APPENDIX E: GEOTECHNICAL ASSESSMENT REPORT

Geotechnical Feasibility Report

Project Name

Downpatrick Eastern Distributor Road

Project Proposals

This geotechnical feasibility assessment has been produced to identify the high level ground engineering constraints relating to the carriageway alignment option for the proposed eastern distributor road link in Downpatrick.

A summary of the proposed scheme activities are presented in Table 1.

Table 1: Proposed scheme construction activities

Alignment Section	Alignment Length	Construction Activity
1. From proposed roundabout at Rathkeltair Rd to proposed roundabout 20m south of Saul Rd.	1050m	• New Carriageway, • Earthworks – embankments and cuttings.
2. From proposed roundabout 20m south of Saul Rd to proposed roundabout at Ballyhoran Rd.	1430m	• New Carriageway, • Earthworks – embankments and cuttings. • Culverts.
3. From proposed roundabout at Ballyhoran Rd to existing Struell Wells Rd.	365m	• New Carriageway, • Earthworks – embankments and cuttings.

Sources of Information

1. Geological Survey Northern Ireland, GSNI http://maps.bgs.ac.uk/gsni_geoindex/
2. Rivers Agency, *Flood Maps Northern Ireland:* http://www.dardni.gov.uk/strategic-flood-map-ni
3. Department of Enterprise, Trade and Investment, DETI, Mining Information: http://www.explorationandmining.com/
4. Department for Communities (DfC), Historic Environment Map Viewer https://www.communities-ni.gov.uk/services/historic-environment-map-viewer
5. Department for Communities (DfC), Northern Ireland Sites and Monuments Record http://appsc.doeni.gov.uk/ambit/
6. Public Records Office Northern Ireland, PRONI Historical Map Viewer https://apps.spatialni.gov.uk/EduSocial/PRONIApplication/index.html
7. Design Manual for Roads and Bridges (DMRB) Volume 4 Section 1 Part 1 HD22/08. Geotechnics and Drainage. Earthworks. Managing Geotechnical Risk

Published Geology

Examination of the GSNI Geoindex geological 1:250 000 scale maps [ref 1] indicate the site to be underlain be the following geological sequence:

Table 2: Summary of Ground Conditions

Strata		Typical Material Description
Drift	Glacial Till	Variable lithology, usually sandy, silty clay with pebbles, but can contain gravel-rich, or laminated sand layers.
Solid	Gala Group Sandstone	Graded beds that may include wacke sandstone, siltstone and mudstone.
	Hawick Group Sandstone	Fine- to medium-grained Sandstone with locally includes coarse-grained detritus and mudstone intraclasts.

The proposed alignment from Saul Rd to Rathkeltair Rd is recorded to be underlain by Gala Group Sandstone with no overlying superficial drift deposits.

The proposed alignment from Saul Rd to Struell Rd is recorded to underlain by superficial deposits of Glacial Till over Hawick Group Sandstone Bedrock.

Extracts of the geological maps are provided as Figure 1 and 2.

Hydrogeology

The GSNI website [ref 1] designates the site to be within a class 5/4c for groundwater vulnerability. A vulnerability of class 5 indicates the groundwater to be vulnerable to most water pollutants with rapid impact in many scenarios. Class 4c indicates the aquifer on site lies beneath low permeability cover and being vulnerable to those pollutants not readily adsorbed or transformed.

Bedrock underneath the site is recorded as a class Bl(f) aquifer: (Limited potential productivity, fracture flow). Moderate yields unusual. Low yields more common. Regional flow limited. Mainly shallow, local flow. The superficial deposits are recorded as not having aquifer potential.

Hydrology

The NIEA Flood Map [ref 2] records the proposed scheme to fall within an area prone to surface water flooding impacting predominately from the Saul Rd to Struell Rd section of the scheme with three ponds presented on the OS map to the west of the proposed alignment near Ballyhoran Rd.

