C
D
S

Discover what's beneath

A Tier 1 Groundwater Risk Assessment Report for South Hinksey Parish Council

Address: Land off of St Laurence Road, South Hinksey, Vale of White Horse, Oxfordshire, OX1 5BA.

Date: 25th January 2021

The CDS Group, Building 51, Wrest Park, Silsoe, Bedfordshire, MK45 4HS
W: www.thecdsgroup.co.uk
T: 01525 864387



Contents

Figures

Tables

Executive Summary

The subject site comprises a parcel of open land off of St Laurence Road, it currently features footpaths as part of the proposed development of the site as a cemetery. The site is considered to be a low to moderate risk considering the desktop review of geological and hydrogeological parameters and current burial number of 3 per annum at the adjacent existing civil cemetery. The risk is mainly attributed to the absence of superficial deposits, proximity of a drain/watercourse to the south east and likelihood of encountering land drains on site. It should be noted that if the burial numbers were to increase from the current level of 3 per annum to 5 per annum, the risk would be classed as moderate. However even if the burial numbers were to increase significantly to 10 per annum, the risk would still be classed as moderate.

The site is mapped on slowly permeable Denchworth soils and is directly underlain by Oxford Clay Formation and West Walton Formation (undifferentiated). The bedrock geology and overall groundwater vulnerability is designated as unproductive strata. The site is not situated within a groundwater source protection zone. The nearest watercourse to the site is a stream/ditch approximately 25m south east of the site, in a field across the other side of St Laurence Road.

Burials are likely to be interred into weathered, clay dominated soils of the bedrock geology. Such soils are perceived to be a good substrate for burials due to the ability for pollutants to be partially mitigated by adsorption via cation exchange. There is the potential for isolated pockets of perched water to be present where less consolidated material is underlain by more consolidated material associated with the weathering profile, however, if found, any water is likely to be in limited quantity and hydraulically isolated.

If the soils on site reflect the mapped geology, the site will be considered suitable for full depth burials and would meet all statutory requirements set out for the locating of a burial ground and for a burial to take place.

However, an intrusive investigation in the form of excavating trial pits or boreholes is considered to be required to clarify the soil characteristics on site. There is a risk that the site is underlain (wholly or at least partly) by Northmoor Sand and Gravel Member deposits given they are mapped immediately off site to the north east. Due to the granular nature of the deposits, there is a risk of encountering shallow perched groundwater at the boundary between the sand and gravel and underlying bedrock.

A survey of the drain/watercourse to the south east should also be undertaken to clarify whether a 10m or 30m non burial buffer is required.

Finally, it is recommended that a shallow surface water drainage scheme is incorporated in the design of the site as the heavy clay soils will be liable to surface waterlogging both seasonally and following periods of prolonged heavy rainfall.

1 Introduction and Site Location

The CDS Group have been asked to carry out a Tier 1 site screening assessment for South Hinksey Parish Council's new parish cemetery. This site will be considered on the basis of groundwater risk and as part of this, a T1 study based on the criteria required by the Environment Agency has been carried out. This is because sites that do not meet the requirements of the Environment Agency should be ruled out at an early stage since the Agency as Primary Consultees are able to prevent any site being developed should the site be deemed to represent too great a risk in respect to water pollution.

The proposed development area has been assessed on a 1km area of influence: grid reference SP 50946 03928, and the nearest postcode is OX1 5BA. The site is calculated as being approximately 0.2 ha.

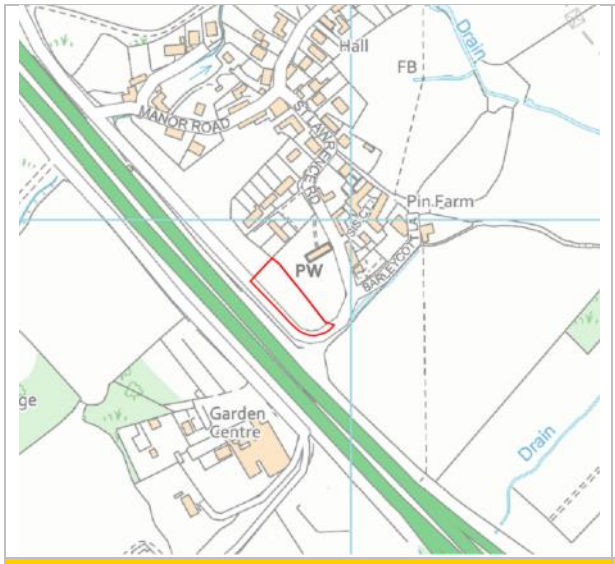

Figure 1. OS map of the site (boundary indicated in red)

Figure 2. Aerial Image of the site (boundary indicated in red)

This report will review the site proposed for use as a burial facility in accordance with the requirements of the Environment Agency's Tier 1 survey. For the purposes of this study, the anticipated burial rate for this site is estimated as being 3 per year. This is based on records provided by our client at the adjacent existing civil cemetery for the previous four years.

2 Background

This section sets out the relevant legal and policy advice relevant to the grant of planning permission for new and also the operation of existing cemeteries. New cemetery developments or extensions to existing cemeteries can be very emotive. However, these concerns are often disproportionate to the actual environmental risk.

Whilst the Local Planning Authority is the principal controlling body in determining approval for new sites or site extensions, significant information is required to ensure that the environmental risks are examined and that the Environment Agency's views are considered. Therefore, measures to prevent pollution must be undertaken and reported. Any regulatory decision-making is based on sound

scientific knowledge. On this basis, a review of potential pollution from cemeteries was undertaken by the Environment Agency in collaboration with the British Geological Survey.

The aim was to review old and new cemeteries and measure the effects of contamination from viruses, bacteria and other microbiological pathogens and to assess the potential of chemical contaminants affecting groundwater supplies from decomposition processes. Preliminary results showed that the operating cemetery examined in the study (25 years old) did show some evidence of bacterial contaminants in groundwater derived from corpses. However, no viruses were detected and the overall contaminant loading was found to be low. The studies found that degradation and attenuation was occurring indicating that potential risks were low. Whilst the outcome of this research found contaminant risk to be low, it should be reviewed in the context that natural attenuation processes may have been optimum at these sites. Therefore, to optimise natural attenuation and reduce the risk of possible groundwater contamination, a series of guidelines have been drawn up that are directly applicable to cemeteries.

The most up-to-date guidance issued by the Environment Agency is provided in:

- 'The Environment Agency's approach to groundwater protection' (February 2018 Version 1.2), which updated 'Groundwater protection: Principles and practice (GP3) (2013)'; and
- 'Cemeteries and burials: prevent groundwater pollution' which was published in March 2017 and updated in February 2018. The purpose of the guidance is to help those operating cemeteries to understand how to manage cemeteries and burial of human and animal remains, to prevent or limit groundwater pollution.

Failure to manage and reduce any environmental risk to a minimum may result in action being taken under the Environmental Permitting (England and Wales) Regulations 2016, the Water Resources Act 1991 and the Anti-pollution Works Notice Regulations 1999.

2.1 Groundwater Protection Policy

Initial risk screening starts with the tools contained in the 'The Environment Agency's approach to groundwater protection' (previously Principles and Practice for the groundwater protection), Section L: Cemetery developments GP3.

Tools include Groundwater Vulnerability and Source Protection Zone (SPZs) maps. These maps highlight where there are likely to be particular risks posed to groundwater from surface activities. Groundwater Vulnerability (GWV) Maps show the damage from pollution to groundwater and the relative importance of the aquifer to water supplies. Risk assessment is made with reference to soil leaching potential and the levels of water tables above major and minor aquifers.

Source Protection Zones are delineated areas around groundwater abstractions used for public consumption and defined by travel, time of biological or chemical contaminants.

The zones are classified in three groups:

Zone 1 High risk
Zone 2 Intermediate to high risk
Zone 3 Intermediate risk

In its Position Statement L1 (p109 of 'The Environment Agency's approach to groundwater protection') the Agency advises that it will object to the grant of planning permission for any new cemetery, or the

extension of an existing cemetery, within Zone 1 of an SPZ or 250 metres from a well, borehole or spring used to supply water that is used for human consumption, whichever is the greater distance.
Position Statement L3 advises on the protection of groundwater in highly sensitive locations. The Agency advises that it will apply a risk-based approach to assessing the suitability of sites outside of the zones noted in position statements L1 and L2 (concerning mass casualty emergencies). It will place a high priority on protecting groundwater within principal aquifers and groundwater catchments for drinking water supply; and seek to avoid new cemetery developments for greater than 100 graves in these high vulnerability areas except where the thickness and nature of the unsaturated zone, or the impermeable formations beneath the site protect groundwater, or the long-term risk is mitigated by appropriate engineering methods. It advises that all cemetery developments and burials must maintain an unsaturated zone below the level of the base of the grave(s) and that the Agency will work with the local authorities to identify alternative options where necessary.
Whilst groundwater is a major part of policy concerns, other water point sources are also considered as requiring an evaluation of risk. These sources include surface water in the form of ditches, spring lines and surface run-off.

