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Discover what's beneath

A Phase I and Phase II Geoenvironmental and Geotechnical Report for East Cambridgeshire District Council.

Address: Mepal Outdoor Centre, Iretons Way, Mepal, CB6 2BA

Date: 21st June 2021

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Executive Summary

The site comprises a disused outdoor leisure centre with onsite accommodation on a lake between Chatteris and Mepal on the outskirts of Cambridge and Peterborough east of the A1. It is proposed to develop a portion of the site into a new Crematoria and café/function building with areas of car parking and a large memorial garden.

Geological records of the area indicate that the site is underlain by River Terrace and Peat (superficial deposits), which in turn overlie the bedrock geology which comprises the Ampthill Clay Formation. The subject site has however been quarried and it is likely that the Peat soils were removed as part of the excavation process and disposed off site. As such the likelihood of encountering Peat soils on site is low, as the quarry was most likely excavated down into the underlying Terrace Gravels.

Three phases of ground investigation have been undertaken which have comprised the following:

- 7 No. Trial pits excavate in the southern section.
- Installation of 6 No. land gas and groundwater monitoring boreholes across the site and
- A series of fifteen windowless sampler boreholes drilled in the northern section of the site.

The soils encountered were found to be variable, but in general comprised a shallow covering of varying made ground/topsoil underlain by variable reworked loose reject sand. Natural soils were found in close proximity to the existing buildings, and comprised of loose to medium dense sand and gravel of similar nature to the reject sand used for backfilling. No evidence of organic soils such as peat were encountered during the investigation.

Due to the variable nature of the ground conditions encountered on site traditional spread load foundations are not considered to be appropriate. Recommendations have been given to consider the use of a piled foundation solution or ground improvement techniques such as dynamic/vibro compaction of the made ground soils.

A suspended floor slab may be considered suitable in areas where a low bearing capacity is anticipated. However, in areas with heavy floor loads, such as the cremator plant room, a re-inforced ground bearing floor slab with a piled foundation solution would be better suited.

Land gas monitoring has identified elevated concentrations of carbon dioxide above the 5% threshold limit and accordingly land gas precautionary measures will be required in the proposed buildings to be constructed on site.

The results of the contamination testing from both the topsoil, made ground and natural soils has shown that the site is generally considered to be free from significant contamination. Further investigation works and a discovery strategy should be put in place during demolition works to address unforeseen pockets of contamination.

A hydrocarbon plume has been identified at the location of WLS106 and BH2, which appears to be spreading to the east towards WLS115. The results of the contamination testing indicate significant concentrations in both the soils and the underlying groundwater and are indicative of a diesel type heavy end fuel product. Further detailed assessment and investigation works will be required to further investigate the source of the hydrocarbon contamination and provide a remedial strategy for the clean-up of the soils and groundwater.

1 Introduction and Site Location

The CDS Group (CDS) were requested to undertake a Phase I Desk Study Assessment/Walkover Survey and a Preliminary Phase II Geotechnical and Geoenvironmental Assessment of the proposed development site to ascertain the historical nature of the site and any potential geotechnical and/or geoenvironmental issues which could impact the future redevelopment of the site.

The proposed development area has been assessed on a 1km area of influence: grid reference 542308, 282928 and the nearest postcode is CB6 2BA. The total site area is approximately 13.1 hectares, and the proposed redevelopment is to be focused around the area where the existing buildings which comprised the former outdoor centre, are situated.

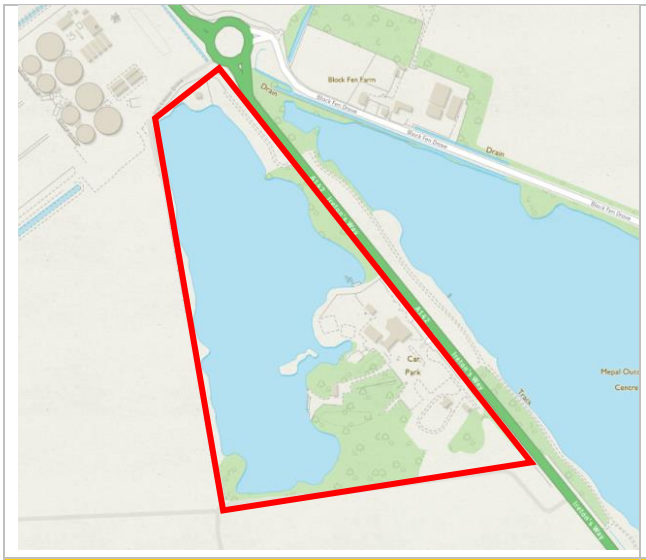


Figure 1. OS map of the site

Figure 2. Aerial Image of the site

2 Development Proposals

The site development proposals comprises the construction of a crematorium and associated service and administration building, function building, memorial garden, natural burial areas, pet cemetery, car parking, new vehicular access from the A142 to the north of the site and landscaping.''

In accordance with published guidance (CLEA Model 2009/C4SL Report 2014), the proposed site redeveloped would be classified as Commercial-Industrial.

CIRIA Guidance (C665) classifies the development type (Commercial) to have a low gas sensitivity.

3 Geological Assessment

Our report utilises third party information from providers such as Envirocheck, British Geological Survey and Cranfield University, whilst the information is deemed to be professionally reliable, CDS do not guarantee the accuracy of third party information.

The full reports of the referenced documents are attached in Appendix C.

3.1 Soil Type

According to the Soil Survey of England and Wales, the soils on site are mapped as belonging to the Ireton Soil Association as described in Figure 3 and Table 1. However, the historical map analysis has shown that the land in the southern corner of the site was initially quarried out and later has been infilled. Therefore the soils on site are likely to comprise made ground soils, and would therefore not be considered representative of the mapped soil type.

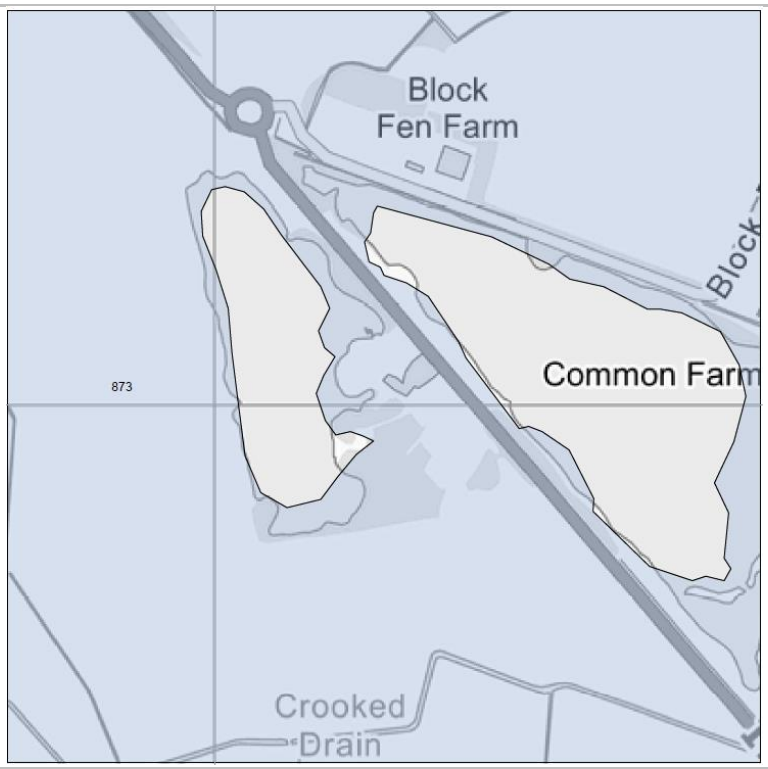


Figure 3. Soil Associations in the vicinity of the site.

Table 1. Soil Associations in the vicinity of the site

Soil Association	Sub Groups	Description
873	Ireton	Permeable humose coarse and fine loamy soils associated with humose calcareous coarse loamy over sandy soils.

3.2 Geology

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

3.2.1 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, there are no mapped artificial deposits on or in the immediate vicinity of the site. However, the historical map analysis has shown that the land in the southern/southeastern part of the site has been infilled and is therefore expected to comprise made ground soils. The made ground soils are likely to be highly variable in composition and given the quarrying history of the immediate surrounding area, could be composed of reject sand and gravel from the excavation of the Mepal Fen to the east. However, we would note that the presence of potentially contaminated soils, organic material and rubble cannot be ruled out at this stage.

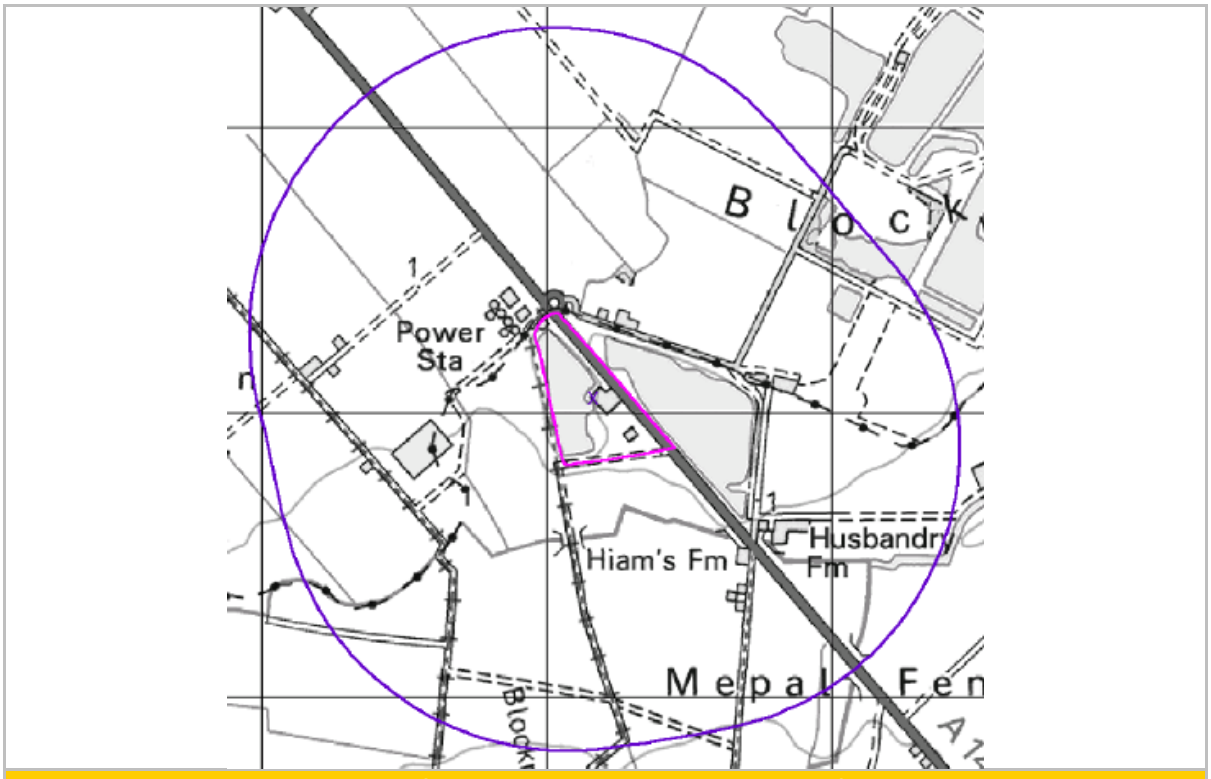


Figure 4. Artificial deposits within the vicinity of the site.

