Consultant Geologist
86 Athlumney Castle
Navan
County Meath
Phone: +353-46-9070070
Email: antalamhireland@gmail.com

29033 **August 2022**

EurGeol **Robert Meehan,** B.A., Ph.D., PGeo.
Soil, subsoil and landscape geologist

86 Athlumney Castle,
Navan,
County Meath.

Tel: +353-(0)46-9070070
Mob: +353-(0)87-6875558
email: antalamhireland@gmail.com

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SCOPE OF THIS REPORT

The findings of this report are the result of a desk study and geological field interpretation. Interpretations and conclusions included in the report are based on knowledge of the ground conditions following detailed investigations, as well as the regional soils, subsoils and bedrock geology, and the experience of the author. Dr. Robert Meehan has prepared this report in line with best current practice and with all reasonable skill, care and diligence in consideration of the limits imposed by the survey techniques used and the resources devoted to it by agreement with the client. The interpretative basis of the conclusions contained in this report should be taken into account in any future use of this report.

Dr. Robert Meehan accepts no responsibility for any matters arising if any recommendations contained in this document are not carried out, or are partially carried out, without further advice being obtained from Dr. Robert Meehan.

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EXECUTIVE SUMMARY

EurGeol. Dr. Robert Meehan PGeo. was retained by Meath County Council to undertake a hydrogeological desk study, subsoils investigation and modelling exercise as part of an investigation into the subsoils of the locality around the proposed cemetery site at Gormanston Townland, Stamullen.

This report provides a description of the geological character of the site and details the nature, extent and complexity of the geological material from the surface downwards through the mineral subsoil. No detailed quantitative geological or hydrogeological field investigations were undertaken; however, trial pits were dug across the site, field mapping as completed, and samples were taken from the subsoil for textural analyses using British Standard BS: 5930. The results of the desk study, walkover survey and trial pitting exercise were collated to assess the drainage characteristics of the subsoil on the site.

The bedrock under the site is expected to be over 10 m deep, and is proven to be >3.0 m deep across the majority of the site, and >2.85 m deep over the entire site. This bedrock at depth is of greywackes, sandstones and siltstones Denhamstown Formation, which is a 'poor' aquifer. The locality has a high groundwater vulnerability rating, owing to the depth and permeability of the subsoil, and the depth to the water table. Groundwater flow under the site is towards the southeast, downslope towards the Delvin River and 'through' the proposed cemetery. This groundwater is at a relatively deep depth under the site, proven to be >3.0 m across the majority of the site, and >2.4 m over the entire site.

The topsoil encountered in the trial pits on-site was seen to be generally well drained sandy loam to loam with pockets of deeper sandy SILT with occasional gravels, which shows a similar drainage class to that suggested by the regional scale soils mapping of the area by An Foras Taluintais (Finch *et al.*, 1983). The subsoil under the site is dominated by a unit of very silty sandy GRAVEL with occasional cobbles, between approx. 0.5 m and 3.15 m depth, interspersed with beds and pods of SAND-dominated material.

With the observation of the majority of the material within the trial pits across the site as being 'well drained', and in some localities sorted and bedded, with rounded to subrounded clasts, the BS 5930 descriptions and the lack of mottling in the major subsoil units in each profile, this would definitively place the sediments within the 'high' permeability class. As well as this, there occurred no infiltrating water in the uppermost 2.4 m of subsoil on the site, though mottling at the base of the trial hole on the lowest portion of the site suggests that water infiltrates to 2.1 m below ground level at that point. This means that the proposed burial ground site is suitable for burials, but would benefit from the importation of 0.6 m depth suitable soil / subsoil across it's lower, southeastern portion.

Thus, as a precautionary measure and in order to ensure no groundwater contamination under the site, no burials should take place at a depth below 2.05 m below current ground level across the entirety of the site. In the southeasternmost portion of the site, where groundwater was met at depths between 2.4 m and 2.95 m below current ground level, and as mottling was observed in one trial hole at 2.1 m below ground level, no burials should take place here at depths below 1.2 m below ground level. In this area, ideally, approximately 0.9 m depth suitable soil and subsoil should be imported across the site, to level it, to ensure that sufficient depth to water table is maintained beneath burials across the entire site.

1.0 INTRODUCTION

EurGeol. Dr. Robert Meehan, PGeo. was retained by Meath County Council to undertake a hydrogeological desk study, subsoils investigation and drainage potential examination as part of a scoping exercise for the proposed new burial ground at Gormanston Townland, Stamullen, County Meath (*Irish National Grid Reference 315650 266250)*. The site is located approximately 1.0 km northeast of the centre of the village of Staullen, on the northwestern terrace of the Delvin River, at an elevation of approximately 19 m - 26 m AOD. The site is approached by a third-class road, and is immediately adjacent to the M1 Motorway route, Figure 1).

The closest surface watercourse as seen on the Discovery Series Map is the Delvin River which runs along the site's southeastern boundary, approximately 25 m to the southeast of the area of the proposed burials. A Mill Race is also shown as passing across the landholding and join the Delvin River flow east of the locality, on the six-inch to one mile sheets of the locality, but this has long been infilled and there is no trace of it on-site at present. Drainage ditches do not seem common in the general area on these maps, and there are no drains marked within 300 m of the proposed burial ground site.

Figure 1 Location of site at Gormanston Townland, Stamullen, illustrating surrounding topography and surface water stream and river features (OS Licence EN 0057922). Grid squares are 1 km distance.

This report provides a description of the geological character of the site and details the nature, extent and complexity of the geological material from the surface downwards through the mineral subsoil. A comprehensive desk study was completed, and trial pits and a visual assessment of the site were completed in the field. The results of the desk study, walkover survey, trial pitting exercise and subsoil sample analysis were collated to assess the potential for installation of the burial ground on-site, and in particular to examine if there may be issues with either bedrock or a shallow water table in the locality.

2.0 SOILS, SUBSOILS, GEOLOGICAL & HYDROGEOLOGICAL CHARACTERISTATION

2.1 Topography.

The site is situated at the eastern extreme of the 'River Valleys' topographic unit in southeastern County Meath, at the edge of the valley of the Delvin River (Meehan, 2012; Figure 1).

The site rests on the southeastern mid- backslope of a low elevation terrace which rises a number of metres above the surrounding, gently undulating landscape of the area. The land in the area is generally relatively well drained upon first impression, although it is noted that this is an area of low effective rainfall. Elevations within the area rise to a high of 26 m AOD in the northwestern extreme of the site itself, with the remainder of the site situated at between *c.* 25 m and 23 m AOD.

2.2 Soils

The site and the area surrounding it is mapped as being underlain by deep mineral soils of good drainage status, and derived mainly from non-calcareous parent materials (Teagasc/EPA, 2006a).

Previously, this area of County Meath was mapped by An Foras Talúntais as being characterised by soils of the Dunboyne Series. Dunboyne Series soils are grey brown podzolics, which are well drained, and of silt to silty clay loam texture. The development of the Dunboyne Series soils is primarily associated with a leaching process; the principal constituent in the 'B' horizon is a finely divided clay fraction. The' B' horizon therefore has a much greater percentage of clay than the 'A' horizon. The water table is usually at depth within the areas occupied by these soils.

The area of the proposed burial ground site, being part of the mid-backslope of a low terrace, has the potential to have soils of very good drainage class throughout it's area. As well as this, the likelihood a water table at a deeper depth than in the surrounding landscape is quite high, as the terrace itself may have subsoil materials different in texture to those around in the lowerlying areas of the landscape.

2.3 Subsoil (Quaternary) Geology

The Quaternary period extended from 1.6 M.A to present day. During this period great Ice Ages took hold in Ireland, the last of these extending from 73,000 years BP until 10,000 years BP. There were several phases of ice flow affecting County Meath. Within these phases, ice flowed from a number of different centres. Ice moving from the west to the east would have been the last ice to cross over the site, as the existing glacial landforms indicate that ice flow direction during the Last Glacial Maximum was approximately easterly across southeastern Meath (Clark and Meehan, 2001). Following this there was a period of deglaciation, when waterlain glaciofluvial sediments were deposited. Since deglaciation ended, a period of post-glacial geological processes has continued until the present day, where natural landscape processes in Ireland are dominated by the action of water.

Glacial deposits in this region are often deep, with bedrock found several metres below the land surface. For example, a borehole drilled in a landholding approximately 250 m west of the subject site at

Gormanston Townland, during the drilling of a domestic well in the early 1900's, was bored to 13.7 m below ground level, and did not meet bedrock (GSI, 2021).

During glaciation across Meath, till (boulder clay) was deposited on top of the pre-existing bedrock at the base of the moving ice sheet. During the advancement of the glaciers, the weight and pressure of the ice broke the bedrock upon which the glaciers moved and ground it down to particle sizes ranging from boulders to clay. This material was smeared by the advancing ice on top of the pre-existing bedrock, leaving the mixture of debris material comprising till. Tills are often over-consolidated, or tightly packed, unsorted, unbedded, possessing many different particle and clast (stone) sizes, and commonly contain sharp, angular clasts. These materials are also common glacially-deposited subsoils across the county of Meath and are mapped as underlying the site in the Gormanston locality (Figure 2).

Figure 2: Subsoils geology of the site and its environs. The purple depicts till derived chiefly from Lower Palaeozoic sandstones and shales, the green depicts 'glaciofluvial sands and gravels', the orange alluvium, and the cyan 'Made' ground (OS Licence EN 0057922).