The factors influencing the risk of groundwater vulnerability include:

- Soil nature and type
  - Physical, mechanical and chemical properties
- Geomorphology
  - Depth to water table and or height above aquifers
  - Groundwater flow mechanisms
  - Aquifer type
- Abstractions
- SPZs
- Proximity to water courses, ditches and drains

Therefore, prior to any consent being given by the Environment Agency, an assessment of risk should be undertaken. The degree of assessment is measured through a series of stages namely:

- Hazard identification
- Identification of consequences
- Magnitude of consequences
- Probability of consequences
- Significance of risk

2.2 Tiered risk assessment

There are 3 Tiers of Risk assessment. The associated size and position of the site will in-part determine which Tier is appropriate**.**

<u>Tier 1</u>
Desktop study of all appropriate documentation including GWV and SPZ maps, topographical, hydrological and geomorphologic maps. After adopting a systematic approach to the assessment of risk, a weighting can be given which is assessed as low, medium or high. If the overall risk is low, the proposal may be accepted by the Agency without further detailed assessment. However, the following practical guidelines would be recommended as appropriate controls to minimise pollution risk:

- 250 m distance from groundwater supply
- 30 m minimum distance from a watercourse or spring

- 10 m distance from field drains
- No burials in standing water

Tier 2

Should the risks not be clearly defined by the Tier 1 desktop study then further "ground truthing" might need to be undertaken. This will include the excavation of trial pits or boreholes on site to assess the nature of the ground conditions on site and whether either perched water or groundwater is encountered.

On further assessment of the ground model the risk assessment for the site can be re-assessed which may indicate the requirement for a pollutant flux model to be carried out to assess the impact of the modelled pollutants on the underlying groundwater and nearest compliance point.

Tier 3

If the risk is considered high, i.e. the number of yearly burials exceeds 1,000; a full groundwater audit will be required. This would include, but not be limited to, a detailed site investigation including installation of a minimum number of three boreholes, back groundwater quality analysis and ongoing monthly monitoring and sampling.

2.3 Water Resources Act 1991 – S161A Anti-Pollution Works Notices

The EA has powers under s161A of the Water Resources Act 1991 and the Anti-Pollution Works Regulations 1999, allowing Works Notices to be served to require specified steps to be taken to prevent or remedy pollution of controlled waters.

2.4 Environmental Permitting (England & Wales) Regulations 2016

Burial of human corpses can result in discharge of hazardous substances and non-hazardous pollutants to groundwater. They are, therefore, covered by the requirements of the EU Groundwater Daughter Directive, issued under the Water Framework Directive 2006 and now transposed in England and Wales by the Environmental Permitting (England & Wales) Regulations 2016 (EPR 2016). It is an offence to cause or knowingly permit pollution of controlled waters other than under and in accordance with an environmental permit.

3 Site Assessment

Envirocheck, British Geological Survey and Cranfield University data was used in this report.

3.1 Historical Land Use

The freely available historical maps of the area identify the site as open undeveloped land on the earliest map dated 1875. The site is bound predominantly by further open land, except to the north where there is a small graveyard adjacent to St Laurence's Church and to the south and south east where roadway is present. By the 1922 map, a roadway is shown within former open land and now bounds the site to the west. The roadway creates a bypass to the west of the village of South Hinksey. The 1936-1939 map shows that the graveyard to the north has been extended further south, meaning the entire eastern boundary of the site is now bound by the graveyard. There are no further changes mapped on site or within the immediate vicinity upto the latest map of the area dated 1976-1981. The site remains to be open land bound by open land to the north, a cemetery to the east and roadways to the south and west.

3.2 Soil Type

According to the Soil Survey of England and Wales, the soils on site are mapped as belonging to the 712b Denchworth Association as described in Figure 3 and Table 1.

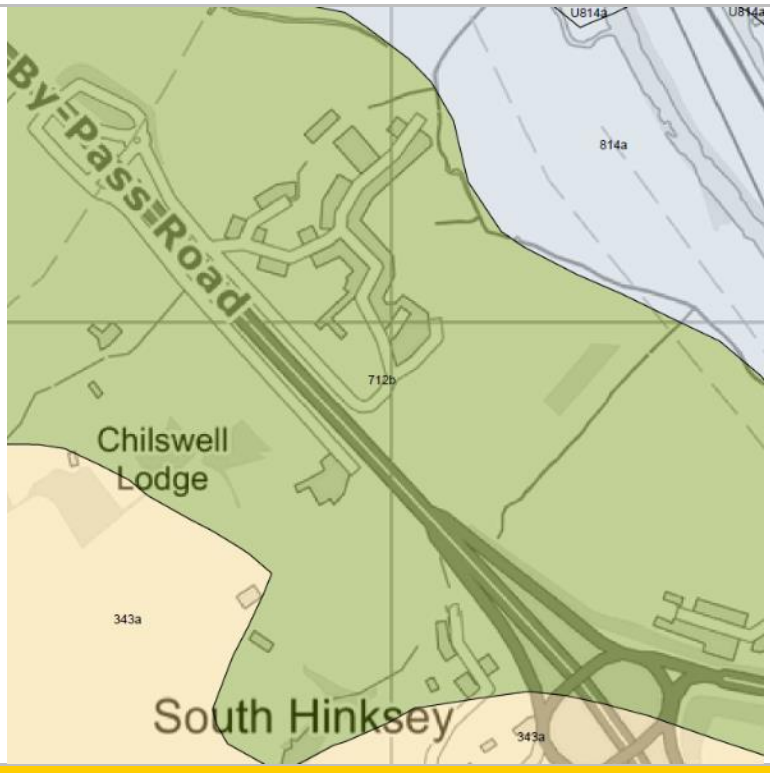

Figure 3. Soil Associations in the vicinity of the site.

Table 1. Soil Associations in the vicinity of the site

Soil Association	Sub Groups	Description
712b Denchworth	711 Wickham 712 Lawford 411 Evesham 572 Oxpasture	Slowly permeable seasonally waterlogged clayey soils with similar fine loamy over clayey soils. Some fine loamy over clayey soils with only slight seasonal waterlogging and some slowly permeable calcareous clayey soils. Landslips and associated irregular terrain locally.

Suitability for use as cemeteries:

The soils are generally considered suitable for use as cemeteries. Pollutants from burials will be partly mitigated due to the high cation exchange capacity of the clayey soils and ability for adsorption. That said, these soils are liable to surface waterlogging during the wetter winter months and following periods of heavy rainfall meaning standing water may be present in and around graves which the bereaved may find distressing. A surface water drainage scheme is likely to be required to manage surface water on site and reduce these issues.

3.3 Geology

The following headings cover the aspects of geology of the immediate area of the proposed development.

3.3.1 Artificial Ground

This is ground at or near the surface that has been modified by man. It includes ground that has been deposited (Made Ground), landscaped, disturbed, excavated (Worked Ground) or some combination of these.

As can be seen in Figure 4 below, there are no mapped artificial deposits on site. Made Ground is mapped within the vicinity which is likely associated with the construction of the Southern By-Pass during the 1920s.

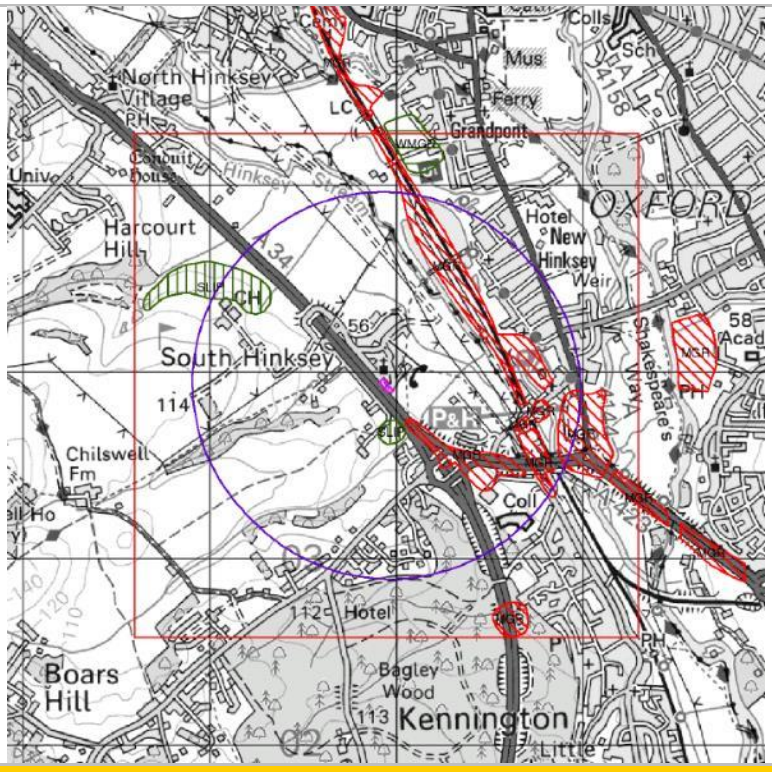

Figure 4. Artificial deposits within the vicinity of the site.

3.3.2 Superficial Deposits

These are relatively young geological deposits formerly known as 'Drift', which lie on the bedrock in many areas. They include deposits such as unconsolidated sands and gravels formed by rivers and clayey tills formed by glacial action. They may be overlain by landslide deposits, by artificial deposits or both (Figure 5).

There are no superficial deposits mapped as present on site. However, sands and gravels associated with the Northmoor Sand and Gravel Member (both upper and lower facets) border the site to the north east. It is therefore likely that such deposits could be present on the subject site.