3.2.2 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.

As can be seen in Figure 5, the superficial deposits are mapped as Peat overlying River Terrace Deposits. However, historical map analysis has shown that the site was initially quarried out to the extent of the boundary and later has been infilled. Therefore, the soils encountered on site are likely to comprise made ground soils and would therefore not be considered representative of the mapped superficial geology.

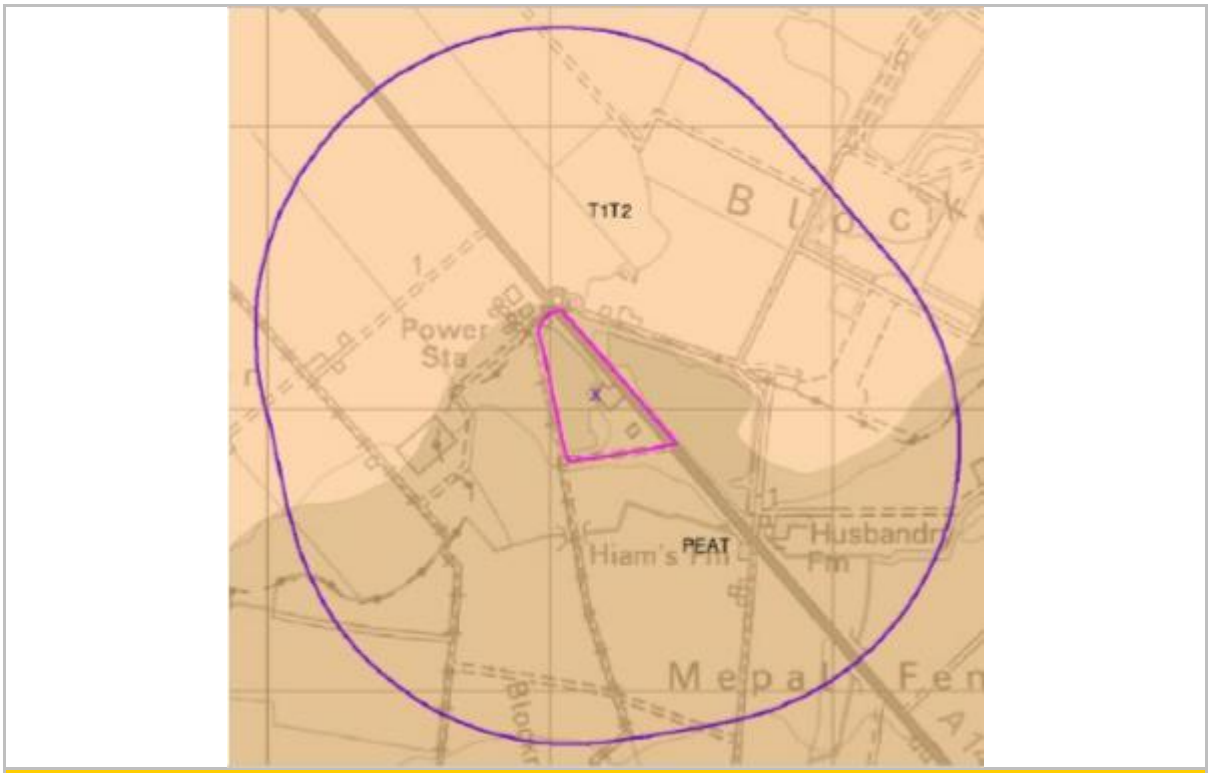


Figure 5. Superficial deposits within the vicinity of the site.

3.2.3 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, the bedrock geology is Ampthill Clay Formation, a mudstone with some argillaceous limestone nodules dating from the Upper Jurassic period.

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

3.3 Additional Geological Considerations

A summary of the potential geological hazards which could be found on site are explained in Table 2 below. This data is obtained from the BGS and the Envirocheck report and should not be considered site specific.

Table 2. Onsite Geological Hazards

Geological hazard	May be significant within site area (Yes/No)?	Comments
Potential Natural Ground Stability Hazards		
Shrink-Swell	No	The mapped geology on the site predominantly comprises granular based sand and gravel, which would not be considered at risk of swelling and shrinkage. The made ground soils encountered on site are also likely to be predominantly granular based and would also not be considered to pose a risk.
Landslides (slope instability)	No	The site is predominantly flat and level, and as such the risk of landslip is considered to be low. There are mounds of imported sand based soils across the subject site, ranging from 1m in height upto 5-6m in height.

Geological hazard	May be significant within site area (Yes/No)?	Comments
		These are not considered an immediate risk but should be assessed during any earthworks.
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	Yes	The site is not situated on a geology which is susceptible to compression and as such there is no risk. However, the made ground soils encountered on the subject site are likely to be loosely compacted and could be subject to ongoing differential settlement and would also be considered prone to inundation settlement in areas where water is discharged, such as soakaways.
Collapsible Deposits	No	The site is not situated on a geology which is susceptible to collapse and as such there is no risk.
Running Sand	**Yes**	Given that the nearby borehole TL48SW2 (some 1500m northeast) contained sand to a depth of 2.9m and that shallow groundwater may be encountered during wet winter months, this is considered to be a high risk if excavations are deepened down to this level.
Other Potential Hazards		
Mining	No	The site is not in an area at risk of mining. However, the site itself and the land to the east, have both been subject to open cast quarrying of sand and gravel.
Flooding	No	The site is classed as Flood Zone 3 and is at high risk of flooding, however the site benefits from flood defences and therefore with suitable mitigation would be suitable for cemetery grounds, however a Flood Risk Assessment may be required to confirm this.
Land Gas	Yes	Unlikely to encounter land gas from natural sources. Land gas could however be encountered from the variable made ground soils which have been deposited in the southern section of the site. Land gas monitoring would be required to further assess the risk.
Radon	No	Level of protective measures: None required.

4 Hydrogeological Assessment

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
Made Ground	Variable permeability associated with the variable nature of the made ground soils.	Boreholes mapped in close proximity to the site, at the same elevation as the site, encountered groundwater at depths of between 3m - 5m bgl.	Unclassified.
River Terrace Gravels	High permeability and high risk of encountering a mobile groundwater table.	Boreholes mapped in close proximity to the site, at the same elevation as the site, encountered groundwater at depths of between 3m - 5m bgl.	Secondary A Superficial Aquifer – a highly vulnerable Secondary Aquifer

Ampthill Clay	Due to the negligible permeability of the soil, groundwater is unlikely to be encountered, though some perched water in localised coarser deposits could be encountered in places.	Groundwater is unlikely to be encountered in the Ampthill Clay Formation.	Unproductive Aquifer.

4.1 Groundwater Vulnerability

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

4.1.1 Source Protection Zones

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

The proposed development site lies outside of any Source Protection Zone. The nearest SPZ is approximately 16km to the south of the site.

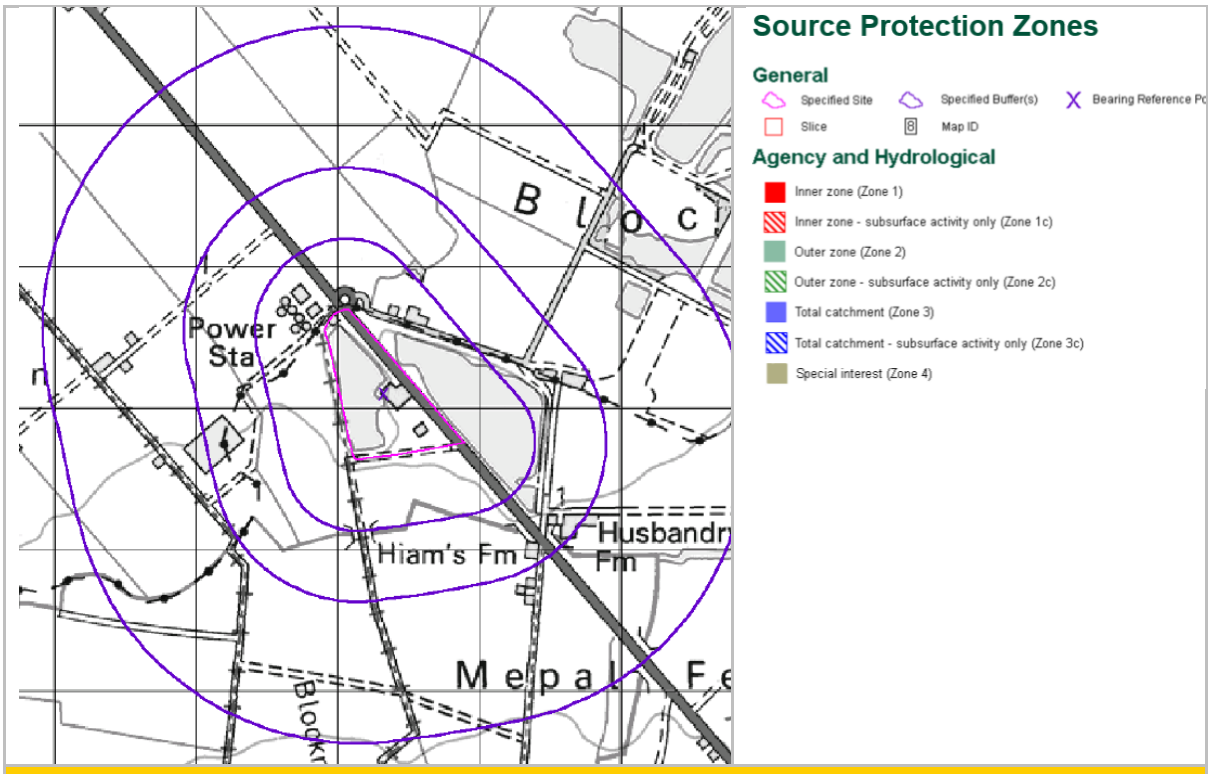


Figure 7. Groundwater Source Protection Zones associated with the site.

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.

4.1.2 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.