Glacial deposits in this region also commonly consist of glaciofluvial sands and gravels, which were formed by glacial meltwater as the ice sheets of the last Ice Age melted. These are mapped as occurring west, east and south of the site at Gormanston Townland, Stamullen (Teagasc/EPA, 2006b, see Figure

2). Sands and gravels, being deposited by glacial meltwater, are usually sorted and well bedded, and comprise well washed and rounded clasts. They are usually unconsolidated, and relatively 'loose' and often prone to collapse when dug in pits. In general, sands and gravels are highly permeable, as they are dominated by gravel clasts and sand, with little silt or clay.

On the subsoil map both tills and sands and gravels are categorised according to their dominant lithological component (Figure 2). Grain size of the matrix, or the texture of the till, is also important, as this determines the permeability of these subsoils, which is important for soil development processes and for infiltration potential. Thus, tills may be described as gravelly, sandy, silty or clayey. From Figure 2 it would appear that the site is located within an area of till derived chiefly from Lower Palaeozoic sandstones and shales, which extends out northwards from the site. The permeability of this till subsoil, as mapped for the County Meath Groundwater Protection Scheme (1995), is 'low'. This is owing to the sorting and bedding, and dominance of fine sediment within this till material.

Post-glacial alluvium is also common in the lowlying river channel area along Delvin River at the southern end of the site (Teagasc/EPA, 2006b, Figure 2). Where the areas around Gormanston and Stamullen have had ground disturbed and covered by concrete and/or tarmacadam over the last few centuries, 'Made' ground has been mapped as a subsoil class in itself. Examining Figure 2, the subsoil geometry in the region therefore seems quite complex, but the site itself lies within an extensive area mapped as till, but at the edge of an extensive area of sands and gravels.

Information from the County Meath depth-to-bedrock map, which was mapped by the Geological Survey of Ireland (GSI, County Meath Groundwater Protection Scheme, 1995) suggests that depth-to-bedrock in the vicinity of the proposed site is greater than 10 m.

2.4 Bedrock Geology

The 1:100,000-scale bedrock geology map of the area (Geology of Meath, Sheet 13; GSI, 1994) indicates that the site is underlain by rocks of the Denhamstown Formation (DD). These were deposited during the Silurian Period (444 to 419 million years ago) and comprise greywackes, sandstones and siltstones (Figure 3). This bedrock extends outwards from the site for at least 1 kilometre in all directions, excepting the northwest where bedrock of the Clatterstown Formation has been mapped as the bedrock from approximately 940 m to the northwest. These rocks were also deposited during the Silurian Period, and comprise thinly bedded siltstones and sandstones (Figure 3).

A major fault occurs in the Denhamstown Formation bedrock approximately 615 m east of the site (Figure 3).

The County Meath Groundwater Protection Scheme vulnerability map suggests that bedrock is present at depths greater than 10 m below ground level beneath the proposed burial ground site, and the closest bedrock outcrop/subcrop is over 650 m to the west-southwest, in the southeastern portion of Stamullin Townland (see greyed locality on Figure 2).

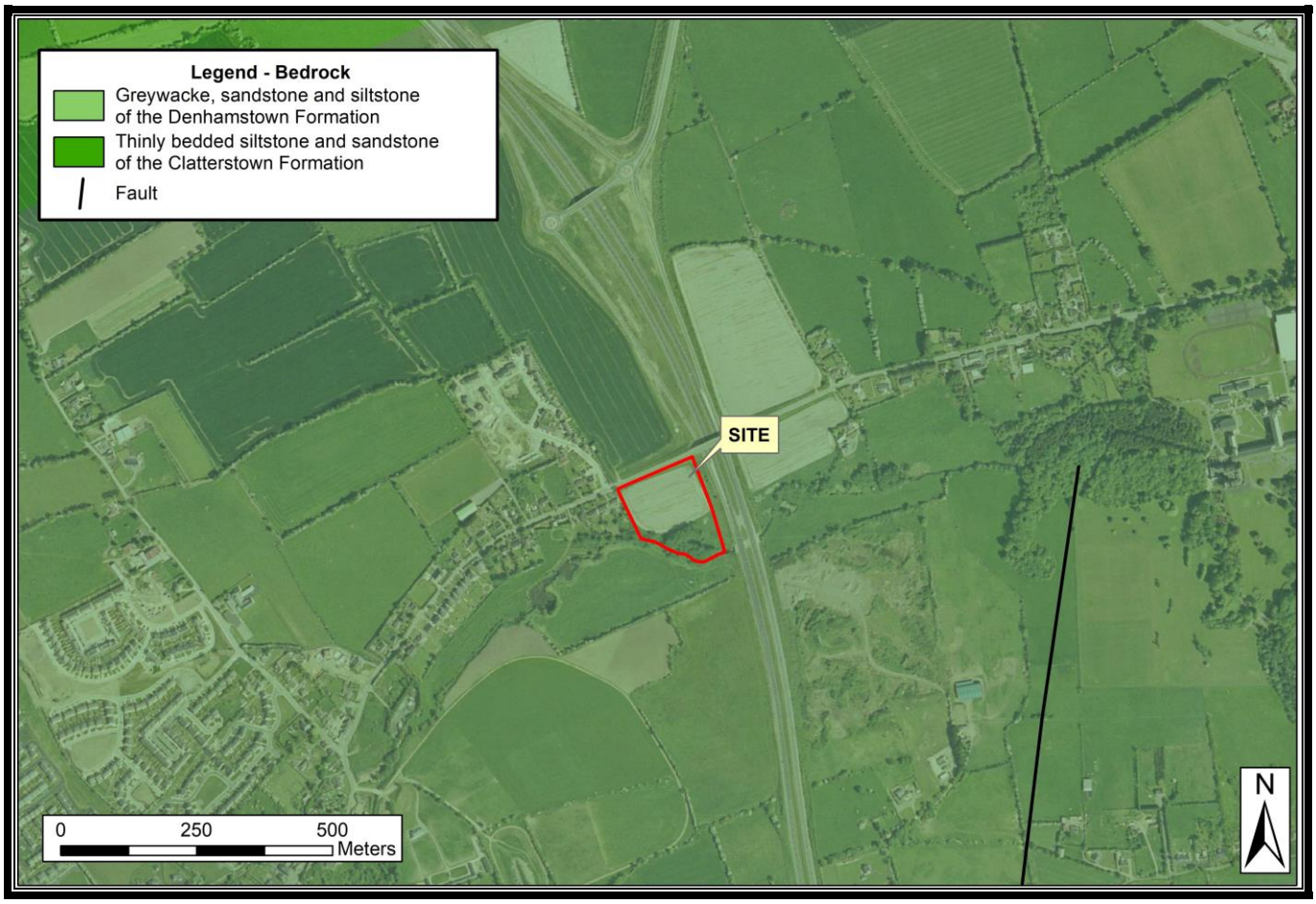


Figure 3: Bedrock geology of the site and its environs (OS Licence EN 0057922).

2.5 Hydrogeology

2.5.1 Groundwater Flow Direction

Groundwater is defined as water that moves through and is stored within sub-terrain geological strata and flow direction generally follows topography.

Groundwater underlying the site is therefore assumed to flow from northwest to southeast, downslope towards the Delvin River at the southeast (Figure 4). This means that any contamination arising from burials will also move along those planes, when mixed with and diluted by subsurface groundwater.