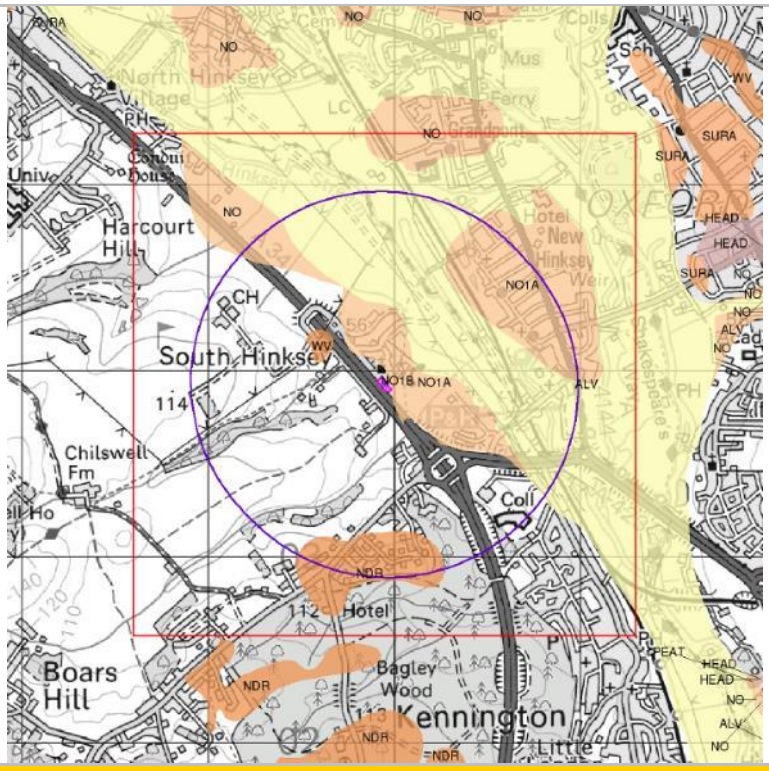

Figure 5. Superficial deposits within the vicinity of the site.

3.3.3 Rockhead Depth

Due to a mapped absence of superficial deposits, the underlying bedrock is expected to be encountered at depths below 0.5m bgl, following any topsoil and subsoil successions.

However, if sands and gravels associated with the Northmoor Member are encountered on site, then the depth to bedrock could be significantly deeper.

3.3.4 Bedrock Geology

Bedrock forms the ground underlying the whole of an area, commonly overlain by superficial deposits, landslide deposits or artificial deposits, in any combination.

As can be seen in Figure 6 below, Oxford Clay Formation and West Walton Formation (undifferentiated) forms the bedrock geology on site. This mudstone is likely to be weathered to clayey head soils at the surface.

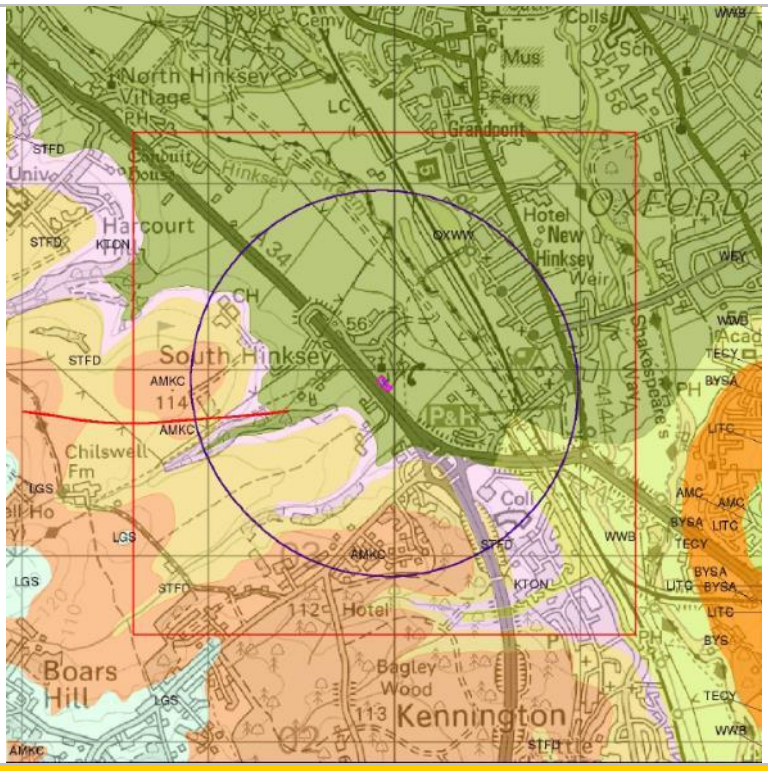

Figure 6. Bedrock Geology within the vicinity of the site.

3.4 Additional Geological Considerations

A summary of the potential geological hazards which could be found on site are explained in Table 2 below:

Table 2. Onsite Geological Hazards

Geological hazard	May be significant within site area (Yes/No)?	Comments
Potential Natural Ground Stability Hazards		
Shrink-Swell	Yes	Due to the presence of clayey Denchworth soils and underlying Oxford Clay/ West Walton bedrock which is likely to be weathered to clay at the surface, there is a perceived risk of shrink-swell on site.
Landslides (slope instability)	No	The site is generally flat and level and as such there is no significant risk associated with landslides. However, the Denchworth soils are liable to slip.
Soluble Rocks (dissolution)	No	The site is not situated on a geology which is susceptible to dissolution and as such there is no risk.
Compressible Ground	No	The site is not situated on a geology which is susceptible to compression and as such there is no risk.
Collapsible Deposits	No	The site is not situated on a geology which is susceptible to collapse and as such there is no risk.

Geological hazard	May be significant within site area (Yes/No)?	Comments
Running Sand	No	The site is not mapped to be situated on a geology which is susceptible to running sands. However, if the Northmoor Sand and Gravel Member deposits are encountered on site then there is a potential for running sands to be encountered.
Other Potential Hazards		
Mining	No	The site is not in an area at risk of mining. No historical evidence of mining was observed on site on the historical maps.
Flooding	No	The site is classed as Flood Zone 1 and is at low risk of flooding from rivers or sea and as such is suitable for use as a cemetery. However, land to the north east is classed as Flood Zone 3. The site is at a very low risk of pluvial (surface) flooding.
Natural Land Gas	No	Unlikely to encounter gas.
Radon	No	Level of protective measures: NO

3.5 Hydrogeology

In lowland areas of the UK with little topographic variation, groundwater is likely to be found at shallow depths of only a few metres. Water table fluctuations will be small as they will be constrained by the ground surface and the base level of the local perennial streams and rivers. In upland areas, precipitation is usually high and the dominantly metamorphic and igneous rocks often have relatively shallow groundwater levels.

This is due to preferential groundwater storage in near-surface weathered and fractured zones with limited drainage into the underlying un-weathered lower permeability rock. Exceptions can occur where higher permeability rocks, such as sandstone or limestone, allow faster throughflow of groundwater towards the nearest stream or other discharge point.

Perched water tables occur where a less permeable horizon (e.g. a clay layer) in an otherwise permeable sequence retains a body of groundwater above the level of the regional water table. They usually occur at shallow depths in alluvial and glacial sediments and can be difficult to identify or to delimit.

An aquifer becomes confined when it is overlain by a less permeable horizon that restricts the upward movement of groundwater. When this less permeable horizon is penetrated (e.g. by drilling), the groundwater level rises above where struck to a level controlled by the hydrostatic pressure. If this is above ground level, overflowing artesian conditions will be encountered. Confined conditions should be anticipated, where possible, in order to plan for the problems they can generate.

Individual sites will always require more detailed assessments to determine the specific impact on groundwater resources. The maps represent conditions only at the ground surface. Where the soil and/or underlying formations have been disturbed or removed the vulnerability class may have been

changed and site-specific data will be required. Sites in urban areas and restored or current mineral workings are classified as having high (urban) soil leaching potential until proved otherwise.

Table 3. Hydrogeology summary

Geological unit	Groundwater potential	Water level and strikes	Groundwater vulnerability classification
Northmoor Sand and Gravel	Moderate due to the permeable nature of the soils. Potential for a perched water table to form.	Unknown, potential for shallow perched water strikes due to the underlying impermeable bedrock geology.	Secondary A Aquifer
Oxford Clay Formation and West Walton Formation	Negligibly permeable due to the dominance of intergranular materials (clay and silt)	None encountered	Unproductive strata.

3.6 Groundwater Vulnerability

This section reviews all components of hydrology, geology and topsoil surface water drainage to assess risk notably to groundwater.

3.6.1 Source Protection Zones

The position of the site relevant to current groundwater protection zones is shown in Figure 7.

The proposed development site lies outside of any groundwater Source Protection Zone.

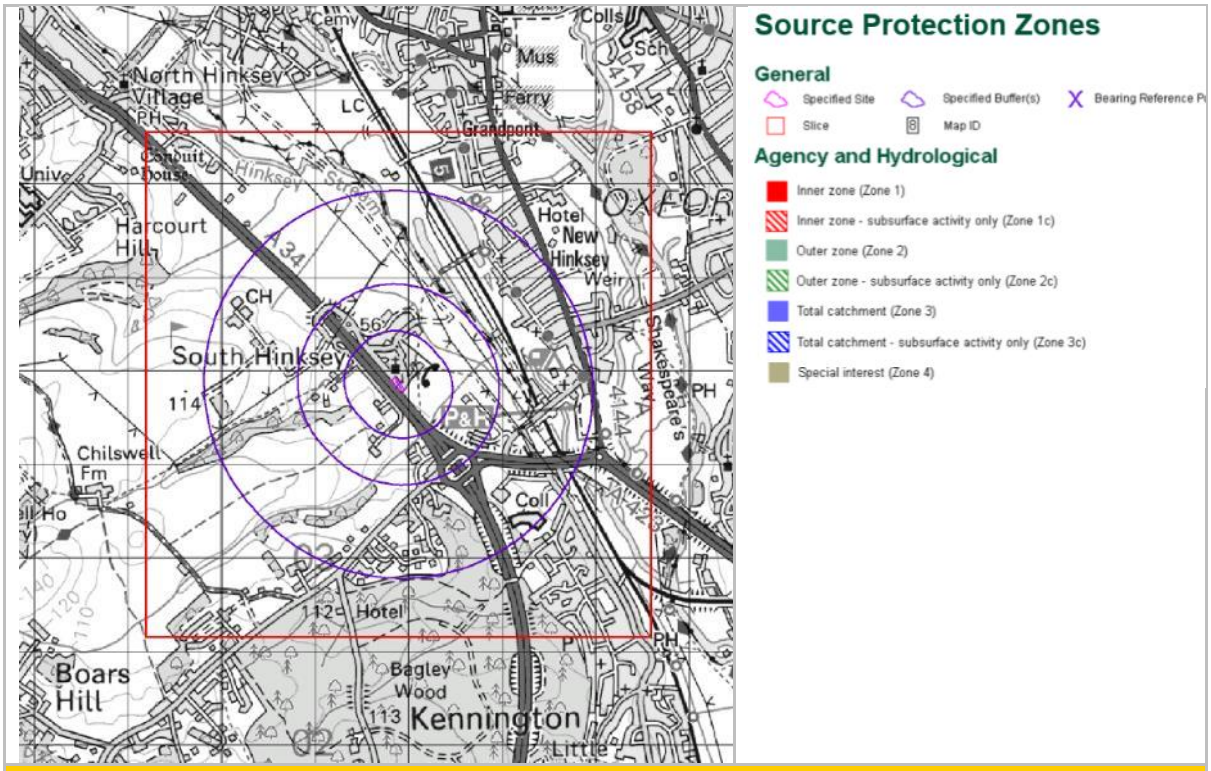

Figure 7. Groundwater Source Protection Zones associated with the site.