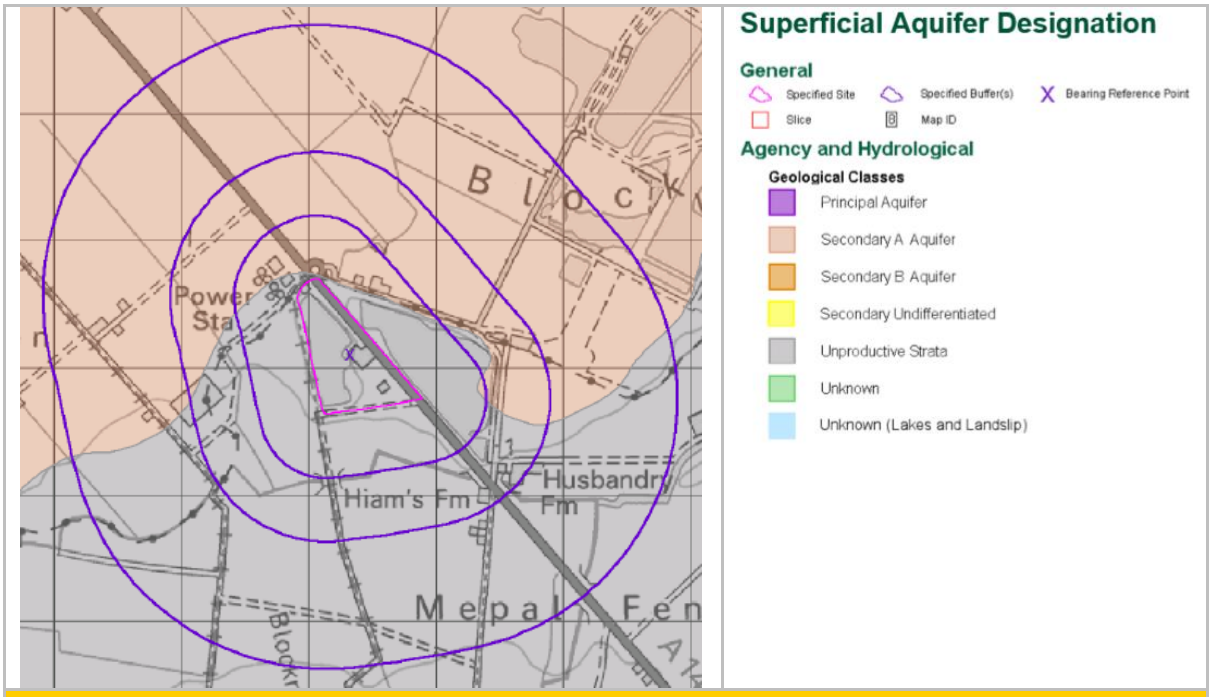


Figure 8. Superficial drift aquifer designation associated with the site.

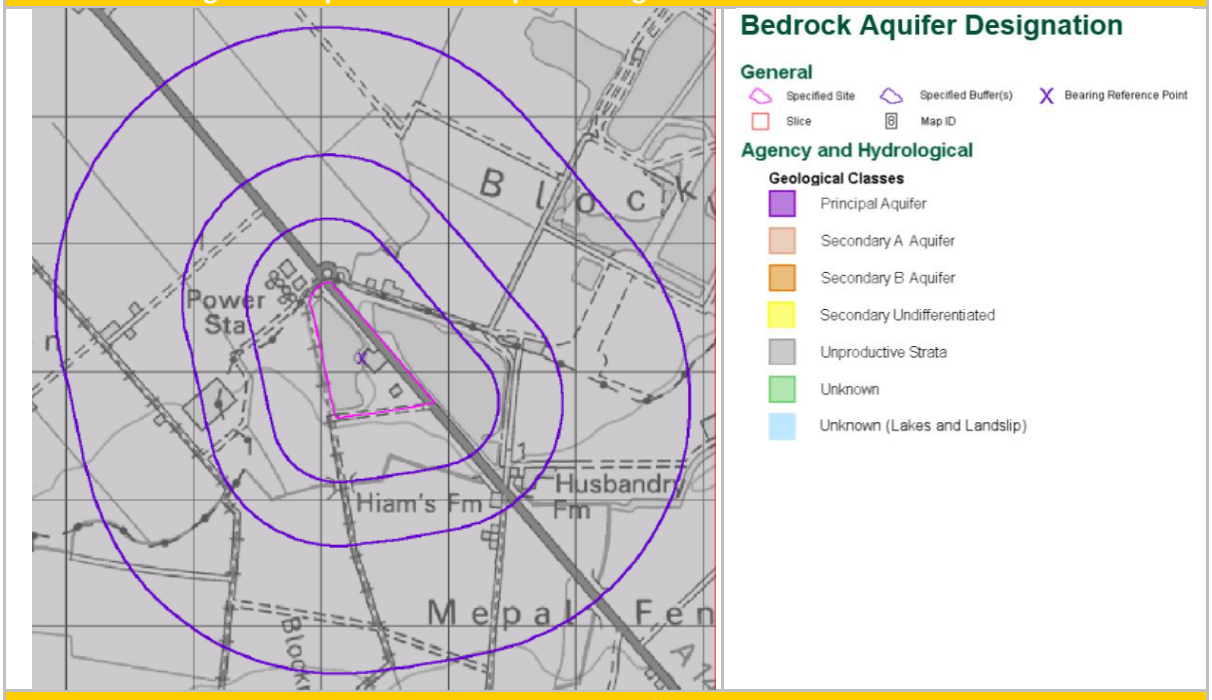


Figure 9. Bedrock aquifer designation

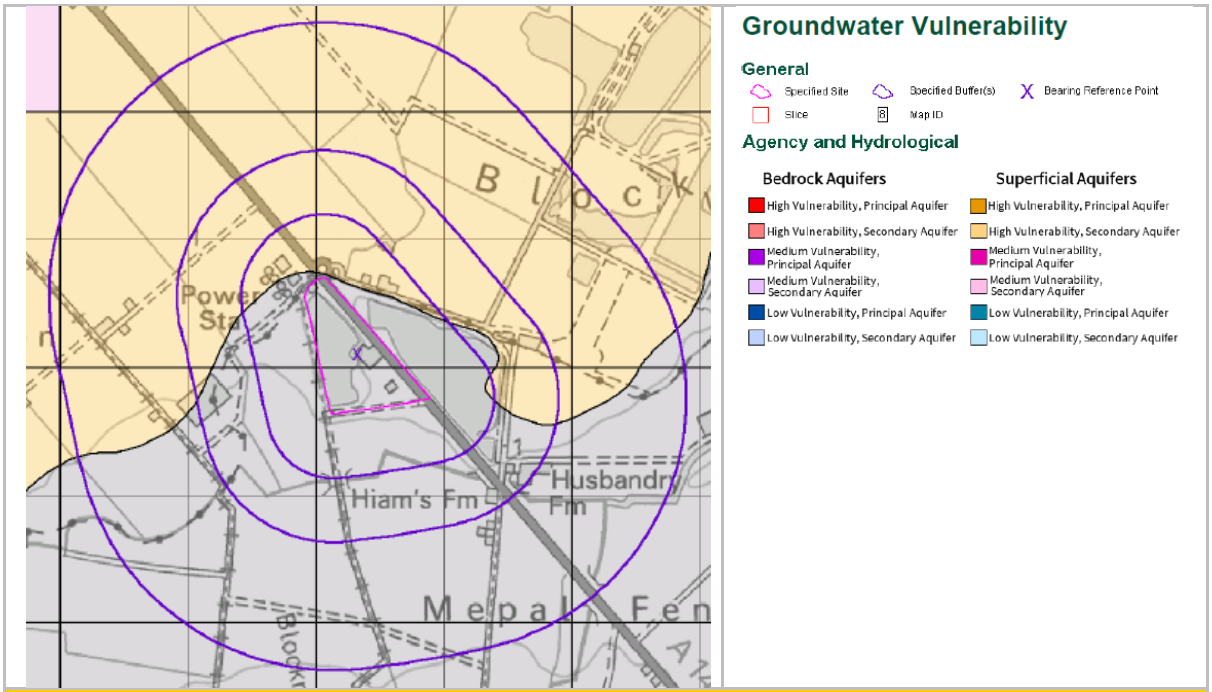


Figure 10. Groundwater vulnerability associated with the site.

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 are no aquifers associated with the mapped superficial deposits (which had been quarried out in any case) and there are also no aquifers associated with the underlying bedrock geology. The site is not within a drinking water safeguard zone however it is within a surface water Nitrate Vulnerable Zone. Though not mapped as an aquifer, the superficial River Terrace Deposits support a secondary aquifer which is locally widespread and is an important source of irrigation water.

4.1.3 Flood Risk

The site is within Flood Zone 3 land which is at very high risk of flooding (Figure 11). However, the site does benefit from flood defences.

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.

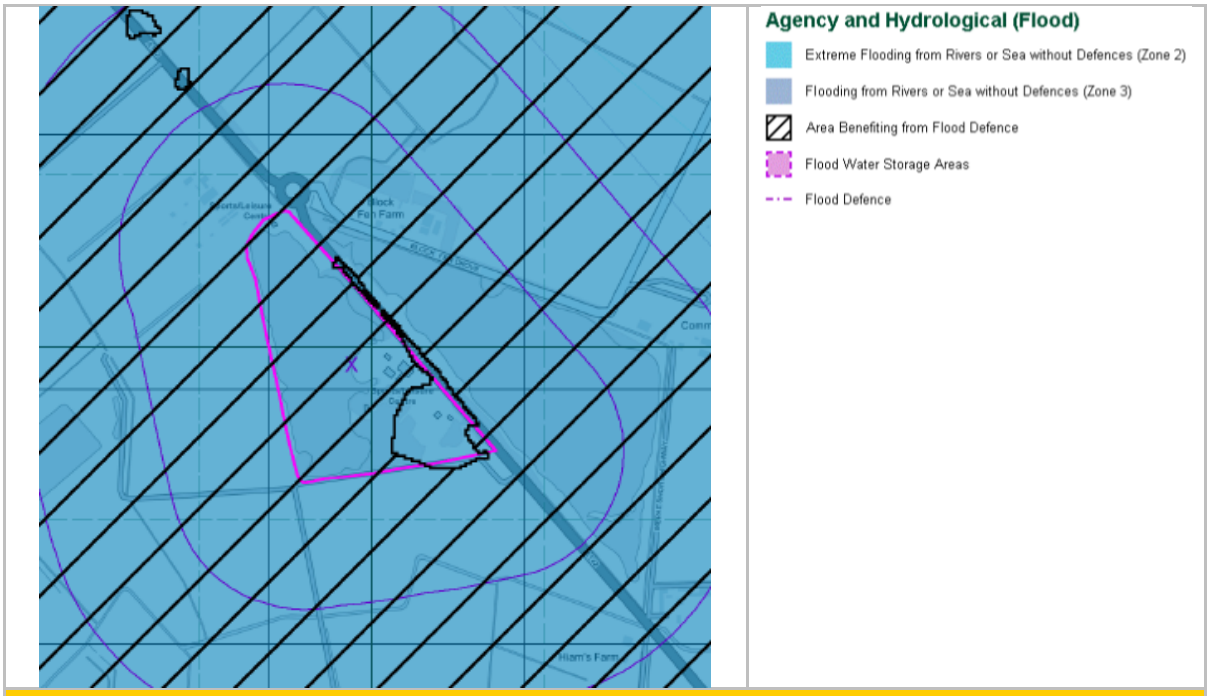


Figure 11. Map of Flood Risk Zones

4.1.4 Wells in the vicinity of the site

There are 26 groundwater abstraction licenses mapped within 250m of the subject site. The abstractions listed are all related to spray irrigation for general agriculture or commercial activities and are abstracting from surface water features and groundwater abstraction points. There are however no potable abstraction wells listed within 1km of the site.