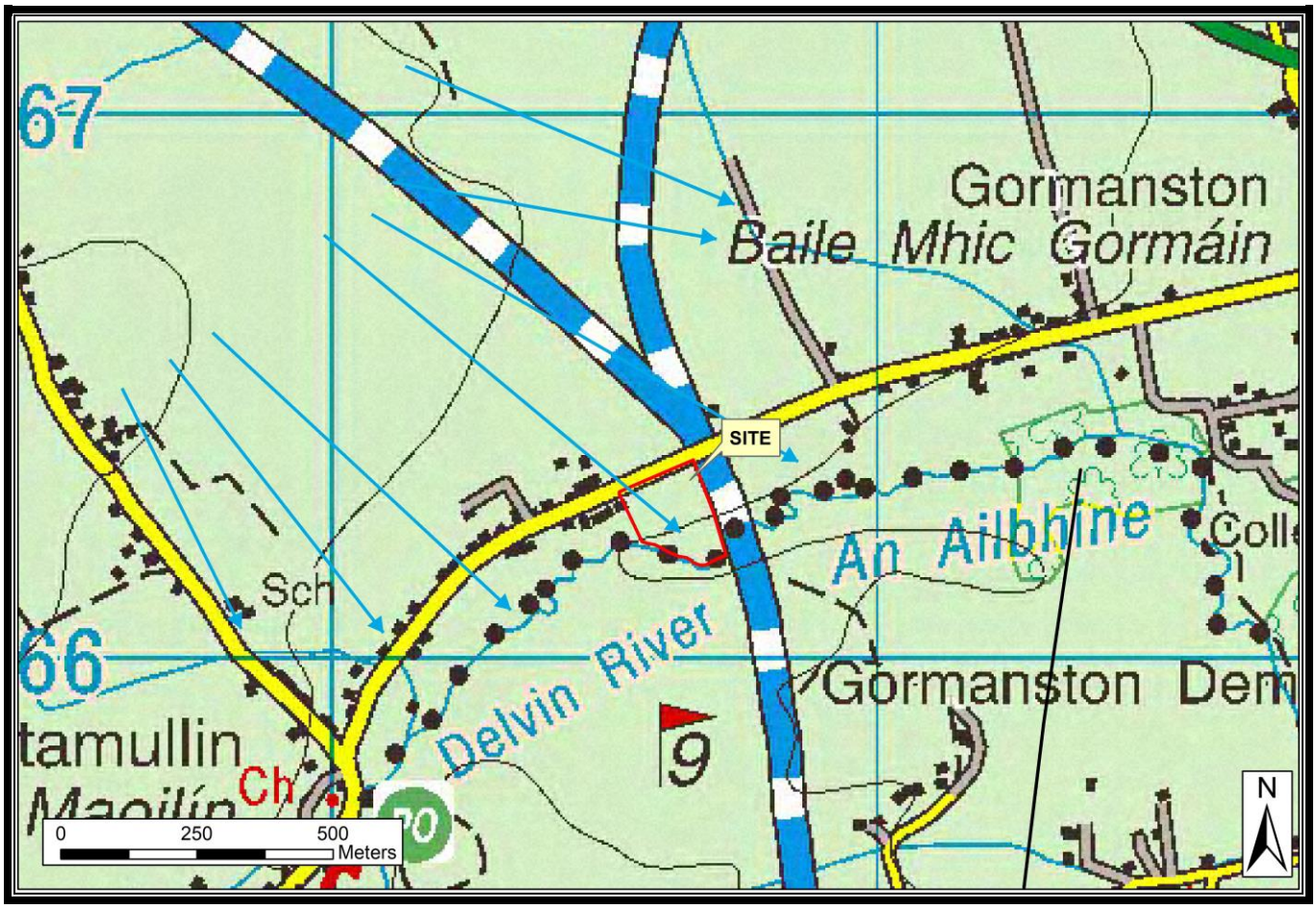


Figure 4: Interpreted groundwater flow directions under the land at Gormanston Townland, Stamullen, using contours from the O.S. 1:50,000 Discovery Series map, levels measured on-site, and surface water stream flow directions. Flow should generally be towards the Delvin River and the lower land to the southeast (OS Licence EN 0057922).

2.5.2 Aquifer Classification

The aquifer potential of a bedrock unit is determined by the groundwater productivity and the productivity is based on hydraulic characteristics compiled from borehole data throughout the country. The national aquifer map of Ireland produced by the Geological Survey of Ireland has classified the Denhamstown Formation bedrock as a poor aquifer (Pu) – bedrock which is generally unproductive, with few and poorly connected fractures, fissures and joints. This low fissure permeability tends to decrease further with depth. A shallow zone of slightly higher permeability may exist within the top few metres of more fractured/weathered rock, and higher permeability may rarely occur along large fault zones. In general, the poor fissure network results in poor aquifer storage, short flow paths (tens of metres) and low 'recharge acceptance'. Groundwater discharge to streams ('baseflow') is generally very limited.

The national aquifer map has classified the bedrock of the Clatterstown Formation to the northwest and northwest of the site as a poor bedrock aquifer (Pl) – bedrock which is generally unproductive, except for

local zones. In these rocks, the permeability, storage capacity, recharge acceptance, length of flow path and baseflow are higher than in Pu aquifers.

East of the site by approximately 630 m (Figure 5), the sands and gravels are sufficiently thick and saturated to be classified themselves as a Locally Important Sand and Gravel aquifer – the Laytown – Gormanston Aquifer. In sand and gravel aquifers, groundwater flows through the pore spaces between sand/gravel grains, and the permeability is mainly determined by the grain size (larger grains give larger pore spaces), and the 'sorting' of the material (the more uniform, the higher the permeability). There is a relatively uniform distribution of groundwater, good aquifer storage and long groundwater flow paths, typically limited by the aquifer's extent. Groundwater gradients are typically low ('flatter' water tables), giving relatively low groundwater velocities. There is generally a strong interaction between surface water and groundwater, with groundwater discharging into streams if the water table is high, or conversely, the surface water moving into the aquifer, if the surface water level is high. Large, dependable springs (>2,000 m^3/d) are often associated with sand/gravel aquifers, especially in low-lying areas or at the periphery of the aquifer.

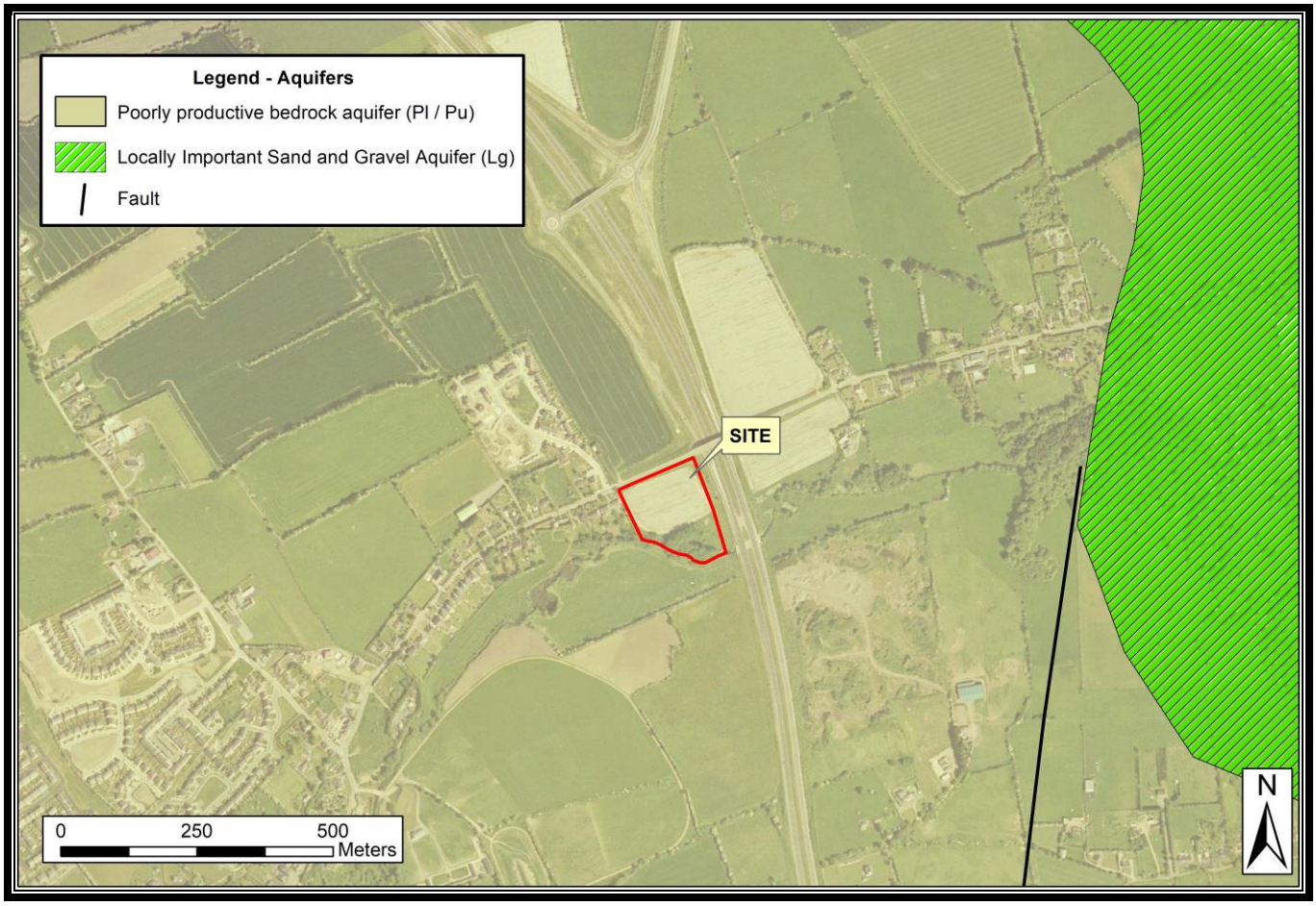


Figure 5: Aquifer map of the site at Gormanston Townland, Stamullen and its environs (OS Licence EN 0057922).

There is a general scarcity of hydrogeological data for the Denhamstown Formation rocks the within the Duleek Groundwater Body, of which the Gormanston Townland, Stamullen locality forms part. Groundwater flow in these Silurian rocks is considered to take place in the upper weathered zone of the aquifer. Flow paths are not considered to extend further than the nearest surface water features and will generally not be greater than 500 m. The flow is usually in relatively localised systems with little continuity between them.

According to the Groundwater Body Summary sheet of the GSI for the Duleek Groundwater Body, it is impossible to quote specific, single figures with respect to permeability, transmissivity and storativity of the aquifer.