Source Protection Zones (SPZs) provide an indication of the risk to groundwater supplies that may result from potentially polluting activities and accidental releases of pollutants. Generally, the closer the activity or release is to a groundwater source the greater the risk. Three zones (an inner, outer and total catchment) are usually defined although a fourth zone (zone of special interest) is occasionally defined.

The Agency has subdivided groundwater source catchments into four zones. Two of these are determined by the travel time of potential pollutants, the third by the source catchment area itself and the fourth is a "Zone of Special Interest". This fourth zone highlights areas where known local conditions mean that potentially polluting activities could impact on a groundwater source even though the area is outside the normal catchment of that source.

- *Zone I (Inner Protection Zone)* **-** This zone is defined by a travel time of 50-days or less from any point within the zone at, or below, the water table. Additionally, the zone has, as a minimum, a 50-meter radius. It is based principally on biological decay criteria and is designed to protect against the transmission of toxic chemicals and water-borne disease.
- *Zone II (Outer Protection Zone)* **-** This zone is defined by the 400-day travel time, or 25% of the source catchment area, whichever is larger. The travel time is derived from consideration of the minimum time required to provide delay, dilution and attenuation of slowly degrading pollutants.
- *Zone III (Total catchment)* **-** This zone is defined as the total area needed to support the abstraction or discharge from the protected groundwater source.
- *Zone of Special Interest* **-** For some groundwater sources an additional Zone of Special Interest may be defined. These zones highlight areas (mainly on non-aquifers) where known local conditions mean that potentially polluting activities could impact on a groundwater source even though the area is outside the normal catchment of that source.

3.6.2 Aquifer Vulnerability

The Groundwater Vulnerability maps are produced at a 1:100,000 scale. They show, by means of colour coding, those areas of the country where water-bearing rocks (aquifers) are present. They also show the vulnerability of groundwater to pollution. The aquifers are classified into Principal, Secondary and unproductive aquifers according to their physical properties and their consequent value as a resource.

The classification of the land surface reflects the ability of contaminants to leach through the covering soils and pose a potential risk to groundwater at depth. The maps also indicate areas where the presence of low permeability drift may provide additional groundwater protection.

These maps can therefore be used for an initial screening assessment of the vulnerability of groundwater to contaminants applied to the surface of the ground. They do not provide all information relevant to the determination of vulnerability, such as the depth to water table or nature of the drift deposits. Site-specific information would always be needed for a detailed assessment of vulnerability at a given location. The original groundwater vulnerability maps were produced some time ago.

Groundwater Vulnerability Maps provide information on how significant the ground waters are likely to be and if they are vulnerable to pollution occurring at the land surface. The maps have descriptions on them to explain the different aquifer and soil types.

Areas shown as principal aquifers have strategic significance for water resource; they often support large abstractions for the public water supply.

Secondary aquifers have a more localised significance to domestic, agricultural and industrial users (although they may still be used for drinking water). Unproductive aquifers do not store significant amounts of groundwater. However, in some areas they can support local supplies: e.g. small springs feeding individual properties.

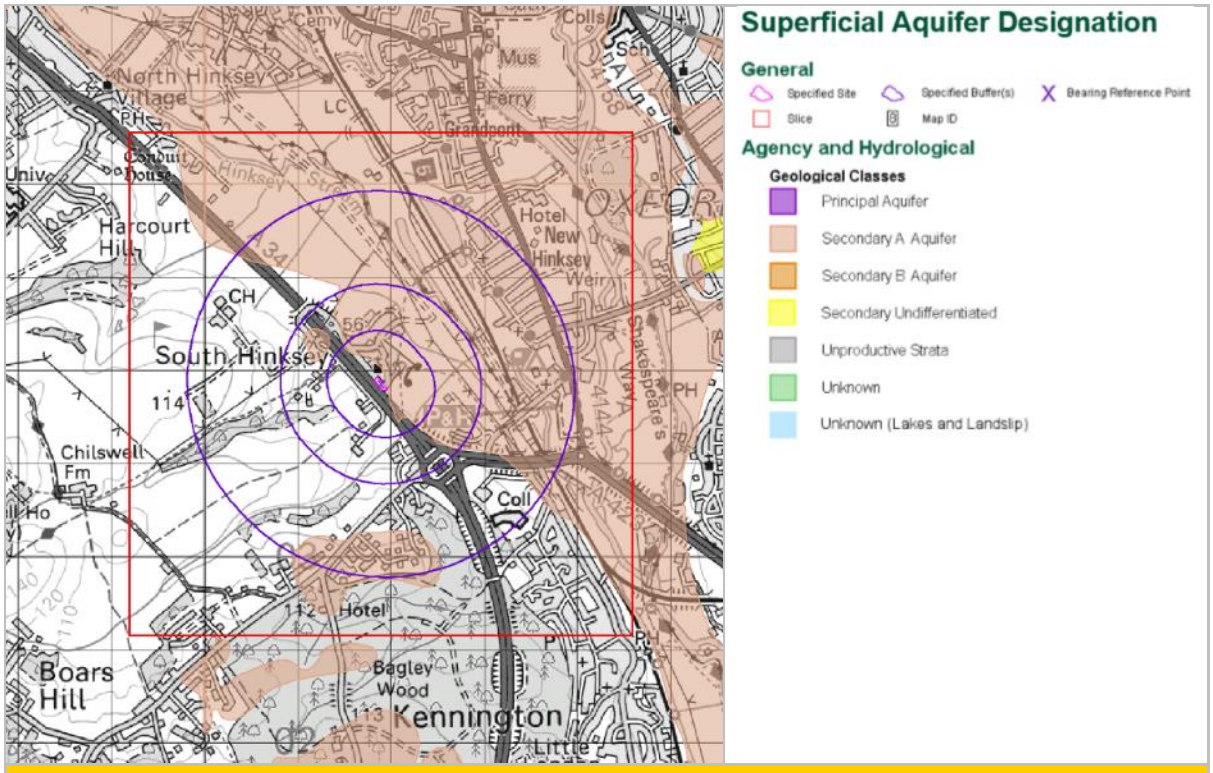

Figure 8. Superficial drift aquifer designation associated with the site.