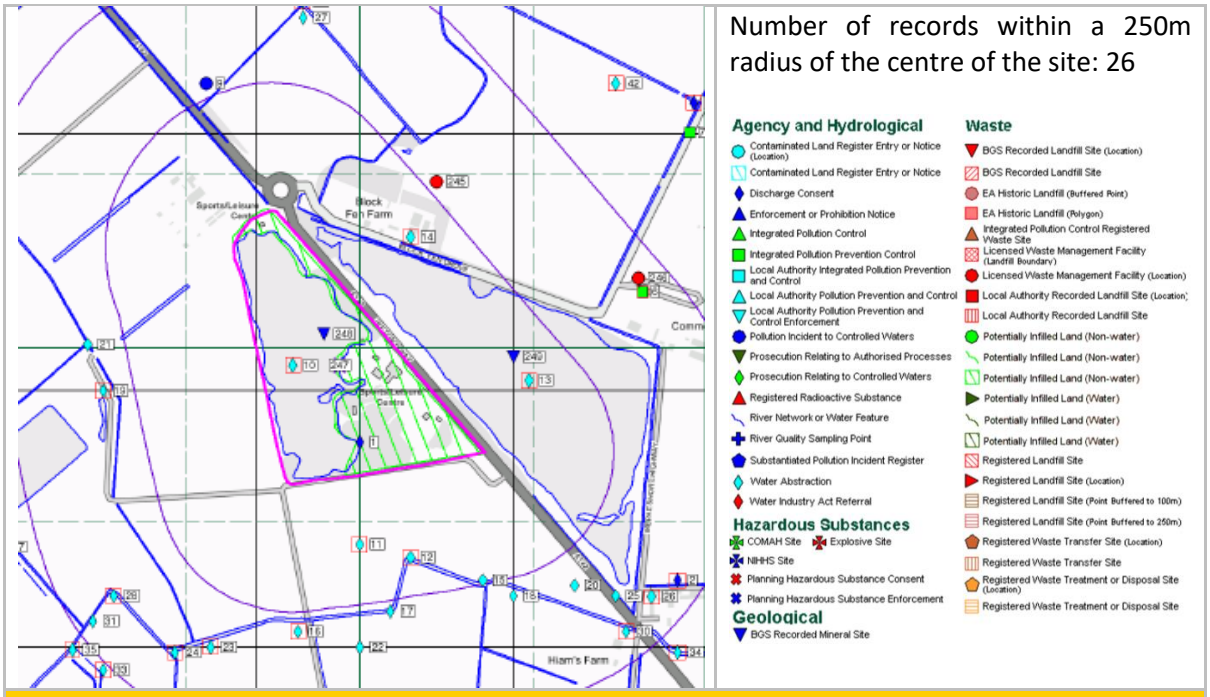
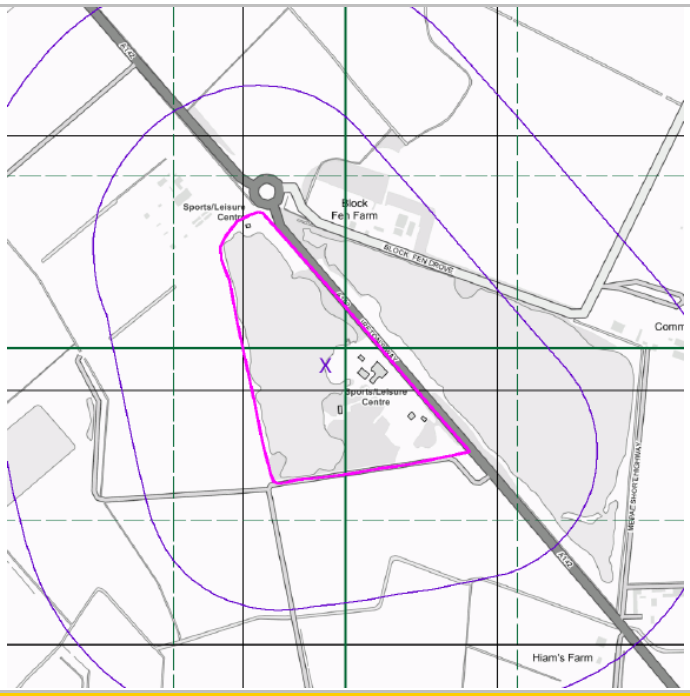


Figure 12. Well records

4.1.5 Borehole records in the vicinity of the site

There are no borehole records within a 300m distance of the site. The abstraction points have no associated borehole records.



Number of records within a 300m radius of the centre of the site: 0

Search area indicated in red.

Figure 13. Borehole records

4.2 Meteorological Data

The agroclimatic index number for this site is 28 with a mean annual rainfall of 574 mm, the Standard Average Annual Rainfall (SAAR) for the site itself is 539 mm.

4.3 Surface Water Issues

There are several areas, as shown in Figure 14 below, which are liable to surface water flooding on the raised area of land in the south-eastern corner of the site. 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.

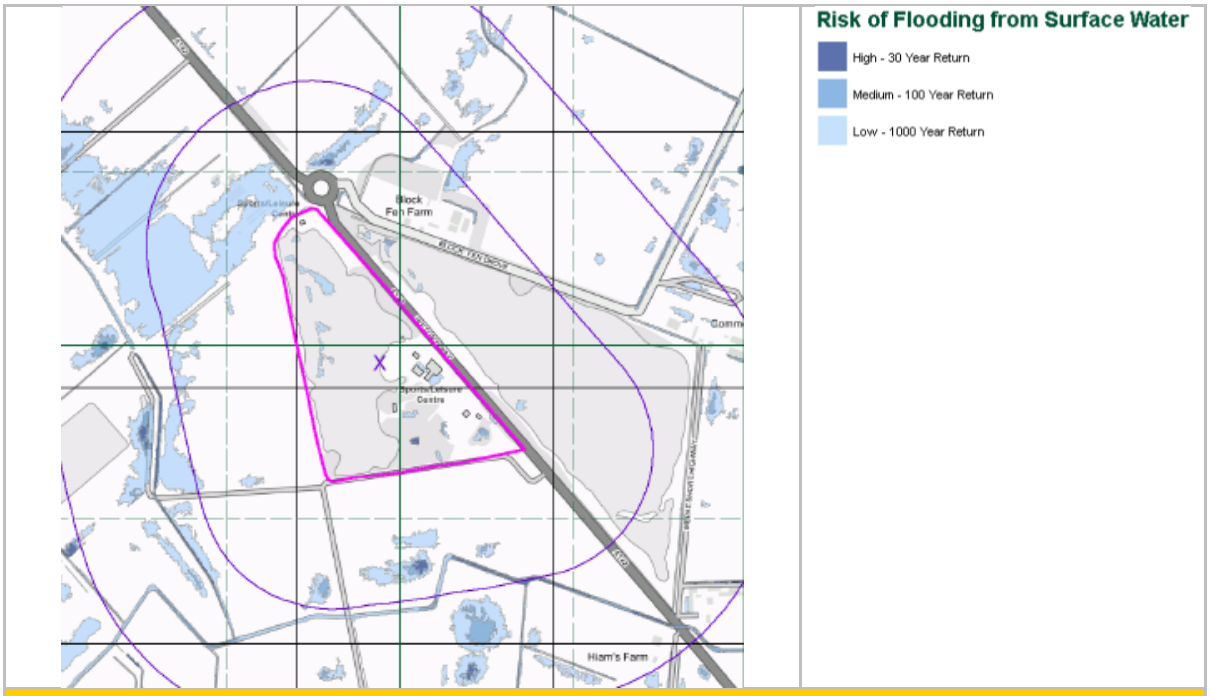


Figure 14. Map of surface water flood risk.

5 Desk Study and Walkover Assessment

5.1 General Site Description

The site comprises a disused Outdoor Centre, which contained numerous derelict buildings and large areas of car park on the central and eastern side of the site. To the south of the car park there is an additional derelict building, associated with the former caravan/camping club, which has been heavily vandalised and is in a poor state of disrepair. The land to the south and east of these buildings comprises overgrown open land with mixed self-sown shrubs and semi mature trees along with small areas of woodland and small ponds. Evidence of sand across the surface of the site and significant burrowing was apparent all across the surface of the site in the southern section.

Towards the centre of the site, to the southwest of the main buildings, a large raised soil mound, approximately 4-6m in height is situated. This mound appears to have been formed with reject sand, however, there is a risk that other types of anthropogenic made ground could be encountered within this raised feature itself. Adjacent to the soil mound were further old derelict buildings and what appears to be an old landing stage onto the lake.

The lake covers the majority of the site, and was observed to be relatively still and clean, with clear water observed on the edges of the lake where access was available. The base of the lake appeared to be made up of sand and gravel, as would be expected given the local mapped geology.

5.2 Historical Map Assessment

A review of the freely available historical maps of the area has been undertaken in order to assess the historical land use of the site and immediate surrounding area in order to review any potential uses which may have an impact on any future development.

The site is first shown on the 1887 map as a series of open fields, with ditch lines shown running broadly east to west. The site is bounded by fields in all directions, and Ireton's Road is mapped directly offsite to the east. The site and the immediate surrounding area remained essentially unaltered up to some point between the 1927 map and the 1952 map when significant change has taken place.

The 1952 map shows that the majority of the site has been excavated as part of a large scale sand/gravel works, a small section of land along the eastern boundary has remained unexcavated, containing several buildings (assumed works buildings) and what appears to be a conveyor belt system. The 1981 map shows that the southeastern corner and the southern part of the site has been infilled, and a car park area has been developed to the south of what appears to be the former works buildings. The land off site to the east by the 1981 map has also been fully excavated and is now mapped as Mepal Fen. It is likely that this excavation is the source of the material which was used to backfill the southern section of the subject site.

By the final map, dated 1990, the southern section of the site, which has now been backfilled, is mapped as the Mepal picnic site. The 1999 aerial map shows that the site was later developed into the Mepal Outdoor Centre, with a number of new buildings constructed on what is thought to be natural ground where the former works buildings were situated. The southern infilled section of the site appears to have been developed into a Caravan Club site, with external outbuildings constructed.