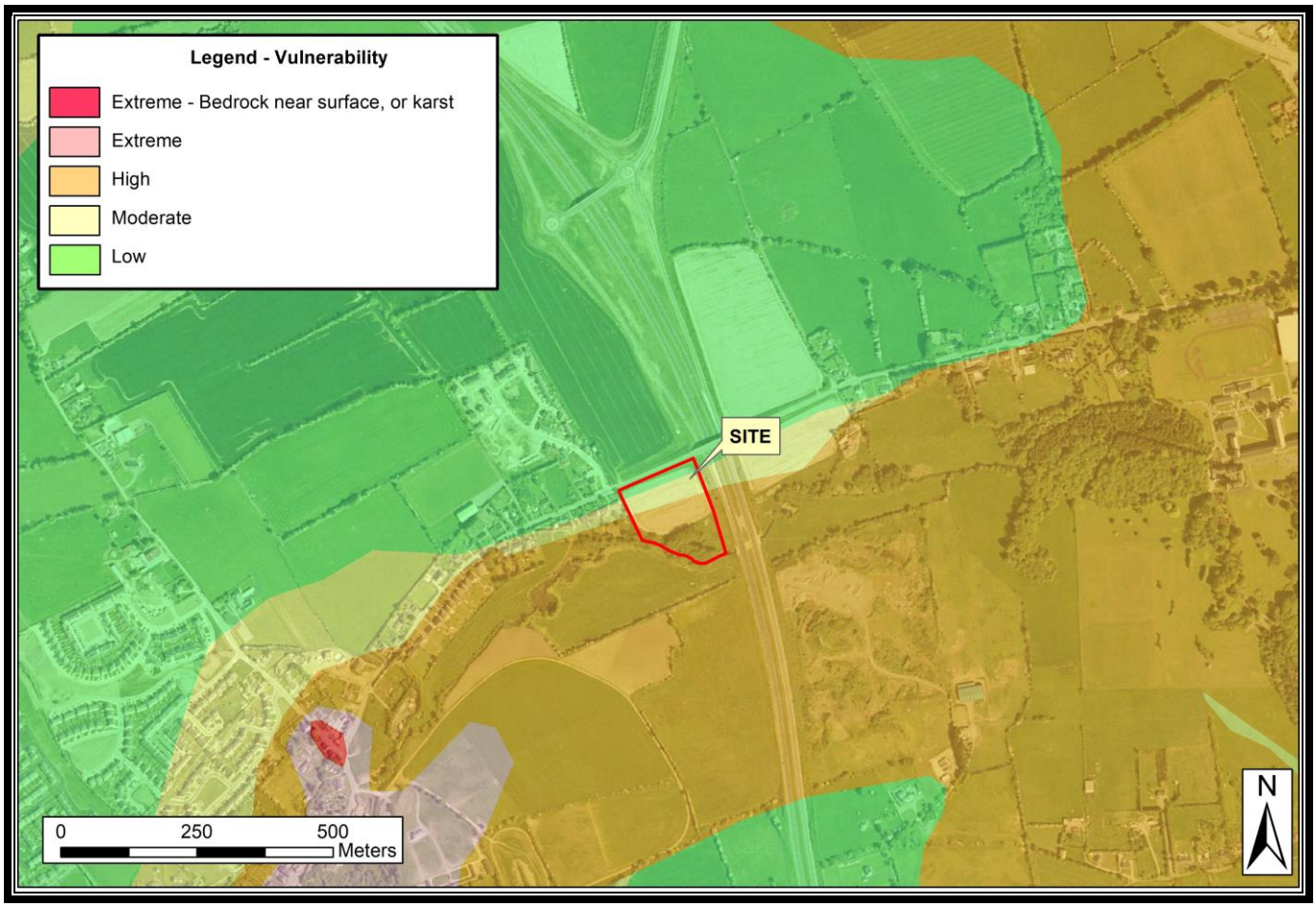


Figure 6: Groundwater vulnerability zonings for the proposed burial ground at Gormanston Townland, Stamullen and its' surrounding areas (OS Licence EN 0057922).

2.5.3 Groundwater Vulnerability

Groundwater vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. The vulnerability of an aquifer is defined as the ease with which infiltrating water and potential contaminants may reach groundwater in a vertical or sub-vertical direction. It is dependent on permeability and thickness of the subsoil.

A groundwater vulnerability map for the area has been completed for County Meath by the GSI and from consultation of the map the site locality is ranked as being in the majority of 'High' groundwater vulnerability. Closer to the road the groundwater vulnerability reduces to, initially, 'Moderate', and then 'Low' (Figure 6).

2.5.4 Recharge

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. Recharge is generally estimated on an annual basis, and is assumed to consist of an input (*i.e.* annual rainfall) less water losses (*i.e.* annual evapotranspiration and runoff). In areas where point recharge from sinking streams etc. is discounted, the main parameters involved in recharge rate estimation are annual rainfall, annual evapotranspiration, and annual runoff.

Diffuse recharge will occur *via* rainfall percolating through the subsoil or through areas of outcropping rock. The proportion of the effective rainfall that will recharge the aquifer is determined by the permeability of the soil and subsoil, and by the slope. The generally deep 'low' permeability subsoil of the Gormanston Townland, Stamullen locality will in some senses restrict percolation of recharge to the aquifer. As well as this, the 'poor' bedrock aquifer beneath the site has a storage limit, and will only allow approximately 100 mm of recharge to infiltrate the groundwater in the aquifer body.

The National Recharge Map produced by the Geological Survey of Ireland (GSI, 2013) has therefore classified the subject site as having a recharge rate of 100 mm per year, owing more to limited recharge acceptance in the 'poor' aquifer under the site, rather than the low permeability of the subsoils in the locality.

2.5.5 Utilisation of Groundwater Resources in the vicinity of the Proposed Development

Approximately eighty houses occur within 500 m of the site, which are all serviced by Irish Water's South Louth and East Meath Water Supply Scheme, and a well audit of the surrounding area identified no water supply boreholes in the immediate vicinity of the site.

There are no down-gradient wells between the proposed burial ground and the nearest receptor, which is the Delvin River to the southeast of the site.

3.0 HYDROGEOLOGICAL INVESTIGATIONS INTO THE SUBSOIL

Intrusive site investigations, comprising trial pitting and walkover survey, were therefore carried out by Robert Meehan in association with Meath County Council at the subject site on 7th September 2021.

3.1 Walkover survey

Initially, a walk-over survey was conducted across the entire site to examine the ground conditions and salient features on-site. The area of the proposed burial ground is covered with good quality arable crops, which had recently been cut. Though pasture covers the field immediately to the south across the river, arable crops are grown in the majority of the fields west, north and northwest of the site.

From this walkover, it was seen that no drainage ditches have been dug on or around the site. No shallow, roadside drainage ditches have been dug along the sides of the road in front of the site either. The majority of the other hedgerows around the site comprise fences and/or dry banks.

None of the land across the site or the surrounding locality hosts rushes and the low terrace forming the site, as well as the land around it, is firm and dry.

3.2 Trenching programme

From the walkover survey, sites were selected for excavation and 8 no. trenches were excavated throughout the site (Figure 7). The holes had to be dug in locations so as to avoid a subsurface high pressure Gas Pipeline, as well as a permanent wayleave granted to Irish Water across the northern portion of the site, as well as a discharge pipe which runs through the site from the City North Hotel to the north (see Figure 7).

Trenches were dug using a JCB Hydradig 110W Excavator. The holes were left open for up to 2 hours to see if there were water inflows and if the water table stabilised following initial examination. Based on the materials logged from the 8 no. trial pits dug within the proposed burial ground site, the subsoil material across the site is relatively consistent and is at least 2.85 m deep throughout the site (in all probability this depth is >3.15 m, as seen from trial pit no. 5).

The pits allow a detailed hydrogeological conceptual model of the subsoils under the site be drawn up. The geological logs showing descriptions of the subsoils encountered in the pits are presented in Appendix A. All subsoils encountered were described in accordance with the British Standards Institution Code of Practice for Site Investigations (BS 5930, 1999) which gives a geotechnical classification of the materials encountered, in particular bulk density, structure and textural characteristics. Bulk samples were collected and retained for analysis, should this be required. A summary of the conditions encountered under each of the localities on-site follows.

The land on the site has a gently undulating to gently sloping topography, with varying slope directions and slope angles generally between 2° and 4°, but up to 6° just off the site to the south, where the drop to the fluvial floodplain of the Delvin River occurs.