Mining/Quarrying

The Department of Enterprise, Trade and Investment (DETI) website [ref 3] and GSNI GeoIndex [ref 1] were reviewed. Both websites indicate there is no historic mining data within the vicinity of the site and there is no current mining licencing for the area surrounding the site

Environmental Information

The DfC historic Environment viewer [ref 4] records two historic site / monument entries which could potentially lie within (or in very close proximity) to the proposed site extents. A site referred to as ‘2 mounds’ is shown approximately half way between the Saul Rd and Rathkeltair Rd in the vicinity of the proposed alignment. The Northern Ireland sites and monuments record (NISMR) [ref 5] entry describes the site as: ‘Two mounds near the summit of a hill are in all probability natural. The SE slopes of the hill show outcropping shale. The two mounds appear to be undulations in the bedrock’.

A site referred to as ‘mound’ is shown approximately along the scheme alignment between the Ballyhoran Rd and Saul Rd. The NISMR [ref 5] entry describes the site as: ‘On low-lying ground adjacent to a marshy area, formerly a

lake, with good views all round. This appears to be a wholly, or at least partially, natural mound which may have been used as a habitation area. The top of the mound is a platform 27m NW-SE x 26m NE to a hedge at SW, probably 30m in total. Bedrock is visible in places, although the sides of the mound appear to be of earth & stone. On the 1834 OS 6" map, it is marked "Fort" & is shown on the 1860 edition as a circular bank'.

Another 2 historic sites are recorded near the proposed scheme extents. A former gasworks is recorded adjacent to the Struell Wells Rd, north of the present day location of Downe Hospital.

A historic well site is recorded along the Ardfern Rd near the boundary fence of house no.8. The site is known as 'Tobernasool Eye Well'. The record for site describes 'The area of the well is now obscured by debris in the form of masonry blocks & planks of wood. The site was visited for treatment of eye ailments'.

Historical Land Use

Historical maps between 1832 and 1969 available online from Public Records Office Northern Ireland (PRONI) [ref 6] were reviewed to ascertain the historical development of the site and determine any geotechnical and/or environmental constraints to development.

A summary of the historical changes in the area surrounding the site is presented in Table 3.

Table 3: Summary of Historical Maps

Year / Origin	Significant change in Land Use
OSNI Historical 1st Edition (1832 – 1846)	Site is located to the east of Downpatrick town. The town covers a similar area to that of present day Downpatrick. The site is within a rural setting. The Townlands of Saul, Kilavees and Struell are marked on the map. The Saul, Ballyhoran and Rathkeltair Road are visible on the map though unnamed. The Struell Wells Rd is also visible (unnamed on map) though the alignment is slightly different to the present day alignment. There are a number of farmhouses and associated out building in and around the scheme extents. A fort is shown approximately half-way between Ballyhoran Rd and Saul Rd. Three ponds are shown near the scheme extents between Ballyhoran and Saul Rd.
OSNI Historical 2nd Edition (1846 – 1862)	No significant change.
OSNI Historical 3rd Edition (1900 – 1907)	Site remains within a rural setting. A Gas Works is located adjacent to the west of the Struell Wells Rd. A Reservoir and a 'Lunatic Asylum' are also located adjacent to the Struell Wells Rd. 'Quarries' are shown to the south of the Rathkeltair Rd – Saul Rd section of the proposed scheme.
OSNI Historical 4th Edition (1905 – 1957)	No significant change.
OSNI 6 inch to 1 mile Irish Grid (1952 – 1969)	No significant change.

Contamination Potential

The potential for encountered contaminated material is considered low. The scheme falls within mainly agricultural land. However the historic maps indicate there was a Gas works adjacent to the Struell Wells Road and though it no longer exists it may pose a potential source of contamination. There is also the potential for encountering contaminates associated with made ground material from existing highway infrastructure.

Preliminary Engineering Assessment

Pavement Construction

A large proportion of the proposed carriageway alignment will be constructed at-grade or comprise minimal earthworks to establish pavement formation level. Subgrade conditions directly underlying the pavement construction will predominately comprise of Glacial Till material. Glacial Till will generally provide a suitable formation/founding material for the construction of pavement without the requirement of ground improvement. It is likely that this material will provide a suitable subgrade material with CBR values in excess of 2.5%.