5.3 Environmental Database Assessment

The Envirocheck Report, which is included in full in Appendix C, summarises a range of historical and current land uses in close proximity to the site, as well as a range of other important information. The following table provides a review of the features and entries listed within 500m of the boundary of the site.

Table 4. Environmental Database Summary

Environmental Database	Distance (m) and Direction	Significant Hazard to the site (Yes/No)?	Notes
Current Land Use	Onsite 121(N) 418(E) 437 (E) 499 (E)	Yes No No No No	Mepal Outdoor Centre – Disused. Agricultural Merchants - Inactive Tarmac – Quarry Engineering Services - Inactive Mepal Quarry
Historical Land Use	Onsite Onsite Onsite	Yes Yes Yes	Former Sand/Gravel pit with works buildings Infilled Land Mepal Outdoor Centre and Caravan Park
Fuel Sites	-	-	None listed within 250m of the site.
Pollution Incidents	279 (NW)	No	Category 3 – Discharge of pesticides into roadside ditch.
Discharge Consents	0	No	Mepal Outdoor Centre – Sewage Discharge-Final/Treated effluent. Receiving body – into land. Permit revoked in 1998.

Environmental Database	Distance (m) and Direction	Significant Hazard to the site (Yes/No)?	Notes
Infilled Land	0	Yes	The southern and southeastern corner of the site has been infilled with what is assumed to be reject sand from the adjacent quarries. Potential for unforeseen pockets of contaminated material cannot be ruled out.
Historical Landfills	-	-	No designated sites listed within 500m of the site.
Current Landfills	-	-	No designated sites listed within 500m of the site.

6 Conceptual Model

6.1 On site Sources of Contamination

6.1.1 Former Quarry

The site was historically a sand and gravel pit, which based on the historical maps covered the majority of the footprint of the site in terms of excavation of material. A small section of land was however left untouched along the central eastern site boundary, where the former works buildings and conveyor belts were shown. There is a risk that around the former works buildings, contamination associated with the commercial/industrial processes could be encountered.

The following contaminants maybe encountered in this area of the site:

- Heavy Metals, Asbestos, Hydrocarbons, SVOC's VOC's, solvents.

6.1.2 Infilled Land

After the quarrying works had ceased, the historical maps show that the site was partially infilled with what is assumed to have been reject sand from the excavation of an additional quarry to the east of the site (Mepal Fen). The infilling has taken place in the southern and southeastern parts of the site and is considered to pose a potential risk to redevelopment of the site due to the possibility of encountering unforeseen pockets of contaminated material and/or organic material.

The following contaminants maybe encountered within the infilled material deposited on site:

- Heavy Metals, Asbestos, Hydrocarbons, SVOC's VOC's, solvents.
- Organic Material – Land Gas Generation – Carbon Dioxide, Methane.

6.1.3 Mepal Outdoor Centre

The former works buildings appear to have been demolished and later replaced by the Mepal Outdoor Centre on a similar footprint area. Whilst the outdoor centre, its associated buildings and areas of hardstanding appear to have no significant potentially contaminative uses, there remains a risk that residual contamination associated with the former works building may have been built over.

As such, the following contaminants may still be encountered in this area of the site:

- Heavy Metals, Asbestos, Hydrocarbons, SVOC's VOC's, solvents.

6.2 Offsite Sources of Contamination

No significant sources of offsite contamination, which would be considered to have a significant impact on the development of the site have been identified during the historical mapping assessment, desk study and walkover survey of the site.

6.3 Pollutant Linkage Model

The identified pollutant linkages based on the desk study assessment have been summarised below in the Site Specific Pollutant Linkage table:

Table 5. Site Specific Pollutant Linkages

Source	Pathway	Receptor	Calculated Risk
Onsite/Offsite contamination arising from current and historical land use	Direct ingestion, direct contact & inhalation of dust/ vapours.	Future Site users.	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered. Remedial works based on the identified contamination would be required to reduce/remove the risk to future end users in line with the sites end use (Commercial/Industrial)
		Construction workers.	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered especially during the demolition phase of the works The provision of suitable PPE/RPE during the demolition/construction phase along with detailed method statements and risk assessments would be required to reduce/remove the risk to construction workers to appropriate levels.
	Leaching and vertical & lateral migration	Controlled waters	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered. Remedial works based on the identified contamination would be required to reduce/remove the risk to controlled waters subject to consent and approval.

Source	Pathway	Receptor	Calculated Risk
	Direct infiltration in water supply pipes.	Service conduits	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered. Services and incoming pipework will need to be designed in accordance with the suppliers specifications based on the level of identified contamination on site.
	Plant uptake.	Vegetation within landscaped areas.	The calculated risk is deemed to be moderate based on the potential for onsite contamination to be encountered. However, as the site is being development into commercial/industrial land use, risk associated with ingestion of plants is removed.
	Lateral migration through groundwater	Off-Site neighbouring properties.	The calculated risk is deemed to be moderate based on the potential for onsite contamination to be encountered. Remedial works based on the identified contamination would be required to reduce/remove the risk to offsite receptors subject to consent and approval.
Potentially contaminated groundwater (onsite or offsite)	Direct ingestion, direct contact & inhalation of dust/ vapours.	Future Site users.	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered. Remedial works based on the identified contamination would be required to reduce/remove the risk to future end users in line with the sites end use (Commercial/Industrial)
	Leaching and vertical & lateral migration	Controlled waters (watercourses including field drains)	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered. Remedial works based on the identified contamination would be required to reduce/remove the risk to controlled waters subject to consent and approval.

Source	Pathway	Receptor	Calculated Risk
Potential for ground gas	Vertical and lateral migration	Human Health and buildings	The calculated risk is moderate to high given that the southern part of the site has been backfilled with reject sand materials and may potentially contain pockets of contaminated material and/or organic material.

7 Site Investigation

7.1 General Site Description

The site, which was formerly a large open cast sand/gravel pit, comprises an area of anticipated virgin land where the former works buildings were situated and an area of land which was subsequently infilled after quarrying.

At the time of our investigation the site comprised a disused Outdoor Centre, which contained numerous derelict buildings and large areas of car parking. The open land to the south and east of these buildings comprised overgrown open land with mixed self-sown shrubs and trees along with small areas of woodland and small ponds.

In the centre of the site, to the southeast of the main building, a large raised soil mound, approximately 4-6m in height is situated. Adjacent to the soil mound were further old derelict buildings and what appears to be an old landing stage onto the lake.

7.2 Tier II Groundwater Risk Assessment - Site Investigation – 19th November 2019

A series of trial pits were excavated across the southern section of the site in November 2019 as part of a detailed groundwater risk assessment associated with the proposed use of this area of land as a cemetery.

A total of 7 No. trial pits were excavated across the proposed burial area to provide an assessment of the ground conditions, to identify the presence and composition of made ground soils and to assess whether any shallow groundwater is encountered on site.

The trial pits were excavated at the approximate locations shown below in Figure 15, to maximum depths of 3.3m. In some areas of the site it was difficult to achieve target depths due to the instability of the made ground soils which comprised loose sand.

Figure 15. Exploratory Hole Location Plan

7.3 Soils as Found

The soils encountered across the site were found to be highly variable and in general comprised made ground soils to depth. At the location of TP107, potentially natural soils, comprising laminated sands were encountered to the base of the pit.

A general summary of the soils as found on site is provided in Table 6, detailed soil logs are attached in Appendix A.

Table 6. Soils as Found

TP102, 103, 104 and 105

Depth m bgl (Top to Base)	Soil Type	Description
GL to 1.4m/1.7m	Made Ground	MADE GROUND comprising highly variable reworked orange-brown clay with abundant fine to coarse flint, brick rubble and whole bricks, concrete, black top, plastic, wood and occasional slate fragments. At the location of TP105 large cobble sized concrete rubble was encountered and occasional fragments of **possible bitumen bound asbestos.**

1.4m/1.7m to 2.9m/3.3m	Made Ground	MADE GROUND comprising very loose, poorly compacted, yellowish orange fine to medium SAND. Numerous side wall collapses, and trench instability observed.

TP101 and TP106

Depth m bgl (Top to Base)	Soil Type	Description
GL to 0.15m/0.3m	Topsoil	Dark brown silty fine sandy TOPSOIL.
0.15m/0.3m to 2.0m to 3.0m	Made Ground	MADE GROUND comprising very loose, poorly compacted, yellowish orange fine to medium SAND. Numerous side wall collapses, and trench instability observed.
2.0m to 2.4m	Sand	Wet, saturated pale grey, silty organic fine SAND with occasional shell fragments.

At the location of TP107, potentially natural soils comprising thinly laminated orangish yellow silty fine SAND were encountered. These soils however were still observed to be loose, with multiple side wall collapses observed, which may indicate that these soils were made ground rather than natural.

7.4 Groundwater

Groundwater was only encountered at TP106, which is in close proximity to the lake. In this pit, saturated natural soils were observed below 2.0m bgl. The nature of the water strike was difficult to assess due to trench stability issues leading to repeated side wall collapses and continual backfilling of the trial pit.

7.5 Trench Stability

During the excavation of the trial pits, evidence of significant trench instability was observed within the loose and poorly compacted made ground soils.

Based on the above, even single depth burial excavations for natural burials would be considered difficult, due to the likelihood of large scale side wall collapse. Any excavation will require close lateral support, which should provide sufficient temporary support to maintain the stability of the excavation.

No personnel should enter any excavation before close lateral support is installed due to the risk of collapse. Consideration should also be given to moving grave arisings further back from open excavations to help reduce lateral loads on the side walls of open excavations.

7.6 Geotechnical and Geoenvironmental - Site Investigation – 23rd March 2020 (Pre Covid 19 Lockdown)

Further to the initial investigation works in November 2019, CDS were commissioned to undertake a preliminary geotechnical and geoenvironmental assessment of the land around the existing buildings site to assess the nature of the underlying ground conditions with regards to building and foundation design and to investigate the potential for onsite contamination to be encountered which was identified in the conceptual model.

An intrusive site investigation was undertaken on the 23rd March 2020, with a total of seven windowless sampler boreholes (Orange Triangles) drilled across the site to provide a geotechnical and geoenvironmental assessment of the ground conditions and to investigate whether any shallow groundwater is encountered on site.

In addition to the windowless sampler boreholes, a total of six hollow stem boreholes (Red Triangles) were drilled across the site to enable the installation of groundwater and land gas monitoring wells to assess the impact of groundwater levels on the future burial area and to assess whether the made ground soils identified posed a risk of land gas generation, which could impact on the design of future buildings on site.

The boreholes were drilled at the approximate locations shown below in Figure 16, to maximum depths of 6.00m bgl. The boreholes were distributed across the entire site to assess soil variability, depth to groundwater and to enable future monitoring works.