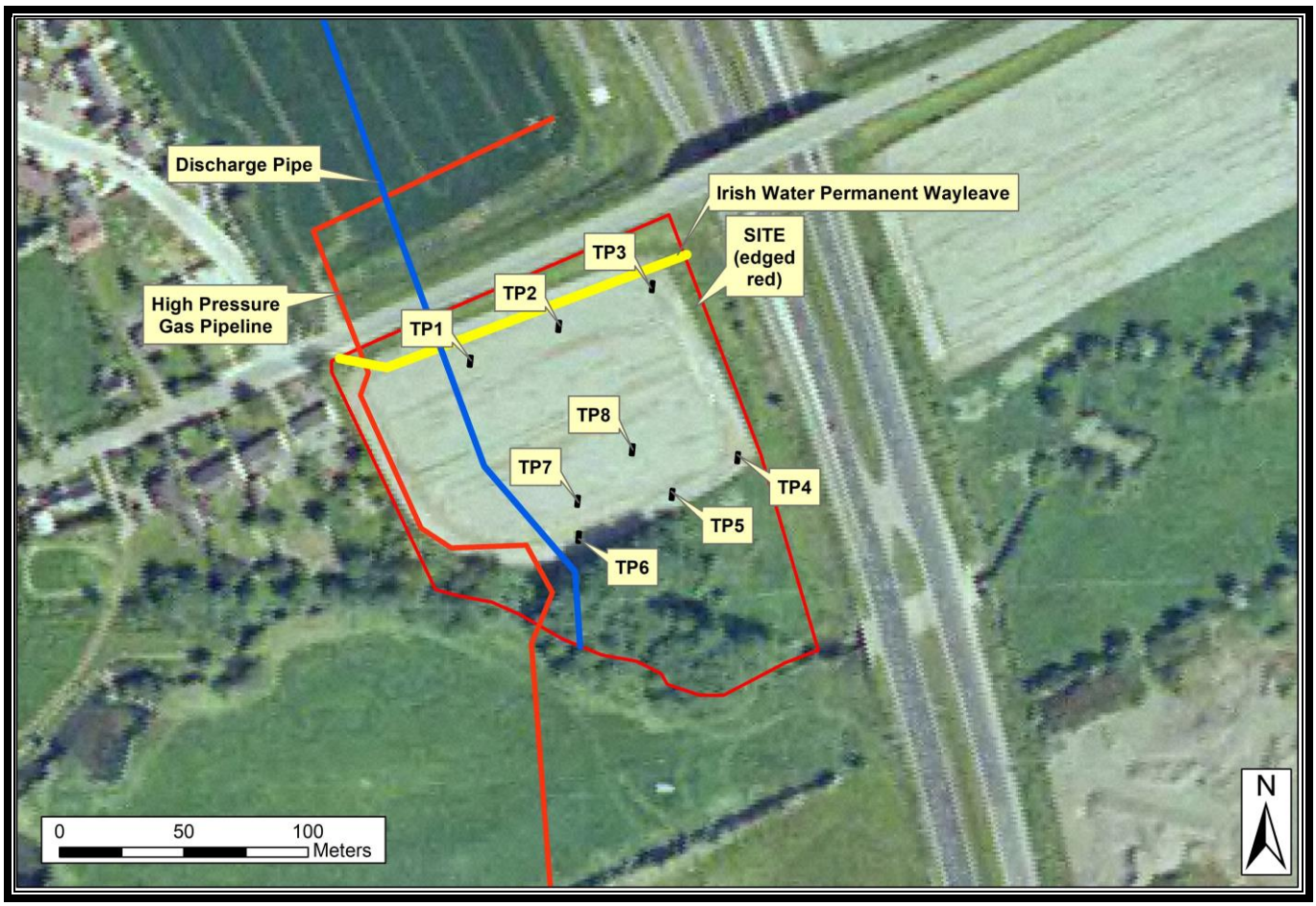


Figure 7: Location of trial trial pits excavated within the proposed Gormanston Townland, Stamullen burial ground site area, as well as infrastructure which had to be avoided during the dig process.

The topsoil encountered in these pits was generally dark brown to very dark greyish brown, sandy loam to loam, underlain in places by sandy SILT with occasional gravels, which was between 0.31 m and 0.52 m deep. This was compact to very soft and was of crumb to subangular blocky structure, with abundant grass roots and rootlets.

The soils sequence, including both the 'A' and 'B' horizons, is of either an acid brown earth or a brown podzolic, which, though not corroborating perfectly the regional Soil Survey Mapping of An Foras Taluintais (Finch *et al.,* 1983), still suggests that the subsoil is well drained in the general locality.

Within the trial pits, only one subsoil unit was encountered in the majority of the pits. The major subsoil layer extends from approx. 0.45 m to approx. 3.15 m+ depth, and is a very soft, well aerated, very silty sandy GRAVEL with occasional cobbles (as per BS5930, 1999). This layer is the major unit in which burial will take place, and is unmottled and dark brown in colour. From this, the unit seems permeable and suitable for burial.

In one of the pits (TP4) a second subsoil unit was met, between 2.1m/2.53 m depth and 3.1 m depth. This unit was a mottled very dark bluish grey and yellowish brown, very sandy CLAY with occasional gravels. As this hole was dug on the lowest portion of the landholding, this unit seems to suggests the ingress of groundwater to that level (2.1 m bgl) during the wettest times of the year.

Groundwater was not met in four of the trial pits, numbers 4, 5, 6 and 8, in the southeasternmost portion of the proposed burial ground site. As stated above, trial hole 4 showed mottled material throughout it's basal profile area, suggesting intermittent waterlogging in this locality.

None of the other trial holes met seepages or water table, and were dry throughout.

Bedrock was not met in any of the pits dug in the proposed burial ground, at up to 3.15 m below ground level. As the depth to bedrock under the site is expected to be at least 10 m (section 2.4) this means that encountering bedrock will not be an issue on the site.

The subsoil under the site is therefore dominated by a unit of very silty sandy GRAVEL with occasional cobbles.

3.3 Permeability of subsoil sediments under the site

The permeability of subsoil is largely a function of (a) the grain size distribution, (b) the amount (and sometimes type) of clay size particles present, and (c) how the grains are packed together. It can also be influenced by other factors such as discontinuities (fissures/cracks, plant roots, pores formed by soil fauna, isolated higher permeability beds or lenses, voids created by weathering of limestone clasts) and density/compactness of the deposit.

In poorly sorted sediments such as glacial tills, these characteristics describe the engineering behaviour of the materials as detailed in the subsoil description and classification method derived from BS 5930:1999 (Swartz, 1999). This method is used to assess the subsoil permeability at each trial pit, and is combined with recharge and drainage observations in the surrounding area for a regional, three-dimensional classification. Each approach used in assessing the permeability is discussed briefly here. Some are described in more detail in the research theses of Lee (1999) and Swartz (1999):

> ***Subsoil Description and Classification Method*** *(derived from BS 5930:1999).* Using this method, subsoils described as gravelly CLAY or CLAY has been shown to behave as low permeability materials. Subsoils classed as sandy SILT and gravelly sandy SILT, on the other hand, are found to have a moderate permeability (Swartz, 1999).
> ***Particle Size Analyses****.* The particle size distribution of sediments describes the relationships between the different grain sizes present. Well-sorted sediments such as water-lain gravels (high permeability, such as under the site at Loganstown) or lacustrine clays (low permeability) will, on analysis, show a predominance of grain sizes at just one end of the scale. Glacial tills, on the other hand, are more variable and tend to have similar proportions of all grain sizes. Despite their

complexity, evaluations of the grain size analyses for a range of tills in Ireland have established the following relationships (Swartz, 1999):

i. Samples described as 'moderate permeability', based on observations of recharge indicators (vegetation, drainage density); typically have less than 35% fines (silt plus clay).
ii. These 'moderate permeability' samples also tend to have less than 12% clay.
iii. Samples described as 'low permeability' frequently have more than 50% fines.
iv. These 'low permeability' samples also tend to have more than 14% clay.
v. 'High permeability' sand/gravel deposits tend to be sorted and have less than 7.5% fines (O Suilleabhain, 2000).

Quantitative Analysis. From a limited number of national field permeability measurements, the boundary between moderate and low permeability is estimated as about 10^{-8}-10^{-9} m/s. While the moderate to high boundary has not yet been examined in detail, one study suggests this boundary may be in the region of 10^{-4} m/s (O'Suilleabhain, 2000). However, permeability measurements are highly scale dependent: laboratory values are often up to two orders of magnitude lower than field measurements, which in turn tend to be lower than regional assessments based on large scale pumping tests. Thus, for regional permeability mapping, qualitative assessments of the recharge characteristics and engineering behaviour of the subsoils are more appropriate than specific permeability measurements.

None of these methods can be used in isolation: a holistic approach is necessary to gain an overall assessment of each site and thereby build up a three-dimensional picture of the permeability. In a given area, as many factors as possible are considered together in order to obtain a balanced, defensible permeability decision.

The observations of the majority of the material within the trial pits across the site as being 'well drained', the unsorted and fine to coarse grained nature of the sediments, the BS 5930 descriptions and the lack of mottling in the major subsoil units in almost all profiles would definitively place the sediments under the site within the 'high' permeability class.

3.4 Conceptual model of the site

The desk study, walkover survey and intrusive trial pitting programme allow the following conceptual model for the site to be drawn up.

- The bedrock under the site is expected to be over 10 m deep from ground surface, and is proven to be >3.15 m in portions of the site, and >2.85 m over the entire site.
- This bedrock is of greywackes, sandstones and siltstones, which comprise a poor aquifer.
- The locality has a 'high' groundwater vulnerability rating, owing to the depth and permeability of the subsoil and the general presence of the water table at a depth greater than 3 m.
- Recharge in the area (the amount of rainfall seeping through the soil and subsoil to groundwater in the bedrock aquifer) is expected to be approximately 100 mm per year, owing more to the

limited recharge acceptance properties of the bedrock aquifer under the site, than to the 'high' permeability of the sands and gravels subsoils.

- Groundwater flow under the site is towards the southeast, downslope and 'through' the burial ground.
- This groundwater is at a relatively deep depth under the site, and was only met in four of the eight trial holes excavated, in the southeastern extreme of the site (and is therefore at least 2.1 m – 2.53m from surface at all times in this portion of the site).
- The soil under the site is hosted at the top of a well drained, unmottled, very silty sandy GRAVEL unit of subsoil, which has occasional cobbles within, and dominates the subsoil across the site to 3.2 m+ depth.
- Analysis of the dominant subsoil unit under the site (as per BS 5930: 1999) would suggest that it is of 'high' permeability status, meaning that infiltration is generally rapid and the subsoil material across the majority of the site remains unsaturated throughout the year.

3.5 Discussion.

The trial pitting on-site proves that the subsoil under the site is variable in its internal geometry with a dominant, unmottled and unsaturated GRAVEL-dominated layer interspersed with unmottled and unsaturated SAND-dominated pods and beds. Some mottled material occurs at depth in the southeastern corner of the site.

The general characteristics around the site at Gormanston Townland, Stamullen are as follows:

- The land use in the area is of arable crops, and wetland indicators such as rushes and willow are absent on and around the low terrace hosting the site. This suggests high to moderate permeability subsoil.
- The artificial drainage density around the site is low, with no observed field drains within 250 m, and no deep ditches around the site. This also suggests generally high to moderate permeability.
- The natural drainage density around the site is also low (<1 km per km^2), also suggesting high to moderate permeability.