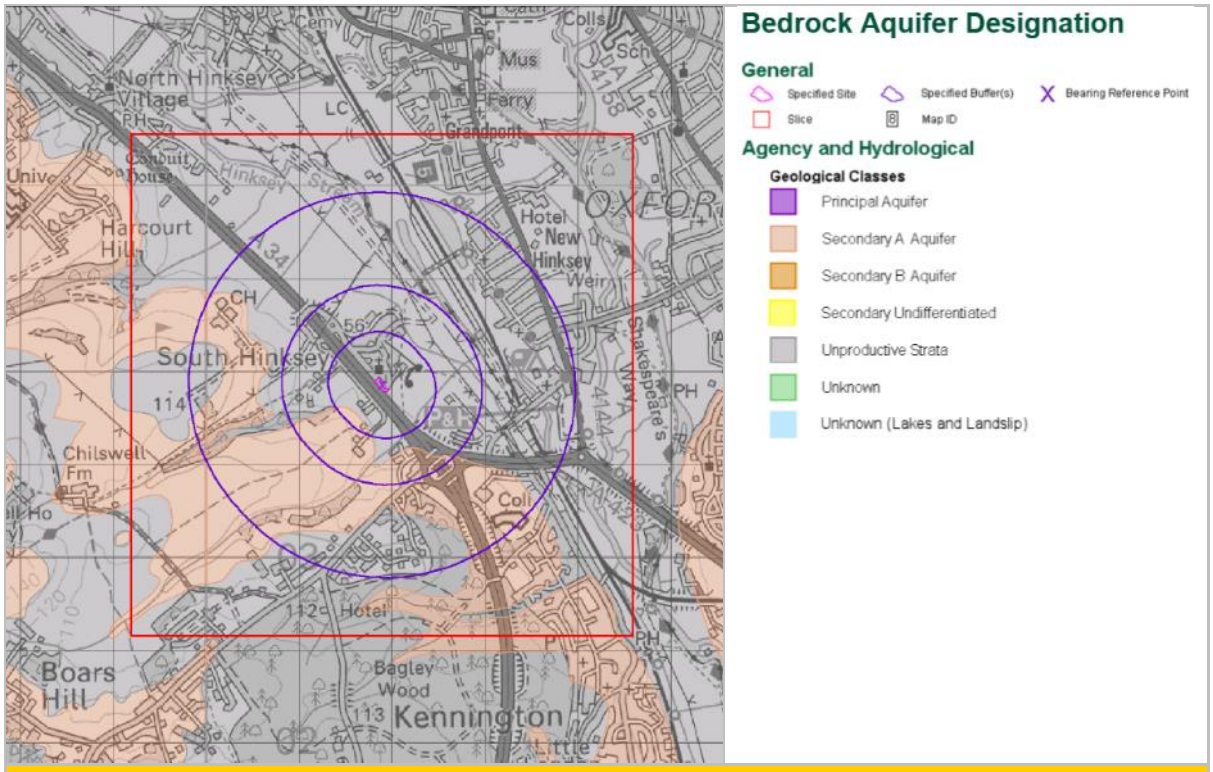

Figure 9. Bedrock aquifer designation

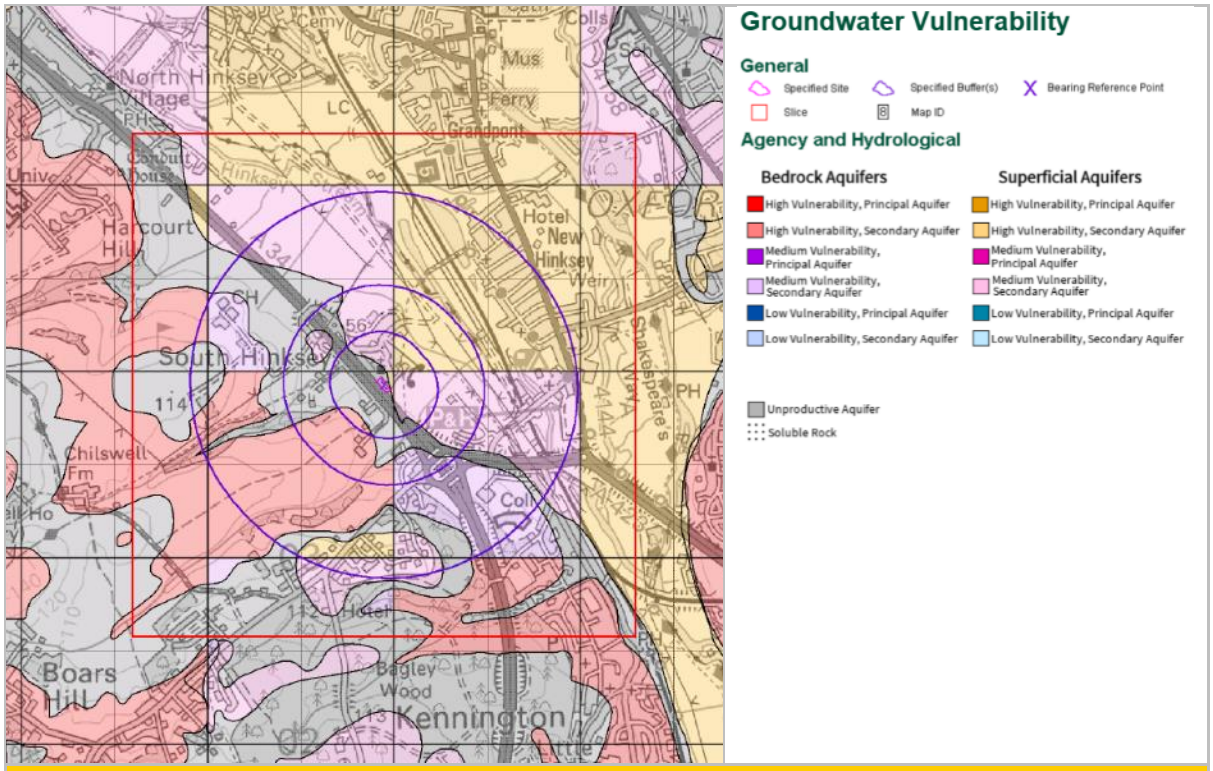

Figure 10. Groundwater vulnerability associated with the site.

Principal and secondary aquifers may be important in contributing to the base-flow of streams and rivers. The maps show where groundwater is protected from above by rocks with a low permeability, such as glacial clay. They also show the characteristics of the soil above.

Superficial drift deposits which overlay the solid geological strata can sometimes be substantial in thickness. They are often variable in composition changing from highly permeable outwash gravels to low permeability clays over short distances both laterally and vertically. The presence of permeable drift deposits is recognised in the form of secondary aquifers except where these overlie a principal aquifer and they then assume the status of a principal aquifer.

There is no aquifer associated with superficial deposits due to the absence of such soils on site. However if the Northmoor Sand and Gravel soils are encountered, then there would be a Secondary A aquifer on site. The underlying bedrock geology is classified as unproductive, the overall groundwater vulnerability is accordingly designated as unproductive strata. The site is within a Surface Water Nitrate Vulnerable Zone, a Surface Water Drinking Water Safeguard Zone and Drinking Water Protected Area.

3.6.3 Flood Risk

The site is within Flood Zone 1 land which is at low risk- less than 1 in 1,000 in any given year (Figure 11). From this respect, the land is suitable for use as a cemetery. Land to the north east is classed as Flood Zone 3. If areas of impermeable surfaces such as buildings, roads etc. are constructed on a greenfield site, a surface water management system designed in accordance with the principles of Sustainable Urban Drainage Schemes (SUDS) will be required.

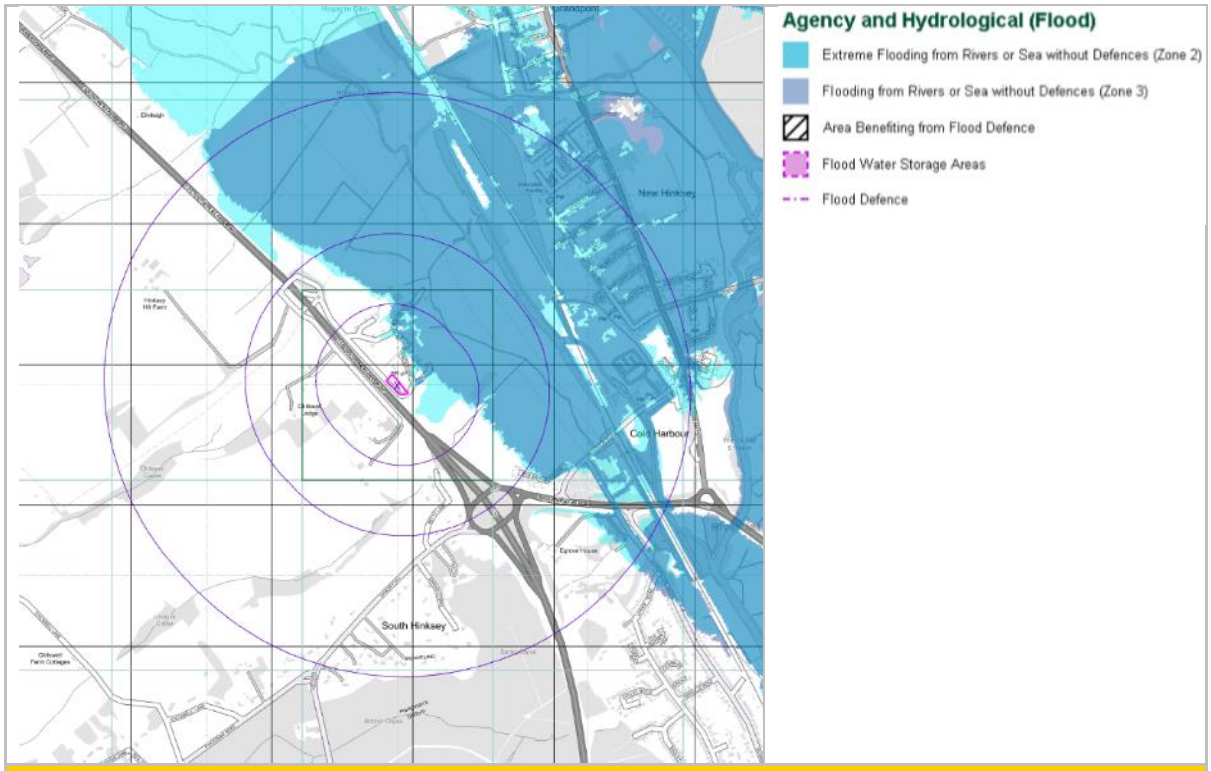

Figure 11. Map of Flood Risk Zones

3.6.4 Wells in the vicinity of the site

There are no water abstractions mapped within a 500m radius of the site.