Figure 16. Exploratory Hole Location Plan

7.7 Geotechnical and Geoenvironmental - Site Investigation – 26th May 2020 (Post Covid 19 Lockdown)

Due to the Covid 19 pandemic and restrictions on working, the second day of the initially planned site investigation works was postponed until the 26th May 2020. The second day of our investigation works comprised a further eight windowless sampler boreholes, drilled across the site to provide a geotechnical and geoenvironmental assessment of the ground conditions.

The additional eight windowless sampler boreholes were drilled at the approximate locations shown below in Figure 17, to maximum depths of 4.00m bgl. The boreholes were distributed across the proposed redevelopment area to assess soil variability and depth to groundwater. Additional boreholes were drilled close to WLS106 and BH2 where a hydrocarbon plume was identified in the first phase of work.

Figure 17. Exploratory Hole Location Plan

7.8 Soils as Found

On review of the 15 windowless sampler boreholes drilled across the site, the identified soil sequence can be essentially divided into two distinct groups – Made Ground arising from the infilling process and natural soils around the former works buildings.

7.8.1 Made Ground

Made ground soils were encountered at the locations of WLS101, 102, 103, 111, 113 and 114. A general summary of the soils encountered is provided in Table 7 below and detailed soil logs are attached in Appendix A.

Table 7. Soils as Found

Depth m bgl (Top to Base)	Soil Type	Description
GL to 0.1m/0.25m	Made Ground	MADE GROUND comprising soft brown silty clay with fine roots and gravel.
0.1m/0.25m to 0.5m/0.7m	Made Ground	MADE GROUND comprising orange brown silty SAND with frequent flint gravel and rare brick fragments.
0.5m to 0.7m (WLS103)	Made Ground	MADE GROUND comprising firm brown organic CLAY.
0.7m to 2.7m/4.45m+	Made Ground	MADE GROUND comprising variable very loose to loose orange brown gravelly fine to coarse SAND.
1.7m/2.7m to 3.45m+ (WLS113 and WLS114)	Sand	Very loose, greenish grey silty fine SAND with frequent pseudofibrous organic material, plant matter, laminations and feint organic odour.
2.9m to 3.5m (WLS102)	Clay	Firm, dark grey mottled brown silty fine sandy CLAY.
3.5m to 4.45m (WLS102)	Sand	Very Dense, dark grey brown gravelly fine to coarse SAND. Gravels comprise fine to coarse subrounded flint.

7.8.2 Natural Soils

The remainder of the boreholes drilled in and around the existing building on the subject site appeared to encounter natural soils, with no clear evidence observed of any reworked material or manmade inclusions observed. The recorded density of the soils observed was however found to vary significantly.

A general summary of the soils encountered is provided in Table 8 below and detailed soil logs are attached in Appendix A.

Table 8. Soils as Found

Depth m bgl (Top to Base)	Soil Type	Description
GL to 0.5m/1.0m	MADE GROUND	Highly variable MADE GROUND soils – see detail in logs
0.5m/1.0m to 1.3m/1.8m	Gravelly Sand	Loose to medium dense, orange brown gravelly fine to medium SAND. Gravels comprise fine to medium subrounded flint.
1.3m/1.8m to 2.3m/2.9m	Sand	Loose to medium dense, orangish yellow silty/clayey fine SAND.
2.1m to 3.05m	Sandy Gravel	Dense, orange brown sandy fine to coarse subrounded to subangular flint GRAVEL.
2.3m/2.9m to 4.45m+	Gravelly Sand	Loose to medium dense becoming dense, orange brown mottled red gravelly fine to medium SAND. Gravels comprise fine to medium subrounded flint.
2.5m to 3.45m	Sandy Clay	Soft, greenish grey mottled grey slightly sandy CLAY.

At the location of WLS106, which was drilled adjacent to BH2 where a hydrocarbon plume was encountered the soils comprised a variable sequence of black stained organic clay to 1.5m bgl with a strong pungent hydrocarbon odour. Below this the soils were found to comprise interbedded layers of fine to medium Sand and fine to medium sandy Gravel. Hydrocarbon staining, odours and potential free product was observed beneath the water table, which was recorded at 2.7m bgl, down to the base of the borehole at 4.00m bgl, where hydrocarbon staining was still apparent.

Windowless sampler boreholes WLS105 (NW), WLS108 (SW), WLS109 (SE) and WLS110 (NE) did not encounter any hydrocarbon impacted materials. Whereas WLS115 (NE) encountered hydrocarbon impact soils below the water table at depths of 2.7m bgl, suggesting that the plume of hydrocarbons is mobile in the groundwater.

At the location of WLS107, which was drilled inside the existing large building, the concrete floor slab was found to be in excess of 600mm thick, with significant 12mm rebar observed at 75mm and 200mm. This suggests that the existing building may have been potentially formed on a reinforced ground bearing floor slab/raft. This correlates with a hand dug foundation exposure pit which was attempted on the outer wall of the same building which encountered brick work associated with the outer wall sitting on a concrete slab down to a depth 0.88m bgl, where the slab then extended out away from the building and was unable to be broken through or excavated past.

7.9 Groundwater

7.9.1 Groundwater Strikes

Table 9 below details the groundwater strikes encountered across the site during our investigation. Groundwater strikes were encountered at all borehole locations.

Table 9. Groundwater Strikes

Location	Water Strike Details
WLS101	Water encountered at 3.2m bgl. Hole backfilled to 3.2m bgl.
WLS102	Water encountered at 2.7m bgl. Hole backfilled to 3.6m bgl.
WLS103	Water encountered at 2.4m bgl. Hole backfilled to 2.5m bgl.
WLS104	Water encountered at 2.4m bgl. Hole backfilled to 2.6m bgl.
WLS105	Water encountered at 3.7m bgl. Hole backfilled to 2.85m bgl.
WLS106	Water encountered at 2.7m bgl. Hole backfilled to 2.8m bgl.
WLS107	Dry – Concrete slab
WLS108	Water encountered at 2.90m bgl. Hole backfilled to 2.50m bgl.
WLS109	Water encountered at 2.90m bgl. Hole backfilled to 2.80m bgl.
WLS110	Water encountered at 3.30m bgl. Hole backfilled to 2.80m bgl.
WLS111	Water encountered at 3.43m bgl. Hole backfilled to 3.30m bgl.
WLS112	Water encountered at 2.30m bgl. Hole backfilled to 2.30m bgl
WLS113	Water encountered at 1.70m bgl. Hole backfilled to 1.90m bgl.
WLS114	Water encountered at 1.70m bgl. Hole backfilled to 1.30m bgl.
WLS115	Water encountered at 2.70m bgl. Hole backfilled to 2.30m bgl.

7.9.2 Groundwater Monitoring Wells

As part of the works, and as discussed in Section 7.6 a total of six groundwater monitoring wells were installed across the site to assess the depth to groundwater. The following table details the water levels within these monitoring wells on completion.

Table 10. Groundwater Strikes

Location	Water Strike Details
BH1	Water level on completion = 2.93m bgl
BH2	Water level on completion = 2.81m bgl. Significant hydrocarbon contamination encountered.
BH3	Water level on completion = 3.27m bgl
BH4	Water level on completion = 3.57m bgl
BH5	Water level on completion = 3.45m bgl
BH6	Water level on completion = 3.34m bgl

7.10 Trench Stability

Open excavations are likely to be unstable due to the influx of shallow groundwater and associated running sands, which would lead to undercutting of side walls and potential side wall collapses. It is possible that during the drier summer months the volume of water in the shallow soils may decrease significantly leading to more stable ground conditions. Trench instability was discovered in earlier intrusive investigations in both the natural and reworked granular deposits. In any excavation where personnel must enter, a risk assessment should be undertaken to assess whether the works could be achieved by using an alternative method. If not, close lateral support will be required and dewatering of excavations from sumps would also be required.

8 Groundwater and Land Gas Monitoring

8.1 Groundwater Monitoring

A series of six groundwater and land gas monitoring wells were installed across the site to assess the depth to groundwater and to undertake groundwater monitoring to assess potential variations in groundwater levels with respect to the suitability of the site for burials. The table below summarises the maximum and minimum depth to groundwater at each borehole location in terms of m bgl and m AOD, and the observed variance in groundwater levels. The raw data along with graphs of the water levels is attached in Appendix E.

Table 11. Groundwater Monitoring Data

Location	Water Level m bgl		Water Level m AOD	
	Minimum	Maximum	Minimum	Maximum
BH1	2.93m bgl	3.5m bgl	-0.95	-1.52
BH2	2.81m bgl	3.3m bgl	-0.99	-1.48
BH3	3.27m bgl	3.8m bgl	-1.05	-1.58
BH4	3.57m bgl	4.0m bgl	-0.94	-1.37
BH5	3.45m bgl	3.9m bgl	-0.85	-1.3
BH6	3.3m bgl	3.8m bgl	-0.67	-1.17

In general, the results of the groundwater monitoring from across the site indicates that any proposed burials, which we understand would be in the southern part of the site, would be considered suitable in terms of depth to groundwater. As a 1.4m burial depth would provide at worst case, an unsaturated zone of at least 1.9m considering the lowest minimum value for boreholes 4, 5 and 6 which were drilled on site within the proposed burial area. Given the permeability of the sandy soils in this area, this unsaturated zone would provide a degree of protection to the underlying water table. The suitability of the site in terms of burials is contained in a detailed T2 Groundwater risk assessment undertaken by CDS in November 2019 and subsequently updated and amended in July 2020 with the results of the subsequent monitoring data from this investigation.

8.2 Land Gas Monitoring

The Conceptual model identified the potential for land gas generation due to the identified made ground soils arising from the infilling of the former quarry. Accordingly, a series of boreholes were installed across the site, to provide general coverage. The borehole locations are shown in Figure 16.

The sensitivity of the site was considered to be low due to the proposed commercial end use, and the generation potential of the source material was assumed to be moderate, given the observed variation in fill material. On this basis, a series of 6 land gas monitoring visits were undertaken over a 3 month period to provide an initial assessment of the risk of land gas.

The results of the land gas monitoring are appended in full in Appendix E, and summarised in the table below:

Table 12. Land Gas Monitoring Results

Monitoring Parameters	BH1	BH2	BH3	BH4	BH5	BH6
Atm. Pressure (mb)	995 - 1034	995 - 1034	995 - 1034	995 - 1034	995 - 1034	995 - 1034
Borehole Pressure (Pa)	-0.4 to -0.8	0.3 to -1.0	-0.4 to -0.8	0.2 to -0.8	0.3 to -0.7	0.3 to -0.7
Flow Rate (l/hr)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PID (ppm)	1.2 to 6.6	6.5 to 49.0	1.0 to 6.0	0.4 to 3.6	1.8 to 6.6	1.1 to 2.3
Methane (%)	<0.1	0.1 to 0.2	<0.1	<0.1 to 0.1	<0.1	<0.1
Carbon Dioxide (%)	1.9 to 3.1	5.6 to 9.4	0.8 to 1.6	0.4 to 0.5	1.9 to 2.7	3.1 to 5.4
Oxygen (%)	18.2 to 19.4	0.2 to 13.3	19.0 to 19.8	19.8 to 20.5	17.7 to 19.1	16.1 to 18.4
Carbon Monoxide (ppm)	0 to 2	0 to 1	0	0 to 1	0	0 to 1
Hydrogen Sulphide (ppm)	0	0	0	0	0	0

8.2.1 Land Gas Monitoring Assessment

The results of the land gas monitoring as shown in Table 12 above has indicated that at the location of BH2 and BH6, the concentrations of Carbon Dioxide have exceeded the 5% threshold value, however at the remainder of the borehole locations the volumes of land gases recorded were found to be low.