With the topsoil encountered in the trial pits on the site:

- The topsoil units on the site, in the uppermost 0.31 m-0.52 m, are well drained and unmottled, suggesting high to moderate permeability.

The major subsoil unit under the site, within which burials would take place:

- Results in a BS 5930 description of very silty sandy GRAVEL with occasional cobbles, which would suggest a high permeability and ready infiltration;
- Generally has a colour of dark brown, which is unmottled and which also suggests high to moderate permeability.
- Has pods and beds of unmottled, unsaturated SAND-dominated material within, which would suggest localised pockets of high permeability.

Given the overall unmottled and GRAVEL-dominated characteristics of the major subsoil unit, and the absence of infiltrating water in the uppermost 2.4 m of subsoil across the majority of the area of the site, it is considered that the locality is suitable for burials.

As a precautionary measure and in order to ensure no groundwater contamination under the site, no burials should take place at a depth below 2.05 m below current ground level across the entirety of the site. This will maintain at least 0.9 m depth of unsaturated subsoil between all burials and the water table.

In the southeasternmost portion of the site, where groundwater was met at depths between 2.4 m and 2.95 m below current ground level, and as mottling was observed in one trial hole at 2.1 m below ground level, no burials should take place here at depths below 1.2 m below ground level. In this area, ideally, approximately 0.9 m depth suitable soil and subsoil should be imported across the site, to level it, and to ensure that sufficient depth to water table is maintained beneath burials across the entire site.

4.0 CONCLUSIONS AND RECOMMENDATIONS

- The soil under the site is well drained.
- The soil under the site is hosted at the top of a well drained, unmottled, very silty sandy GRAVEL unit of subsoil, with occasional cobbles, which dominates the subsoil across the site to 3.15 m+ depth.
- The bedrock under the site is expected to be over 10 m deep, and is proven to be at a depth >3.0 m across the majority of the site, and >2.85 m over the entire site.
- This bedrock at depth is of greywacke, siltstone and / or sandstone, which is a poor aquifer.
- The locality has a high groundwater vulnerability rating, owing to the depth and permeability of the subsoil, as well as the depth of the water table.
- Groundwater flow under the site is towards the southeast, downslope 'through' the burial ground.
- This groundwater is at a relatively deep depth under the site, proven to be >2.85 m across the majority of the site, and >2.1 m over the entire site.
- Recharge in the area (the amount of rainfall seeping through the soil and subsoil to groundwater in the bedrock aquifer) is expected to be approximately 100 mm per year.

- **Given the overall unmottled and GRAVEL-dominated characteristics of the major subsoil unit, and the absence of infilltrating water in the uppermost 3.0 m of subsoil across the majority of the area of the site, it is considered that the locality is suitable for burials, especially given the well drained nature of the surrounding land and the general absence of drains adjacent to the site.**
- **As a precautionary measure and in order to ensure no groundwater contamination under the site, no burials should take place at a depth below 2.05 m below current ground level across the entirety of the site. This will maintain at least 0.9 m depth of unsaturated subsoil between all burials and the water table.**
- **In the southeasternmost portion of the site, where groundwater was met at depths between 2.4 m and 2.95 m below current ground level, and as mottling was observed in one trial hole at 2.1 m below ground level, no burials should take place here at depths below 1.2 m below ground level. In this area, ideally, approximately 0.9 m depth suitable soil and subsoil should be imported across the site, to level it, and to ensure that sufficient depth to water table is maintained beneath burials across the entire site.**

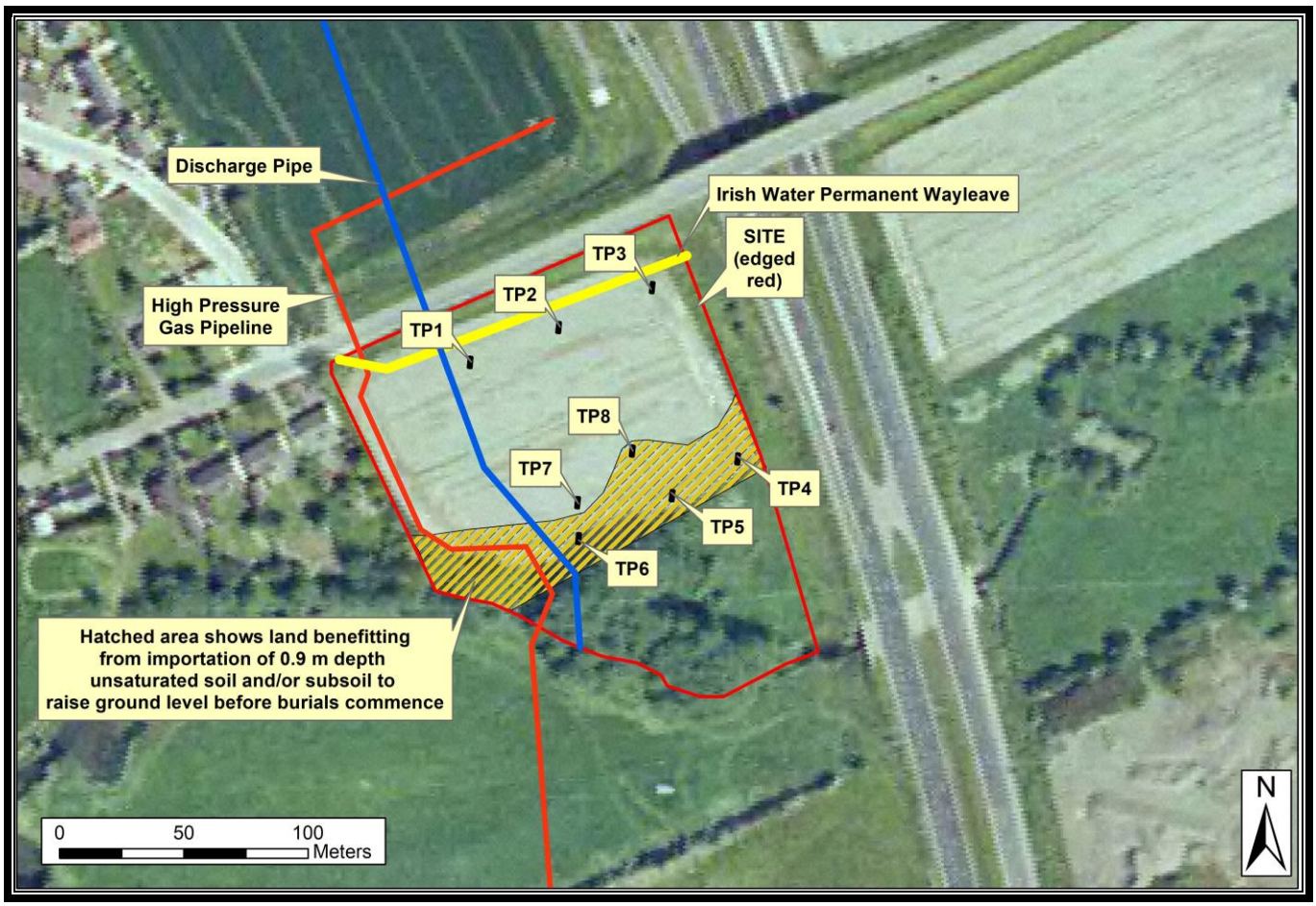


Figure 8: Plot showing the are across the site where no burials can currently take place below 1.5m below ground level, and where the importation of 0.6 m depth suitable soil and/or subsoil would be required in order to bury at depths up to 2.05 m depth.

NOTES:

Neither the whole nor any part of this report or any reference thereto may be included in any document, circular or submission, without our prior written consent as to the form and context in which it appears. This report is for the use solely of the party to whom it is addressed and no responsibility is accepted to any third party.

All information supplied by the Client, the Client's staff and professional advisers, local authorities, other statutory bodies, investigation agencies and other stated sources is accepted as being correct unless otherwise specified.

This report is not a design specification for surface water or foul water drainage systems and as such should not be used as one.

All data and methods of analysis presented are, to the best of my knowledge, valid at the time of report generation.

Areas presented, off site distances and elevations are sometimes computed from Ordnance Survey maps and not from physical surveys. They are approximate unless otherwise stated.

REFERENCES

Ball, D., 1998. Assessment of the Proposed Burial Site at Killeen near Tower, County Cork. Report for Cork County Council Sanitary Services Division, 7pp.

British Standards, BS5930, 1999. Code of Practice for Site Investigations.

Clark, C. and Meehan, R., 2001. Subglacial bedform geomorphology of the Irish Ice Sheet reveals major configuration changes during growth and decay. Journal of Quaternary Science. Volume 16, Issue 5. 483-496.

Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland, 1999 Groundwater Protection Schemes;

Department of the Environment, Heritage and Local Government, 2005. European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005 (S.I. No. 788 of 2005).

Drinking Water Regulations (SI 439 2000) . Irish Government Supplies Agency. 25pp.

Environment Agency, 2002. Groundwater impact of Danescourt Cemetery, Wolverhampton. National Groundwater and Contaminated Land Centre, 40pp. Environment Agency, Solihull, U.K.

Environment Agency, 2004. Assessing the Groundwater Pollution Potential of Cemetery Developments. 20pp. Environment Agency, Bristol, U.K.

Environmental Protection Agency, 2002. Guidelines on the Information to be contained in Environmental Information Statements;

Environmental Protection Agency, 2002. Water Quality in Ireland 1998-2000.