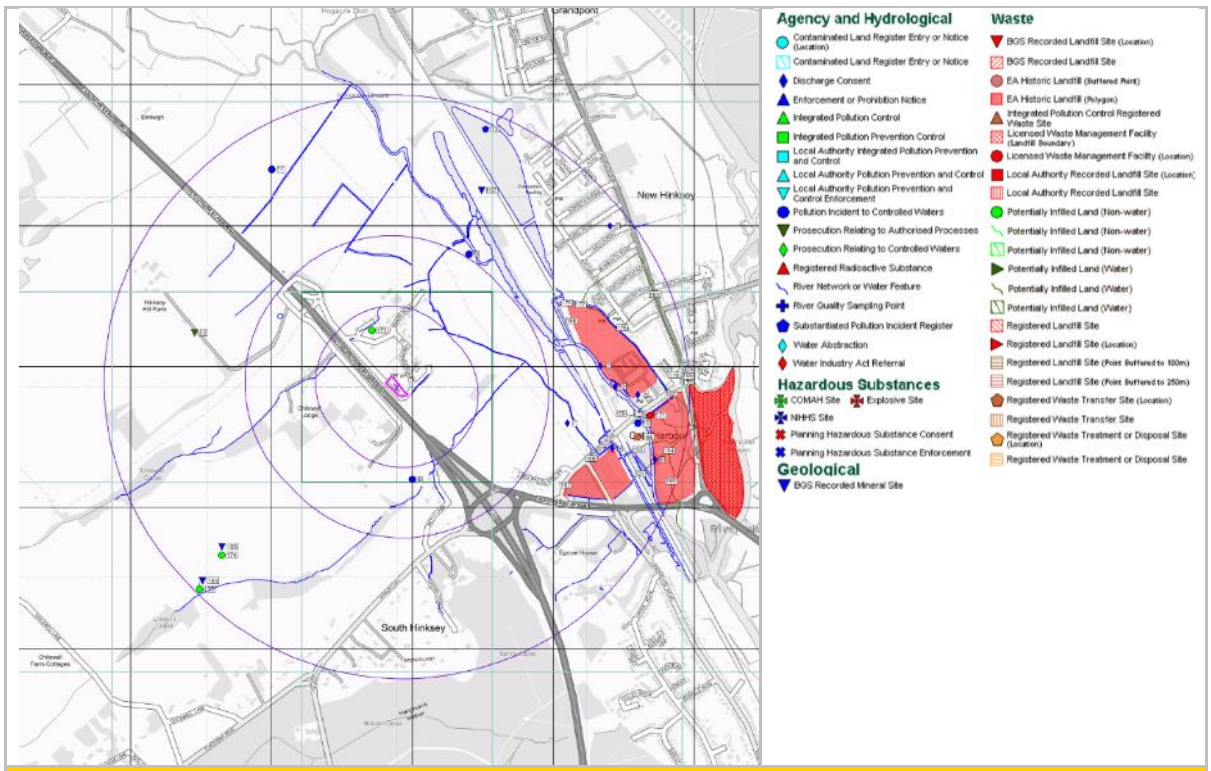

Figure 12. Well records

3.6.5 Borehole records in the vicinity of the site

There are 7 boreholes within 250m of the site, further details are provided below.

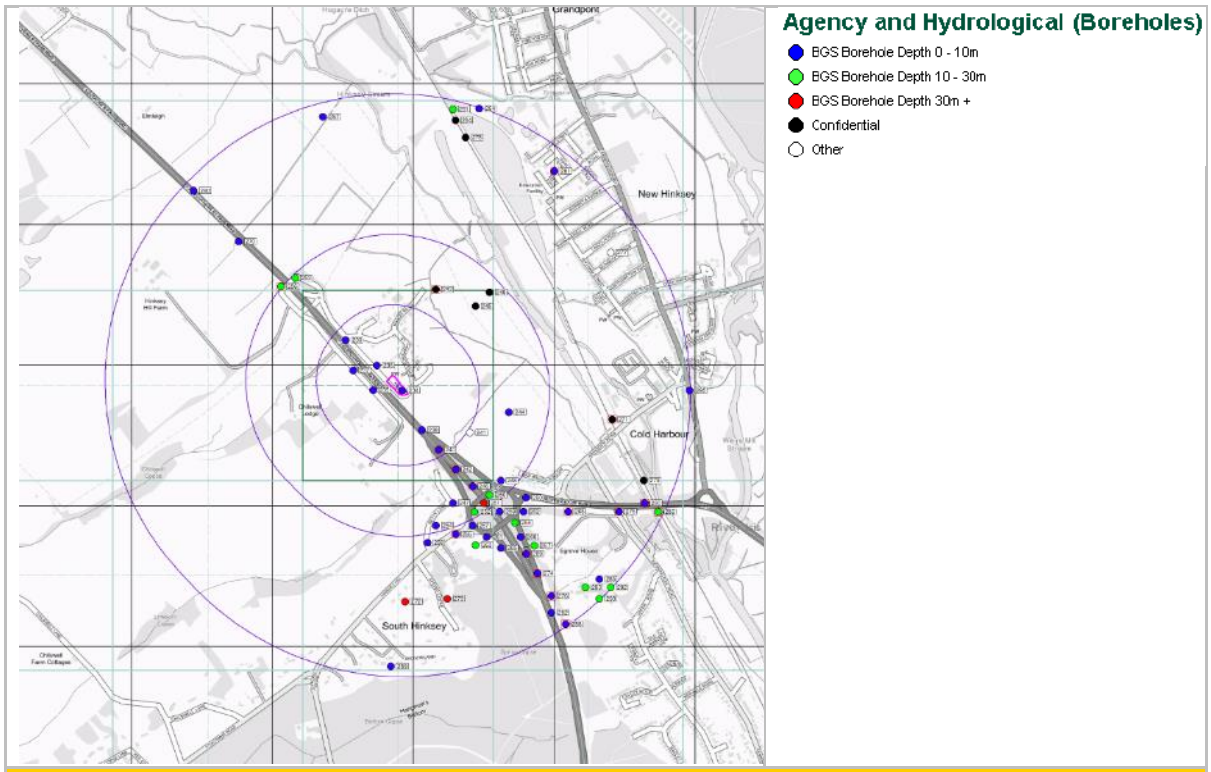

Figure 13. Borehole records

Borehole Map ID	Distance	Borehole Name	Link to Borehole Scan
234	0	Oxford Southern By Pass Bh332	http://scans.bgs.ac.uk/sobi_scans/boreholes/335717
235	58	Area 3 - A34 Trunk Road South Hinksey Garden Centre 1	http://scans.bgs.ac.uk/sobi_scans/boreholes/18952097
236	66	Oxford Southern By Pass Bh331	http://scans.bgs.ac.uk/sobi_scans/boreholes/335716
237	116	Area 3 - A34 Trunk Road South Hinksey Garden Centre 2	http://scans.bgs.ac.uk/sobi_scans/boreholes/18952098
238	137	Abingdon By-Pass Section 1 A34 Bh1	http://scans.bgs.ac.uk/sobi_scans/boreholes/335522
239	208	Oxford Southern By Pass Bh330	http://scans.bgs.ac.uk/sobi_scans/boreholes/335715
240	226	Abingdon By-Pass Section 1 A34 Bh2	http://scans.bgs.ac.uk/sobi_scans/boreholes/335523

3.7 Meteorological Data

The Standard Average Annual Rainfall (SAAR) for the site itself is 638 mm.

3.8 Surface Water Issues

The site is at a very low risk of surface water flooding. Any works which might increase the risk of flooding on or off site need to be identified and the risks assessed and mitigated using a suitable SUDS compliant approach.

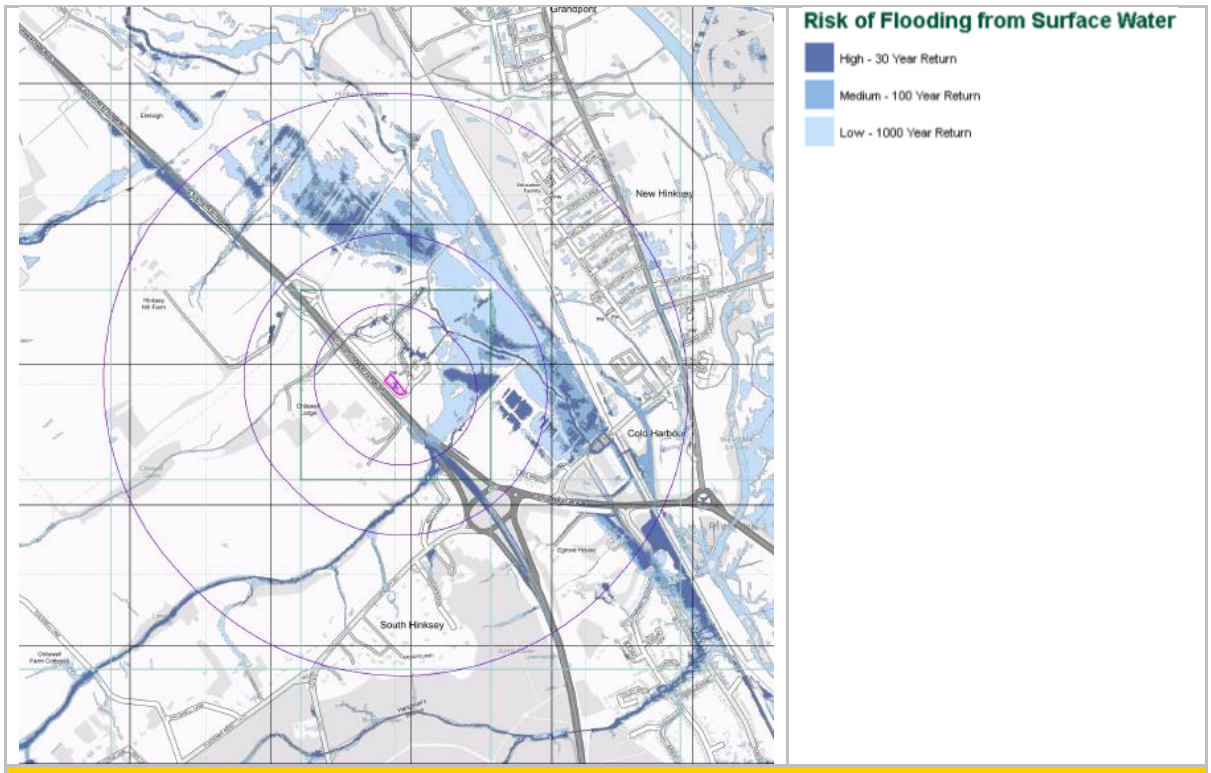

Figure 14. Map of surface water flood risk.

4 Pollutant Risk

Based on the number of annual burials on the site, which is due to be approximately 3 per annum, the cumulative ammoniacal nitrogen concentrations are likely to be low with similar levels of total organic compounds (TOC).

Pathogens
There has been some evidence from recent studies of the occurrence of Enterococci and Clostridium bacteria found in drainage water of cemeteries. Enterococci are bacteria that are commonly found in the bowel of normal healthy individuals. They can cause a range of illnesses including urinary tract infections, bacteraemia (blood stream infections) and wound infections.