Table 13 below summarises the hazardous gas flow rate for each borehole location for Carbon Dioxide only, as the concentrations of others land gases such as methane, were not observed to be elevated. Due to the low flow rates recorded during the monitoring visits, we have assumed a flow rate equal to that of the machines limited of detection (0.1l/hr) for the calculation of the GSV.

Table 13. Land Gas Monitoring Assessment

Monitoring Parameters	BH1	BH2	BH3	BH4	BH5	BH6
Flow Rate (l/hr)	0.1	0.1	0.1	0.1	0.1	0.1
Maximum Carbon Dioxide (%)	3.1	9.4	1.6	0.5	2.7	5.4
Maximum Gas Flow Rate (GSV)	0.0031	0.0094	0.0016	0.005	0.0027	0.0054
Characteristic Situation (CS)	CS1	CS2	CS1	CS1	CS1	CS2

The results of the land gas monitoring have indicated that the site in general is considered to be low risk. The CS value at BH2 and BH6 have been increased to CS2, as whilst the calculated GSV falls below the CS1 classification, the maximum concentration of CO2 exceeds the 5% threshold.

8.2.2 Assessment of Gas Protection Measures

Under the guidance of the BS8485:2015, the site is considered to fall under a Type C building (Commercial/Public). Given that at the location of BH2 and BH6, the CS value was increased to CS2 due to the increased carbon dioxide concentrations, it is reasonable to assume a worst case scenario and determine that the entire site be considered CS2, which means that the proposed building will require 2.5 points in its gas protection score.

These points can be accumulated based on the construction style of the proposed building in a series of sections:

- Structural Barrier (floor slab style)
- Ventilation/Dilution (passive vs active ventilation)
- Gas Membrane (membrane vs no membrane)

An initial assessment, based on traditional construction techniques for a crematorium style building would suggest that the development would not score higher enough on the floor style and underfloor ventilation alone and that a basic land gas membrane will be required as part of the construction of the building.

In addition to the basic land gas membrane, there is a potential requirement for a hydrocarbon resistant membrane due to the identified hydrocarbon hotspot at the location of BH2/WLS106 which is discussed in Section 10 of this report.

9 Preliminary Geotechnical Assessment

9.1 Foundation Design

A series of fifteen windowless sampler boreholes (WLS101-WLS115) were drilled across the site to assess the nature of the ground conditions, investigate potential sources of onsite contamination and to attempt to delineate between areas of natural ground around the former works buildings and the made ground soils arising from the importation of reject sand. The aim of the investigation was to determine if any new proposed structure could be positioned on natural soils which may have sufficient bearing capacity to facilitate a traditional shallow foundation solution, or whether a piled foundation is required.

The approximate extent of the natural ground as shown in Figure 18 below, has been found to be very limited and would severely restrict the placement of a new building on site in areas to achieve a traditional foundation solution versus a piled foundation solution. In addition, any new crematorium would need to be placed 50 yards back from the highway (45.7m) which effectively pushes the proposed building off the natural soils and back onto the made ground soil.

Natural ground, which was found to be generally loose to medium dense based on insitu test results has been recorded in the green triangles whereas made ground, which was generally loose to very loose has been recorded in orange triangles.

Figure 18. Natural Ground vs Made Ground

Standard penetration tests (SPT's) were undertaken at various depths in target borehole locations. Detailed soil logs and Insitu test results are attached in Appendix A.

The results of the standard penetration tests or both the natural ground and made ground are shown in Table 14 below, with the maximum, minimum and average 'N values'

Table 14. SPT N Values

Test Depth (m bgl)	Made Ground SPT Results (N Value)	Natural Soil SPT Results (N Value)
1.0	Maximum = 12, Minimum = 2, Average = 7	Maximum = 19, Minimum = 6, Average = 11
2.0	Maximum = 6, Minimum = 0, Average = 3	Maximum = 33, Minimum = 8, Average = 14
3.0	Maximum = 4, Minimum = 0, Average = 2	Maximum = 38, Minimum = 0, Average = 17
4.0	Maximum = 2, Minimum = 0, Average = 1	Maximum = 50, Minimum = 49, Average = 50

9.1.1 Natural Soils

Based on the results on the insitu tests carried out in the natural soils to date, shallow traditional foundations such as strip/pad/trench would be considered suitable. Foundations would need to be placed in the loose to medium dense, natural sandy soils above the underlying ground water table (greater than 2m bgl). Based on the averaged 'N values' an allowable bearing capacity of between 90kPa to 110kPa could be considered. Due to the observed variability in the density of the soil, we would also recommend the inclusion of nominal mesh reinforcement to help reduce the effects of potential differential settlement.

Open excavations in the sand are likely to be unstable and allowance should be made for close lateral support of all excavations.

9.1.2 Made Ground Soils

Based on the results on the insitu tests carried out to date, the highly variable ground conditions, and low recorded allowable bearing capacities where the made ground soils are encountered, these areas of the site are not considered to be suitable for traditional spread load foundations. This is due to the observed variability and likely differential and ongoing settlement that would be encountered, especially in areas where increased localised loading are situated such as the plant room. In addition, the observed shallow groundwater table, and loose nature of the soils would likely cause trench stability issues and need for dewatering of open excavations would also make forming spread load foundations difficult.

Based on this, our recommendation would be to consider an alternative foundation solution such as piling. Further deeper cable percussive boreholes would be required to provide preliminary pile design parameters.

Alternatively, consideration could be given to ground improvement techniques such as:

- Vibrostone Columns
- Dynamic Compaction
- Vibro compaction

9.2 Floor Slabs

Consideration could be given to the use of either a suspended floor or a reinforced ground bearing floor slab combined with either ground improvement techniques or a mini piled foundation solution. However, the proposed floor slab loading will influence the type of floor slab which could be utilized.

A suspended floor slab may be considered suitable in areas where a low bearing capacity is anticipated, whereas in areas with heavy point loads, such as the cremator plant room, a reinforced ground bearing floor slab with a mini piled foundation solution would be better suited.

9.3 Settlement

Settlement is likely to be highly variable across the site, due to the nature of the loose imported fill material and the denser nature soils. Where the natural medium dense sand and gravels are encountered, settlement is expected to be within tolerable limits (<25mm) based on the loadings given above. Where localised increased loads are anticipated, such as the cremator plant room, settlement assessments should be carried out to ensure that the increased loads do not lead to differential movement.

Settlement in the made ground soil is however likely to be significant and variable, as such, if any structures are to be constructed on these soils some form of ground improvement or special foundation measures such as piling would be required to ensure that settlement is with tolerable limits and does not cause significant damage to any buildings or sensitive equipment.

9.4 Roads

Given the variability of the soils observed and the presence of loose soils associated with the backfilled reject sand it is likely that any roads and areas of formal car parking will require excavating down to a depth of approximately 1m below finished level. The excavated soils, assuming reject sand and no pockets of unsuitable organic material or rubbly made ground are encountered, is considered suitable to be re-used to form the subgrade for the road. The reject sand would however need to be placed in layers and proof rolled to achieve the required compaction and CBR value.

9.5 Drainage

Preliminary falling head soakage tests were carried out in monitoring wells installed on site. The water levels during the test fell rapidly (less than 60 seconds) back to the back groundwater levels which were measured before the start of the test. This suggests that both permeable paving and soakaways will function well as part of any future drainage strategy. Once a design has been finalised, gravel filled BRE365 tests will need to be undertaken at the location of the proposed soakaway to provide an accurate design rate.

As the water levels across the site have been measured to be around 3m bgl at the highest point, soakaways will need to be kept shallow (<2m), to prevent direct discharge into the underlying groundwater table. This will reduce the effective storage volume of the soakaways and would mean that a shallower crate system would likely perform better than traditional ring soakaways.

Where soakaways are to be placed into the made ground soils there is a significant risk that the concentration of water discharge into loose sand will lead to inundation settlement, leading to potential damage to areas of hardstanding above or buildings. As such soakaways should be kept remote from proposed buildings are areas of hardstanding to reduce the risk of damage to structures and to enable remedial works to be undertaken.

10 Preliminary Environmental Assessment

10.1 Analytical Assessment Criteria

CDS have undertaken the contamination assessment based on the Source – Pathway – Receptor risk assessment methodology.

Soil screening values have been utilised where possible from the CLEA model (Updated Technical Background to the CLEA Model, 2009), which utilises toxicological data to calculate a Soil Guidance Value or SGV, which can be used as a screening value based on the proposed end use of the site (i.e residential/commercial/industrial).

Where an SGV is not available for a given substance, a screening value is derived based on guidance including the LQM/CIEH S4UL's for Human Health Risk Assessment (2014) and The EIC/AGS/CL:AIRE Soil Generic Assessment Criteria for Human Health Risk Assessment (2009).

Screening values for the identified contaminants are valid at the time of writing and any assessment of on site contamination is made against these published figures at the time of writing. Any changes to the proposed end use or published changes to screening values dated after the issue of this report would invalidate any assessment and recommendations made here within.

10.2 Environmental Sampling

The aim of this preliminary investigation and subsequent sampling was to provide coverage around the area of the site where the proposed redevelopment works are to take place. This area is in and around the existing buildings on the central eastern boundary of the site, where the former works buildings were situated.

10.3 Environmental Testing

Our walkover survey and preliminary conceptual model identified that the site has been backfilled following initial quarrying works.

Potential sources of onsite contamination in the form of unknown made ground soil was identified which could contain a wide range of contaminants including Asbestos, Heavy Metals, Hydrocarbons and PAHS.

The following tests were undertaken on both made ground and natural soil to assess the potential presence of onsite contamination.