Environmental Protection Agency, 2021. Code of Practice: Domestic Waste Water Treatment Systems (Population Equivalent ≤10).

Fetter, C.W., 2001. Applied Hydrogeology 4th ed. Prentice-Hall Inc, Upper Saddle River, New Jersey 07458.

Finch, T., Gardiner, M., Comey, F. and Radford, T., 1983. Soils of County Meath. An Foras Taluintais, Dublin.

Gardiner, M. and Radford, T., 1980. Soil associations of Ireland and their land-use potential. Explanatory Bulletin to Soil Map of Ireland. An Foras Taluintais, Dublin.

Geological Survey Ireland (2021). Online Groundwater Data Viewer, www.gsi.ie

Geological Survey of Ireland & Eastern River Basin District, 2005. Duleek Groundwater Body Summary of Initial Characterisation, 8pp.

Lee, M., 1999. Surface indicators and land use as secondary indicators of groundwater recharge and vulnerability. Unpublished (Research) MSc thesis. Department of Civil, Structural and Environmental Engineering, Trinity College Dublin.

McConnell, B., Philcox, M. and Geraghty, M. 2001. Geology of Meath: A geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 13, Meath. *With contributions from J. Morris, W. Cox, G. Wright and R. Meehan.* Geological Survey of Ireland, 78pp.

Meehan, R., 1998. The last glaciation and deglaciation of northwest Meath and adjacent parts of Westmeath and Cavan. Unpublished PhD Thesis, National University of Ireland.

Meehan, R., 2008. Report detailing Site Characterisation and Risk Assessment for a proposed Cemetery Extension at Dalgan Park, Dowdstown, Navan, County Meath. Report for Columban Fathers as part of a Planning Application to Meath County Council, 28pp.

Meehan, R., 2012. The Making of Meath. Meath County Council, 96pp.

Minerex 1983. *The hydrogeology of Co. Meath. A Preliminary Assessment of Groundwater Potential.* Report to Meath County Council.

Ó Súilleabháin, C., 2000. Assessing the Boundary between High and Moderately Permeable Subsoils. Unpublished M.Sc. thesis, Trinity College Dublin.

Swartz, M., 1999. Assessing the Permeability of Irish Subsoils. Unpublished (Research) MSc thesis. Department of Civil, Structural, and Environmental Engineering, Trinity College Dublin.

Teagasc, 2006a. Digital soil map of County Meath. Prepared as part of the EPA Soil and Subsoil Mapping Project, Teagasc, Kinsealy, Dublin.

Teagasc, 2006b. Digital subsoil map of County Meath. Prepared as part of the EPA Soil and Subsoil Mapping Project, Teagasc, Kinsealy, Dublin.

Trick, J. and Klinck, B., 2002. Grave concerns: health risks from human burials. British Geological Survey Chemical Incident Report, October 2002, p. 18.

Woods, L., Meehan, R.T. and Wright, G., 1998. County Meath Groundwater Protection Scheme. Geological Survey of Ireland, March 1998. 54pp.

Appendix A
Trial pit logs

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP1

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

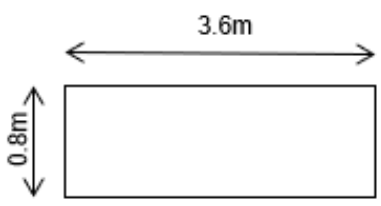
Logged by: R. Meehan Date: 07/09/2021

Easting: 315583 Northing: 266304

Ground level OD: 25.0m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.16-0.21					24.8			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.41-0.47					24.6			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								
1.0								
1.5								'C' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
2.0								Pods of clayey SAND up to 0.2m thick and 0.4m long.
2.5								
2.95					22.05			**Trial pit completed at 2.95m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.0								
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 12° (N-S)

Stability :

Trial pit walls underconsolidated, and some collapse in side walls following excavation.

General remarks :

Dug in northwestern portion of the proposed burial ground site, into a dry locality, at one of the highest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Dry.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 2.95m+ depth.
No bedrock.

Plate A1: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.95m depth, in trial hole TP1. See the absence of the water table and bedrock at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP2

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

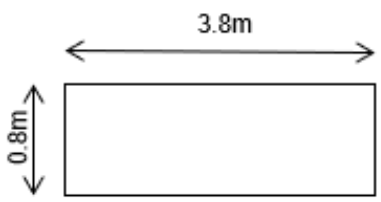
Logged by: R. Meehan Date: 07/09/2021

Easting: 315617 Northing: 266317

Ground level OD: 24.5m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.14-0.2					24.3			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.38-0.42								TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5					24.1			
1.0								'C' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.5								Pods of clayey SAND up to 0.1m thick and 0.5m long.
2.0								
2.5								
3.0					21.5			**Trial pit completed at 3.0m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 16° (N-S)

Stability :

Trial pit walls underconsolidated, and much collapse in side walls following excavation.

General remarks :

Dug in north central portion of the proposed burial ground site, into a dry locality, at one of the highest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Dry.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 3.0m+ depth.
No bedrock.

Plate A2: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 3.0m depth, in trial hole TP2. See the absence of the water table and bedrock at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP3

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

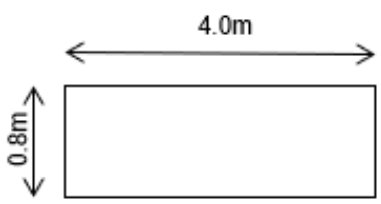
Logged by: R. Meehan Date: 07/09/2021

Easting: 315656 Northing: 266334

Ground level OD: 23.5m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.14-0.22					23.3			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.42-0.51					23.0			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								
1.0								
1.5								'C' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
2.0								
2.5								
2.95					20.55			**Trial pit completed at 2.95m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.0								
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 6 (N-S)

Stability :

Trial pit walls underconsolidated, and some collapse in side walls following excavation.

General remarks :

Dug in northeastern portion of the proposed burial ground site, into a dry locality, at one of the highest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Dry.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 2.95m+ depth.
No bedrock.

Plate A3: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.95m depth, in trial hole TP3. See the absence of the water table and bedrock at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP4

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

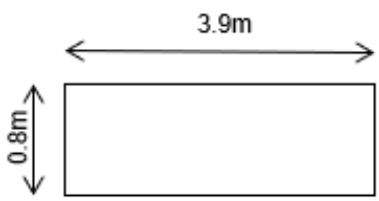
Logged by: R. Meehan Date: 07/09/2021

Easting: 315689 Northing: 266264

Ground level OD: 20.5m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.16-0.21					20.3			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.41-0.47					20.1			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								'C_1' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.0								Pods of clayey SAND up to 0.2m thick and 0.4m long.
1.5								
2.0								
2.1-2.53								'C_2g' horizon (SUBSOIL): very soft, massive, yet fissile, mottled very dark bluish grey (6/1, GLEY 2) and yellowish brown (5/6, 10YR), very sandy CLAY with occasional gravels.
2.5								
3.0								
3.1					17.4			**Trial pit completed at 3.1m on mottled very dark bluish grey and yellowish brown, massive, yet fissile, very soft, very sandy CLAY with occasional gravels (glacial TILL subsoil).**
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 352° (N-S)

Stability :

Trial pit walls underconsolidated, and some collapse in side walls following excavation.

General remarks :

Dug in southeastern portion of the proposed burial ground site, into a dry locality, at one of the lowest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Groundwater met at 3.0m depth, and rises steadily to 2.7m bgl after 2 hrs.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 3.1m+ depth.
No bedrock.

Plate A4: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.1m-2.53m depth, in trial hole TP4. See the presence of the water table at 2.7m depth at the base of the hole, in a unit of mottled till subsoil.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP5

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

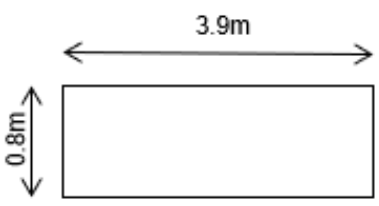
Logged by: R. Meehan Date: 07/09/2021

Easting: 315664 Northing: 266249

Ground level OD: 20.5m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.13-0.2					20.3			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.4-0.44								TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5					20.1			
1.0								'C_1' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.5								Pods of SAND up to 0.1m thick and 0.6m long.
2.0								
2.5								
3.0								
3.15					17.35			**Trial pit completed at 3.15m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 86° (W-E)

Stability :

Trial pit walls consolidated, and little collapse in side walls following excavation.

General remarks :

Dug in southern portion of the proposed burial ground site, into a dry locality, at one of the lowest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Groundwater met at 3.1m depth, and rises steadily to 2.95m bgl after 2 hrs.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 3.15m+ depth.
No bedrock.

Plate A5: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 3.15m depth, in trial hole TP5. See the presence of the water table at 2.95m depth at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP6

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

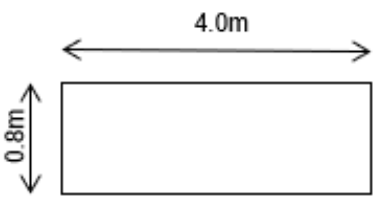
Logged by: R. Meehan Date: 07/09/2021

Easting: 315627 Northing: 266231

Ground level OD: 21.0m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.11-0.19					20.8			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.42-0.48					20.6			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								'C_1' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.0								Pods of SAND and sandy GRAVEL up to 0.2m thick and 0.9m long.
1.5								
2.0								
2.5								
2.85					18.15			**Trial pit completed at 2.85m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.0								
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 82° (W-E)

Stability :

Trial pit walls consolidated, and little collapse in side walls following excavation.