The two most common species of Enterococci are E. faecalis and E. faecium. During the mid-1980s, enterococci with resistance to glycopeptide antibiotics such as vancomycin and teicoplanin emerged, termed glycopeptide-resistant enterococci (GRE). Most GRE are E. faecium.

Due to the nature of the soil and geomorphology, there is unlikely to be much movement of pathogenic organisms, notably Pseudomonas aeruginosa and Faecal streptococci. Pathogens tend to be short lived away from the host and if there is no immediate groundwater risk or potable well supply, the risk may be considered acceptably low.

This site is mapped to be underlain by clayey Denchworth Association soil which is directly underlain by Oxford Clay Formation and West Walton Formation (undifferentiated) bedrock. This mudstone bedrock geology is likely to be weathered to silty clay soils in its upper reaches. Therefore, it is considered that there is ample opportunity for mitigation of pollutants from burials due to the ability for adsorption via cation exchange in such clay dominated soils. The protection afforded by the mapped rock types to any groundwater is significant and risk posed from this development is likely to be low in respect to pathogens.

If however the Northmoor Sand and Gravel soils are encountered onsite, then there is a greater potential for the movement of burial contaminants and pathogens away from the source due to the permeable nature of such soils and potential for shallow perched groundwater especially in wet winter months.

5 Depth of Burial

Due to the nature of the mapped soils, shallow groundwater is not anticipated to impede the depth at which burials occur. There is a small possibility that limited quantities of pocketed perched water may be encountered within the upper weathered material of the Oxford Clay / West Walton Formation where the soils are less consolidated due to weathering. Any such perched seepages are likely to be limited in quantity and hydraulically isolated.

Full depth burials are considered suitable on the subject site; burials should not be interred any shallower than 1.6m bgl.

If however the Northmoor Sand and Gravel soils are encountered onsite, then there is a potential for a shallower perched water table to be encountered which could restrict burial depths in some area of the site. Investigation is required to assess the presence/absence of such soils.

6 Greywater Management

Groundwater protection is a statutory requirement for all cemetery sites under the Water Resources Act. The Environment Agency have also laid down strict guidelines for the development of new cemeteries and operation of all existing cemeteries with active burial and reopens, which include but are not limited to the following:

- Graves should not hold any standing water when dug.
- There should be at least 1 metre between base of grave and water table; more if the soil has high infiltration rates.
- Graves should be at least 250m away from wells and potable water supplies.
- Pumping out of graves and discharging "grey" water directly or indirectly into surface or groundwater sources if found to be polluted is an offence under the Groundwater Regulations 1998.
- No burials within 10 meters of land drains.

During the winter months, it is a common requirement to pump water out of newly opened graves. There are a number of reasons why water enters graves, it is important therefore, to determine where the water is coming from. There are usually three main sources:

6.1 Surface Water

In the winter and during periods of heavy and sustained rainfall, surface water is likely to be the most common source of water seepage into graves particularly on site situated on relatively impermeable subsoils such as clay. The shallow soil profile soon becomes saturated and the soil exceeds field capacity, meaning that all the soil's pore space is filled with water. The greater the water input, the deeper this waterlogged layer becomes. Clay soils may only allow infiltration rates of between 2mm to 3 mm per hour, however, if the soil is consolidated, then this rate could be reduced to less than 1 mm per day leading to prolonged periods of standing water and rapid runoff from sites when rainfall begins.

In high rainfall events (10-15 mm per hour), the upper horizon (topsoil) soon becomes saturated as water movement downwards is impeded by the less impermeable soils below, eventually precipitation exceeds the speed of downward infiltration and excess surface water then moves horizontally and generally down slope over the surface, ponding in depressions such as over new graves or in areas where older graves have not been suitably topped-up. Furthermore, if the drainage network designed to capture surface water and drain it away from burial areas is not adequately maintained then these systems can backup leading to surface water flooding.

Excavating a new grave in a previously unoccupied plot of land will allow water to flow through the soil into the newly excavated grave. This water in most cases will be unpolluted, provided it is a new grave up-slope from existing graves. Pumping is an option and is likely to pose little pollution risk if discharged to land and allowed to soak away, alternatively water can be discharged into the surface water or foul-water drainage system although permission from the water company will be required.

If a grave is being re-opened, even if the soil has been compacted over the previous burial, it is likely some water will have gathered around the previous interment. In the worst cases this may extend up through the soil to the depth of the next burial. This water will be polluted and should be treated as grey water. It must not be discharged untreated into a surface water or groundwater outfall, nor

should it be pumped onto the surface. If the burial is relatively recent, pathogen loading in the water could be high and may present an immediate biological risk to staff and visitors if discharged onto the surface. Even for an old burial the water is likely to be chemically contaminated, posing a risk to the receiving waters. In all cases such water should be disposed of either to a foul sewer (with appropriate permission) or be tankered away to a suitable water treatment works.

The better the compaction of the backfill over a grave, the less likely water is to move through the soil and gather around a coffin at burial depth. Equally, if the grave can be regularly topped up to avoid the formation of a depression over the grave then water will run off the surface and away from the grave rather than ponding over a grave in filtrating down to burial depth.

If the water in the burial has a sheen/odour and is anticipated to be 'greywater' then this water cannot be discharged onto land or into drains as this would breach guidelines with respect to discharge of suspected polluted water.

6.2 Groundwater

If, when digging a grave, water appears to enter the pit at lower levels and / or through the base of the pit it is almost certainly groundwater. The speed at which the water enters a pit or grave can vary depending the nature of the soils. If groundwater is encountered in a freely draining soil such as a fractured weathered bedrock or a highly permeable sand/gravel then the flow may well be rapid, filling the pit or grave quickly. However, if groundwater is encountered in an intergranular soil such as fine sands/silt, then the rate of inflow may be slow and, in some cases, may not be instantly apparent. If left for an hour or so and re-examined, groundwater may appear as slow seepage into the pit or as a sheen of water droplets on the pit base and sides. However, both cases could indicate the presence of groundwater within burial depth and accordingly it is not appropriate to undertake a burial in such conditions as it would be considered in breach of two statutory requirements.

- Graves should not hold any standing water when dug.
- There should be at least 1 metre between base of grave and water table; more if the soil has high infiltration rates.

It should be noted, however, that on some sites a shallow perched water table may be encountered which has no direct connection to groundwater or surface water features. Often sites with a clay soil may contain pockets made up of sand and gravel known as "lenses". If a grave is dug into such a lens, it will cause the water to drain from the lens into the grave. The size of the lens will determine the speed and quantity of water ingression into the grave. Depending on whether the new burial is in close proximity to other burials and depending if other graves in the cemetery are at, or above, the level of these lenses, the water entering the burial may or may not be considered to be contaminated. When considering pumping out, this water should be managed as part of a health and safety management approach (see later discussion).

6.3 Intergrave Seepage

As discussed previously, surface water arising from periods of heavy or sustained rainfall on heavy clay soils will migrate to depressions, which in cemeteries are often associated with settlement of graves. The backfill material of a grave is usually less consolidated than the surrounding undisturbed soil due to the fact that the soils has been reworked and placed back leaving fissures and voids in the soils. If the surrounding matrix is less permeable, water will accumulate in the pore spaces and voids within the grave. This "free water" is mobile and is under a "head" of pressure which increases with depth.

If a new grave is dug downslope of, or adjacent to, an existing grave it is likely that seepage of "grey" water from the adjacent plot will occur. Based on the age of the adjacent burial (<10 years or younger), there is a significant risk that the water draining into the excavation will be contaminated. Recent evidence shows that this greywater may contain clostridium and streptococcal bacteria. Concern has now also been raised about the possible presence of the CJD vector.

Pumping "grey" water without adequate protection of water courses, staff and public is potentially dangerous and irresponsible. Environment Agency representative advice as of January 2007 is as follows:

> *"Grey water should be managed in the first instance by the prevention of surface water entering grave plots, old and new. This can be done by installing cut-off or surface management drainage systems. If water is subsequently pumped from the grave, the water must be stored and subsequently disposed of by a professional environmental waste management company. Alternatively, the water can be treated on site by either mobile or permanent treatment systems prior to discharge or recycling."*

7 Archaeology

It is recommended that consultation with the county archaeological team be undertaken to ascertain any archaeological interest in the area.

8 Risk Evaluation

Assessment of general hazards.

The potential of a number of pollutant pathways and the degree of associated risk assessed numerically on a 0-10 score with 10 being the highest risk is shown in Table 4. From the resultant data, the final values are assessed against burial number and a determinant of risk calculated from EA flow charts and nomographs.

The table below also contains risk scores in brackets () based on if the Northmoor Sand and Gravel soils were to be encountered on site.