- Heavy Metal Screen - (6 made ground samples, 2 natural soil samples)
- PAH's -USEPA 16 - (6 made ground samples, 2 natural soil samples)
- Asbestos Screen- (6 made ground samples, 2 natural soil samples)
- Hydrocarbon Testing
    - EPH - (3 natural soil samples)
    - TPH CWG - (5 natural soil samples)
    - VOC's - (5 natural soil samples)

10.4 Environmental Test Result Analysis – Heavy Metals, PAH's and Asbestos

10.4.1 Soil Type – Made Ground

A total of six samples of made ground from around the proposed development area were sampled and screened for the range of contaminants identified above. The full results are included in Appendix D and are summarised in the table below:

Table 15. Made Ground – Contamination Results

Determinand	Unit	Number of Samples	Mean	Range	Screening Values (Commercial/Industrial)
Heavy Metals					
Arsenic	mg/kg	6	22.67	17.0 – 28.0	640
Cadmium	mg/kg	6	<0.2	<0.2	190
Chromium	mg/kg	6	22.83	17.0 – 33.0	8600
Copper	mg/kg	6	15.93	8.6 – 19.0	100
Lead	mg/kg	6	17.96	7.8 - 25	2330
Mercury	mg/kg	6	<0.3	<0.3	29 - 320
Nickel	mg/kg	6	27.3	21.0 – 32.0	60
Selenium	mg/kg	6	<1.0	<1.0	12000
Zinc	mg/kg	6	52.3	31.0 – 69.0	200
PAH's					
Naphthalene	mg/kg	6	<0.5	<0.5	77 – 430
Benzo[a]pyrene	mg/kg	6	0.77	<0.05 – 1.3	36
Total PAH's	mg/kg	6	6.5	<0.8 – 14.8	-
Other					
Asbestos Screen	-	6	-	None detected (ND)	-

The results of the contamination testing have identified no elevated concentrations of heavy metals, PAH's or asbestos above the site specific screening values for Commercial/Industrial land use. As such, based on the results from the soils tested to date, there would be no requirement for any remedial measures for the redevelopment of the site with regards to the Source – Pathway – Receptor risk assessment methodology.

However, there remains the chance to encounter unforeseen pockets of contamination during demolition and construction works which may potentially be contaminative and would require assessment and specific remedial requirements would be put in place as part of a discovery strategy.

10.4.2 Soil Type – Natural Soil

Two samples of natural soil from WLS108 @ 1.5m and WLS109 @ 0.4m were sampled and screened for the range of contaminant identified above.

The results of the contamination testing have identified no elevated concentrations of heavy metals, PAH's, and asbestos above the site specific screening values for Commercial/Industrial land use.

10.5 Environmental Test Result Analysis – Hydrocarbons

During the drilling and installation of the groundwater monitoring well at BH2, significant hydrocarbon contamination was observed from a depth of 0.5m bgl, with visual staining, free product and strong odour. An additional windowless sampler borehole, WLS106, was drilled adjacent to the monitoring well at BH2 to enable accurate logging and sampling of the hydrocarbon plume.

In order to undertake a preliminary assessment of the extent and direction of the hydrocarbon plume, additional boreholes were drilled to the south (WLS108), east (WLS109), west (WLS104) and north (WLS115).

10.5.1 Soil Type – Natural Soil

During the excavation of BH2, significant hydrocarbon contamination, with observed free product and strong odorous material was encountered. An additional borehole, WLS106 was drilled adjacent to the monitoring well to undertake discrete sampling of the observed hydrocarbon pollution at various depths.

The table below summarises the results of the testing from WLS106 against the 2014 LQM values assuming a worst case 1% SOM value.

Table 16. Hydrocarbon Testing

Determinand	Unit	WLS106 @1.0m	WLS106 @1.75m	WLS106 @ 2.7m	WLS106 @ 3.3m	WLS115 @2.7m	Screening Values (Commercial/ Industrial)
Benzene	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
Toluene	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
Ethylbenzene	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
p & m-xylene	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
o-xylene	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
MTBE (Methyl Tertiary Butyl Ether)	µg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-
TPH-CWG - Aliphatic >EC5 - EC6	mg/kg	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	3200
TPH-CWG - Aliphatic >EC6 - EC8	mg/kg	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	7800
TPH-CWG - Aliphatic >EC8 - EC10	mg/kg	< 0.001	4.8	0.74	1.4	< 0.001	2000
TPH-CWG - Aliphatic >EC10 - EC12	mg/kg	8.0	460	47	75	24	9700
TPH-CWG - Aliphatic >EC12 - EC16	mg/kg	71	3500	510	990	770	59000
TPH-CWG - Aliphatic >EC16 - EC21	mg/kg	130	4400	630	1300	1000	160000
TPH-CWG - Aliphatic >EC21 - EC35	mg/kg	82	2000	650	990	860	160000
TPH-CWG - Aliphatic (EC5 - EC35)	mg/kg	290	10000	1800	3300	2700	-

TPH-CWG - Aromatic >EC5 - EC7	mg/kg	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	26000
TPH-CWG - Aromatic >EC7 - EC8	mg/kg	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	56000
TPH-CWG - Aromatic >EC8 - EC10	mg/kg	< 0.001	1.4	0.52	0.61	< 0.001	3500
TPH-CWG - Aromatic >EC10 - EC12	mg/kg	1.2	190	2.4	34	3.7	16000
TPH-CWG - Aromatic >EC12 - EC16	mg/kg	43	2600	140	780	440	36000
TPH-CWG - Aromatic >EC16 - EC21	mg/kg	53	4700	250	1500	1000	28000
TPH-CWG - Aromatic >EC21 - EC35	mg/kg	34	3400	270	1400	1200	28000
TPH-CWG - Aromatic (EC5 - EC35)	mg/kg	130	11000	660	3700	2700	-

The results of the testing, when compared to the commercial/industrial screening values indicate that the levels of contamination identified would not be considered a risk to the proposed development based on a commercial/industrial end use. The recorded concentrations would also pass screening against the more stringent Public Open Space Park screening value.

We would however recommend that the identified hotspot is further investigated and delineated to ensure that the source of the hydrocarbon contamination is accurately identified and the source material remediated. This would remove the risk of the contamination from impacting the future development of the site and from further polluting the underlying groundwater table.

10.5.2 Groundwater

A single sample of groundwater was taken from BH2 during a groundwater monitoring visit. Prior to sampling the borehole was measured with an interface meter, no discernible free product of either LNAPL or DNAPL was recorded prior to the borehole being sampled.

The results of the groundwater sample taken from BH2 are attached in full in Appendix D and in general no elevated concentrations of BTEX or MTBE were recorded above the detectable limit (<1.0ug/l). The results of the banding indicates that the substance recorded in the groundwater was predominantly in the Aliphatic C12-C35 range (170000ug/l) and a smaller proportion of C12-C35 Aromatic compounds (34000ug/l).

The results of the groundwater sample from BH2 broadly match the signature of the compound encountered in the soils at WLS106, suggesting that the source of the groundwater contamination is likely to be the identified point source at the location of WLS106.

Further detailed investigation will be required to accurately define the extent and impact caused by the observed pollution at WLS106 and will best be undertaken post demolition. A remedial strategy can then be implemented to remove the identified source material and undertake remediation of the groundwater if proven to be required.

10.6 Summary of Results

The results of the contamination testing in both the shallow topsoil, made ground soils and the underlying natural soil has identified no elevated concentrations of heavy metals, PAH's and asbestos the site specific screening values for Commercial/Industrial land use.

Hydrocarbon contamination was encountered at the location of BH2 and WLS106 in both the groundwater and the soils which will need further investigation and assessment post demolition.

The results of the land gas monitoring has identified elevated concentrations of carbon dioxide above the 5% threshold value and as such any proposed development on site will require land gas precautionary measures to be installed.

11 Revised Conceptual Model

Based on the results of the investigation and subsequent land gas monitoring and contamination testing the initial site conceptual model has been reviewed and revised to reflect the findings of the investigation.

Table 17. Revised Conceptual Model

Source	Pathway	Receptor	Calculated Risk
Onsite/Offsite contamination arising from current and historical land use	Direct ingestion, direct contact & inhalation of dust/ vapours.	Future Site users.	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume. Further detailed investigation and remedial works will be required to reduce/remove the risk to future end users in line with the sites end use (Commercial/Industrial)
		Construction workers.	The calculated risk is deemed to be moderate to high based on the potential for onsite contamination to be encountered especially during the demolition phase of the works The provision of suitable PPE/RPE during the demolition/construction phase along with detailed method statements and risk assessments would be required to reduce/remove the risk to construction workers to appropriate levels.
	Leaching and vertical & lateral migration	Controlled waters	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume.

Source	Pathway	Receptor	Calculated Risk
			Further detailed investigation and remedial works will be required to reduce/remove the risk to controlled waters
	Direct infiltration in water supply pipes.	Service conduits	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume. Services and incoming pipework will need to be designed in accordance with the suppliers specifications based on the level of identified contamination on site.
	Plant uptake.	Vegetation within landscaped areas.	The calculated risk is deemed to be low based on the results of the contamination testing to date.
	Lateral migration through groundwater	Off-Site neighbouring properties.	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume. Remedial works will be required to reduce/remove the risk to offsite receptors subject to consent and approval.
Potentially contaminated groundwater (onsite or offsite)	Direct ingestion, direct contact & inhalation of dust/ vapours.	Future Site users.	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume. Remedial works based on the identified contamination would be required to reduce/remove the risk to future end users in line with the sites end use (Commercial/Industrial)
	Leaching and vertical & lateral migration	Controlled waters (watercourses including field drains)	The calculated risk is deemed to be moderate due to the identified hydrocarbon plume. Remedial works will be required to reduce/remove the risk to offsite receptors subject to consent and approval.
Potential for ground gas	Vertical and lateral migration	Human Health and buildings	The calculated risk is moderate due to the elevated concentrations of Carbon Dioxide recorded above the 5% threshold limit. Recommendations have been given to the inclusion of land gas precautionary measures in proposed new buildings in accordance with CS2 requirements

12 Conclusion

The made ground soils encountered on site are considered to be unsuitable for a traditional foundation solution due to low bearing capacities, differential settlement, and shallow groundwater. Recommendations have been given to include the use of a piled foundation solutions or ground improvement techniques such as dynamic compaction or vibro compaction.

Further works will be required in order for the structural engineers to provide a foundation proposal for the development which would include deeper boreholes and geotechnical testing. Consultation with specialist ground improvement companies should be carried out to assess the economic viability of the various techniques which could be utilized.

Land gas monitoring has identified elevated concentrations of carbon dioxide above the 5% threshold limit and accordingly land gas precautionary measures will be required in the proposed buildings to be constructed on site.

The results of the contamination testing from both the topsoil, made ground and natural soils has shown that the site is generally considered to be free from significant contamination. Further investigation works and a discovery strategy should be put in place during demolition works to address unforeseen pockets of contamination.

A hydrocarbon plume has been identified at the location of WLS106 and BH2, which appears to be spreading to the east towards WLS115. The results of the contamination testing indicate significant concentrations in both the soils and the underlying groundwater and are indicative of a diesel type heavy end fuel product. Further detailed assessment and investigation works will be required to further investigate the source of the hydrocarbon contamination and provide a remedial strategy for the clean-up of the soils and groundwater.

13 Reporting Details

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