General remarks :

Dug in southwestern portion of the proposed burial ground site, into a dry locality, at one of the lowest points in the landholding. Dug on a 1° slope, falling southeastwards.

Groundwater :

Groundwater met at 2.8m depth, and rises steadily to 2.6m bgl after 2 hrs.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 2.85m+ depth.
No bedrock.

Plate A6: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.85m depth, in trial hole TP6. See the presence of the water table at 2.6m depth at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP7

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

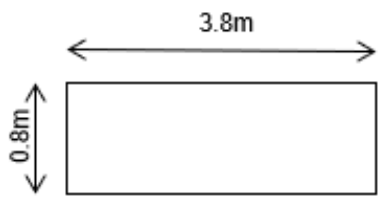
Logged by: R. Meehan Date: 07/09/2021

Easting: 315625 Northing: 266247

Ground level OD: 21.5m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.12-0.18					21.3			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.4-0.49					21.1			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								'C_1' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.0								Pods of SAND and sandy GRAVEL up to 0.3m thick and 1.4m long.
1.5								
2.0								
2.5								
2.85					18.65			**Trial pit completed at 2.85m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.0								
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 352° (N-S)

Stability :

Trial pit walls consolidated, and little collapse in side walls following excavation.

General remarks :

Dug in south central portion of the proposed burial ground site, into a dry locality, at the lower end of the terrace top. Dug on a 1° slope, falling southeastwards.

Groundwater :

Dry.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 2.85m+ depth.
No bedrock.

Plate A7: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.85m depth, in trial hole TP7. See the absence of the water table and bedrock at the base of the hole.

Robert Meehan
Consultant Geologist

TRIAL PIT RECORD TP8

Project: Hydrogeology of proposed cemetery at Gormanston

Site: Gormanston
Client: Meath County Council
Project No.: 29/033

All dimensions on this sheet are in metres unless otherwise stated

Method and Equipment:: JCB Hydradig 110W Excavator

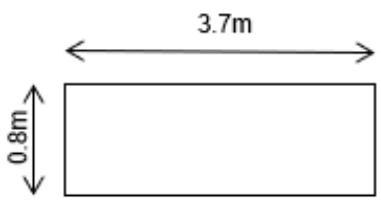
Logged by: R. Meehan Date: 07/09/2021

Easting: 315647 Northing: 266265

Ground level OD: 22.0m

Samples & in-situ tests			Result Peak (Residual)	Water	Strata details			
Depth taken	Type	No			O.D. Level	Legend	Depth	Description
0.11-0.19					21.8			TOPSOIL 'A' horizon: compact, crumb, dark brown (3/3, 10YR) sandy loam with abundant gravels and occasional wheat roots and rootlets.
0.42-0.48					21.6			TOPSOIL/SUBSOIL 'B' horizon: soft to firm, subangular blocky, dark brown (3/3 10YR), sandy SILT with occasional gravels and occasional grass rootlets.
0.5								'C_1' horizon (SUBSOIL): very soft, massive, yet fissile, dark brown (3/3, 10YR), very silty sandy GRAVEL with occasional cobbles.
1.0								Pods of SAND and sandy GRAVEL up to 0.2m thick and 0.9m long.
1.5								
2.0								
2.5								
2.65					19.35			**Trial pit completed at 2.65m on dark brown, massive, yet fissile, very soft, very silty sandy GRAVEL with occasional cobbles (glaciofluvial SANDS and GRAVELS subsoil).**
3.0								
3.5								
4.0								
4.5								
5.0								

Plan



Bearing : 352° (N-S)

Stability :

Trial pit walls consolidated, and little collapse in side walls following excavation.

General remarks :

Dug in central portion of the proposed burial ground site, into a dry locality, at at the lower end of the terrace top. Dug on a 1° slope, falling southeastwards.

Groundwater :

Groundwater met at 2.6m depth, and rises steadily to 2.4m bgl after 2 hrs.

Sequence summary:
Well drained topsoil over a highly permeable subsoil to 2.65m+ depth.
No bedrock.

Plate A8: Profile of well drained topsoil overlying unmottled very silty sandy GRAVEL with occasional cobbles to 2.65m depth, in trial hole TP8. See the presence of the water table at 2.4m depth at the base of the hole.

Appendix B
Methodology for Burial Ground Risk Assessment

In Ireland, there has been little attention given to the risk assessment of cemeteries. A preliminary study was conducted for Cork County Council in 1998 by David Ball, Consultant Hydrogeologist, for a proposed burial ground development at Killeen in County Cork, which gives an excellent basis for risk assessment under Irish conditions and was referred to in this current study. As well as this, the author has prepared a risk assessment for a proposed cemetery extension at Dalgan Park, Navan, County Meath (Meehan, 2008), the existing cemetery at Robinrath, Navan (January 2009), a proposed cemetery extension at Rush, Dunboyne (December 2013), and a proposed new cemetery at Loganstown, Trim (August 2021). In order to outline a complete risk assessment framework, consultation with documents from Britain was also required.

The Environment Agency Guidance Document (2004) provides much of the material required to structure a risk assessment under Irish conditions. A three-tiered approach to assessing the risk from cemeteries is recommended. Each tier of the risk assessment involves the same series of stages, namely:

- hazard identification;
- identification of consequences;
- magnitude of consequences;
- probability of consequences;
- significance of risk.

The three tiers are the risk screening tier (desk study), the preliminary quantitative risk assessment tier (detailed desk study and preliminary site investigation), and a detailed quantitative risk assessment. Sites are ranked as having low, intermediate (moderate) or high risk. Only sites which comes up as intermediate risk or higher in tier 1 qualify for tiers 2 and 3, and only those sites considered high/uncertain risk in tier 2 qualify for tier 3 assessment.

It is notable that these recommendations do not take into account the flow direction of groundwater. Risk assessments in Ireland, for example that for On-Site Wastewater Treatment Systems and for Landfills, use the Source-Pathway-Receptor Model for Risk Assessment, which always takes into account groundwater flow direction. This means a more knowledge-based (and, eventually, less restrictive) approach to the screening of sites at risk. From this, a combination of the relevant portions of the Environment Agency report, as well as utilising some of the methodology of Irish Site Characterisation and Assessment, were used in this study at Gormanston Townland, Stamullen. The three-tier assessment procedure was employed, involving desk study, site characterisation and risk quantitative assessment, and buffers were considered using an assessment of groundwater flow direction as for assessments for installations such as On-Site Wastewater Treatment Systems and Landfills.

Appendix C
Quantification of contaminant loading in proposed burial ground at Gormanston Townland, Stamullen

Data are supplied by the British Environment Agency in their Guidance Document (2004) on the composition rate of corpses and potential pollution releases, reproduced in Table 1.

Composition	*Percentage Weight*
Water	64
Protein	20
Carbohydrate	1
Mineral salts	5
Fat	10
Elemental Component	*Mass (g)*
Oxygen	43000
Carbon	16000
Hydrogen	7000
Nitrogen	1800
Calcium	1100
Phosphorous	500
Sulphur	140
Potassium	140
Sodium	100
Chlorine	95
Magnesium	19
Iron	4.2
Copper	0.07
Lead	0.12
Cadmium	0.05
Nickel	0.01
Uranium	0.00009
Total body mass	**70000**

Table 1: Composition and elemental components of an average human body (70kg).

These pollutants derived from bodies are found as dissolved and gaseous organic compounds and dissolved nitrogenous forms (particularly ammoniacal nitrogen).

When examining bodies in terms of their rate of degradation, it is seen that 60% of the material is readily degradable, 15% is moderately degradable, 20% is slowly degradable and 5% is non-degradable. Those proportions that are non-degradable, as well as much that is slowly degradable, may be considered inert (ashes forming final stable residue, and bones).

The primary process governing the production, release and potential migration of pollutants from a buried corpse is microbial decay. The rate of decay depends on the extent of microbial growth and activity, which is in turn affected by the availability of nutrients and moisture, climate, soil lithology and burial practice. Therefore, in Irelands' wet, temperate climate, the vast majority of the mass of a human body is readily degradable, given that a well drained, porous subsoil medium forms the receiving environment.

The die off of pathogens will occur naturally and will rapidly decrease in concentration with increasing distance from the grave.

A human corpse normally decays within 10 to 12 years. It is estimated that over half of the pollutant load leaches within the first year and halves year on year (Environment Agency, 2004). Less that 0.1% of the original loading may remain after 10 years.

Year	*TOC*	*NH_4*	*Ca*	*Mg*	*Na*	*K*	*P*	*SO_4*	*Cl*	*Fe*
1	6.00	0.87	0.56	0.010	0.050	0.070	0.250	0.210	0.048	0.020
2	3.00	0.44	0.28	0.005	0.025	0.035	0.125	0.110	0.024	0.010
3	1.50	0.22	0.14	0.003	0.013	0.018	0.063	0.054	0.012	0.005
4	0.75	0.11	0.07	0.001	0.006	0.009	0.032	0.027	0.006	0.003
5	0.37	0.05	0.03	<0.001	0.003	0.004	0.016	0.012	0.003	0.001
6	0.19	0.03	0.02	<0.001	0.002	0.002	0.008	0.006	0.002	<0.001
7	0.10	0.01	0.01	<0.001	0.001	0.001	0.004	0.003	<0.001	<0.001
8	0.05	<0.01	<0.01	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001
9	0.02	<0.01	<0.01	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
10	0.01	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 2: Potential contaminant release (kg) from a single 70kg human burial.