Table 4. Summary of pollution risk associated with the site

Risk	Assessment (High, Moderate, Low)	Comment	Score
Burials per annum	Low	Expected to be around 3 per annum based on data provided by our client.	-
Drift / superficial data	Very High	There is a recorded absence of superficial deposits on the subject site, which would class the risk as very high.	9-10 (7-8)

Risk	Assessment (High, Moderate, Low)	Comment	Score
		If Northmoor Sand and Gravels are encountered, these would be considered a high risk due to their permeability.	
Drift thickness	High	Due to the likely absence of significant thicknesses of drift deposits burials are anticipated to take place within weathered clay soils of the Oxford Clay / West Walton (undifferentiated) bedrock. We have therefore assumed a high risk.	7-8
Depth to Water Table	Very Low	Based on the mapped soils and geology of the site, shallow groundwater is not anticipated as the site is mapped directly on unproductive bedrock geology. There is the potential for isolated pockets of perched water to occur where less consolidated material is underlain by more consolidated material associated with the weathering profile however, if found, it is likely to be in limited quantity and hydraulically isolated. If Northmoor Sand and Gravels are encountered, these would be considered a high risk due to their permeability and potential for a shallow perched water table.	1-2 (7-8)
Flow mechanism	Very Low	Considered very low due to the presence of clay dominated intergranular materials. If Northmoor Sand and Gravels are encountered, these would be considered a high risk due to their permeability and potential for a shallow perched water table.	1-2 (7-8)
Proximity to Wells or potable water source	Very Low	There are no water abstractions mapped within a 500m radius of the site.	1-2
Aquifer Type	Very Low	The site is mapped directly on unproductive strata. If Northmoor Sand and Gravels are encountered, these would be considered a moderate risk due to the soils being mapped as a secondary aquifer.	1-2 (5-6)
Abstractions and SPZ	Very Low	The site is not situated within any groundwater Source Protection Zone.	1-2
Proximity to water course/springs	Very High	The nearest watercourse comprises a small watercourse/ditch approximately 25m south east of the site, in a field across the other side of St	9-10

Risk	Assessment (High, Moderate, Low)	Comment	Score
		Laurence Road. The risk is given as very high due to the proximity.	
Proximity to land drains	Very High	It is possible that old agricultural land drains underly the site given the slowly permeable soils on site. The historical map review also revealed that the site was formerly situated within a larger open field which may have been used for agricultural use.	9-10
Met data	Moderate	Annual rainfall moderate	N/A
Archaeology	Low	Will require County Archaeologist assessment	N/A
		Total (Minimum to Maximum)	**39-48**

Table 4 is assessed using the groundwater vulnerability-ranking criteria in Table 5. The total score comes to 39-48 and is considered as a moderate risk. These data are then assessed against the burial rate of 3, 5 and 10 per annum on the groundwater risk nomograph p.37 of PP223. The final assessment of risk for this site according to the nomograph (Figure 15), would class it as being low to moderate risk depending on the annual burial rate.

Table 5.Groundwater risk ranking

Ranking	Very Low 1-2	Low 3-4	Moderate 5-6	High 7-8	Very High 9-10
Drift Type	Clay	Silt	Silty sand	Sand/gravel	Absent
Drift Thickness	>5 m	>3-5 m	3 m	0-3 m	Absent
Depth to water Table	>25 m	11 – 25 m	10 m	5 – 9 m	<5m
Flow mechanism	Intergranular				Fissured
Proximity to wells					Within 250 m
Aquifer type	Non Aquifer		Secondary aquifer		Principal aquifer
Abstractions and SPZs	Outside Zone III	Within Zone III	Close to boundary of Zone II	Within Zone II	Within Zone I
Water courses and springs	>100m	>70m<100m	>50 <70 m	>30 <50 m	<30 m
Drains	>100 m	>40 <100 m	30 – 40 m	>10 <30 m	<10 m

If the Northmoor Sand and Gravel is encountered on site, the overall risk score for the site changes. The total score comes to 47-56 and is considered as a moderate risk. These data are then assessed against the burial rates of 3, 5 and 10 per annum on the groundwater risk nomograph p.37 of PP223. The final assessment of risk for this site according to the nomograph (Figure 16), would class it as being low to moderate risk depending on the annual burial rate.

Table 6.Groundwater risk ranking – Northmoor sand and Gravel

Ranking	Very Low 1-2	Low 3-4	Moderate 5-6	High 7-8	Very High 9-10
Drift Type	Clay	Silt	Silty sand	Sand/gravel	Absent
Drift Thickness	>5 m	>3-5 m	3 m	0-3 m	Absent
Depth to water Table	>25 m	11 – 25 m	10 m	5 – 9 m	<5m
Flow mechanism	Intergranular				Fissured
Proximity to wells					Within 250 m
Aquifer type	Non Aquifer		Secondary aquifer		Principal aquifer
Abstractions and SPZs	Outside Zone III	Within Zone III	Close to boundary of Zone II	Within Zone II	Within Zone I
Water courses and springs	>100m	>70m<100m	>50 <70 m	>30 <50 m	<30 m
Drains	>100 m	>40 <100 m	30 – 40 m	>10 <30 m	<10 m

8.1 Groundwater Risk Nomograph

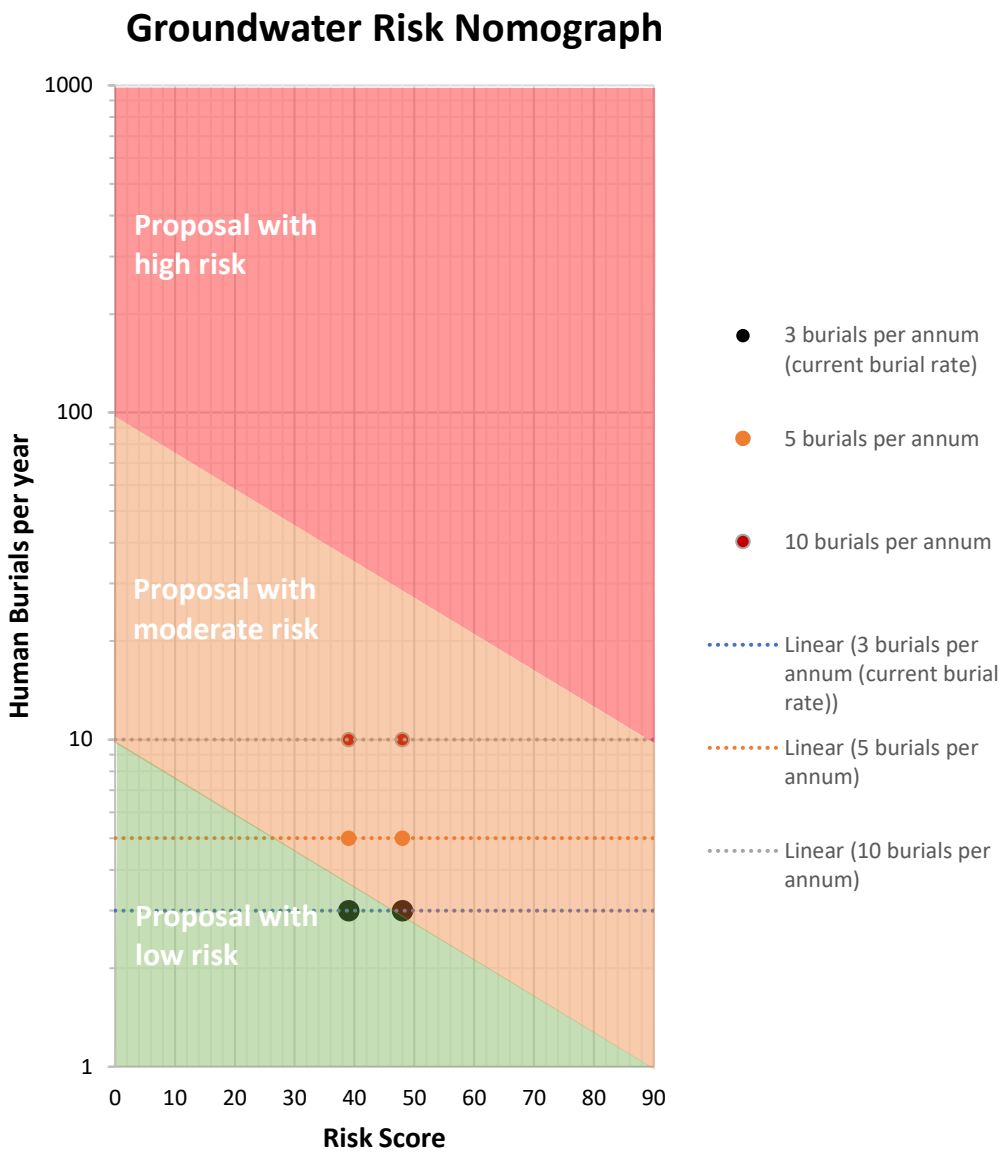

Figure 15. Groundwater Risk Nomograph

9 Conclusion

The site is considered to be a low to moderate risk with the risk mainly attributed to the absence of superficial deposits, proximity of a drain/watercourse to the south east and likelihood of encountering land drains on site. It should be noted that if the burial numbers were to increase from the current level of 3 per annum to 5 per annum, the risk would be classed as moderate. However even if the burial numbers were to increase significantly to 10 per annum, the risk would still be classed as moderate.

From the desktop review, the site is mapped to be underlain by slowly permeable Denchworth soils which are directly underlain by unproductive Oxford Clay / West Walton mudstone bedrock. Burials are likely to be interred into weathered clay soils of the bedrock geology which is perceived to be a good substrate for burials due to the ability for pollutants to be partially mitigated by adsorption via cation exchange. There is the potential for isolated pockets of perched water to occur where less consolidated material is underlain by more consolidated material associated with the weathering profile however, if found, it is likely to be in limited quantity and hydraulically isolated.

If the soils on site reflect the mapped geology, the site will be considered suitable for full depth burials and would meet all statutory requirements set out for the locating of a burial ground and for a burial to take place.

However, an intrusive investigation in the form of excavating trial pits or boreholes is considered to be required to clarify the soil characteristics on site. There is a risk that the site is underlain (wholly or at least partly) by Northmoor Sand and Gravel Member deposits given they are mapped immediately off site to the north east. Due to the granular nature of the deposits, there is a risk of encountering shallow perched groundwater at the boundary between the sand and gravel and underlying bedrock.

A survey of the drain/watercourse to the south east should also be undertaken to clarify whether a 10m or 30m non burial buffer is required.

Finally, it is recommended that a shallow surface water drainage scheme is incorporated in the design of the site as the heavy clay soils will be liable to surface waterlogging both seasonally and following periods of prolonged heavy rainfall.

10 Reporting Details

Report Author: Lucy Pedder BSc

Verification: Darryl Kelly MGeol FGS

Date: 25.01.2021