Ground improvement to improve subgrade conditions is likely to be required where recent deposits of fluvial material are present, associated with surface water features, or made ground material is encountered.

The proposed sub-grade level for highways design should be confirmed at a preliminary design stage and an allowance should be made for removal of soft or loose material from the subgrade formation level.

Structures (culverts)

Existing drainage channels are present along site area. These surface water courses may require the land around them to be raised and culverted to allow the proposed carriageway to bridge them.

Firm to stiff clay (Glacial Till deposits) should largely provide a suitable formation/foundation stratum for proposed culverts, headwalls and wingwalls.

For these lightly loaded structures it is anticipated that shallow foundations could be adopted within the fill that will be placed to raise site levels. For preliminary purposes an allowable bearing capacity between of 50 and 100 kN/m^2 may be acceptable subject to the assessment overlying permanent and transient loads, settlement criteria and design tolerances.

It is not envisaged that a chemically aggressive environment is present within the scheme area. However, sulphate testing to assess levels of chemical attack for concrete design will be required during the design stage. This should be conducted in accordance with BRE Special Digest 1.

Earthworks

Earthworks in the form of cuttings and embankments will be required to cater for the significant difference in ground levels along the proposed alignment.

The material classification and acceptability of the Glacial Till deposits will be of greater importance during construction as they are likely to form new cut slopes and be used as a source of fill in the construction of embankments.

Glacial Till material is deemed adequate for the direct re-use as fill without the requirement for drying or secondary mixing and is likely to be classed as ‘Class 2 Material (General Cohesive Fill)’ as defined in Table 6/1 of The Specification for Highway Works, Series 600.

It is anticipated that recent deposits and made ground material will not be a significant source of fill material during earthwork activities. However, it is likely that the proposed alignments will encounter this material during construction and handled as an unacceptable earthworks material.

All material to be excavated and re-used for earthworks material will require classification in accordance with Series 600 of MCHW Vol 1. Confirmatory geotechnical testing and a full earthworks specification will be required prior to construction.

It is anticipated that the cuttings will be constructed through Glacial Till deposits for the majority of the proposed works. Where cut slopes are formed above the groundwater table, a minimum safe long term design cut slope

gradient of 1(vertical):2(horizontal) is recommended for preliminary design purposes. The design of the cut slopes should consider the presence of sand lenses may occur within the Glacial Till which may reduce stability of the slopes as they provide groundwater flowpaths.

The presence of shallow bedrock material should be considered during preliminary earthworks, notably regarding the rippability of rock material and re-use potential as part of the earthworks balance assessment.

The use of site-won material may account for a large proportion of embankment fill material from the Glacial Till deposits. For preliminary design purposes it is recommended that embankment slope angles of 1(vertical):2.5(horizontal) for embankments up to 2.5 metres in height and 1(vertical):3(horizontal) for embankments exceeding 2.5 metres in height are considered.

The Glacial Till (firm to stiff clay) deposits should also provide a suitable formation/founding material for the construction of any embankments depending upon the loads and settlement tolerances.

Stability and settlement analyses will be required in order to ensure that adequate factors of safety are maintained both during construction and for the long term condition. The presence of loose or soft material beneath the proposed embankments may require removal and replacement with a suitable fill material or ground treatment undertaken prior to construction of the embankment. Should there be a requirement for the embankments to be founded directly on loose/soft material the placement of geogrids should be considered.

If groundwater or perched water is encountered at embankment founding levels, pre-earthwork drainage measures should be installed accordingly. It is likely that drainage blankets and/or starter layers will be required in areas prone to flooding or having very high groundwater levels. Additionally 1m trench drains may be required along the toe of embankments.

A preliminary geotechnical design risk register has been presented in table 4 for the proposed scheme, qualitatively summarising potential geotechnical risks identified at this desktop study stage.

Recommendations

Subject to approval of this scheme option and proposed route alignment, it is recommended that the requirements of DRMB Volume 1 Section 1 Part 1 HD 22/08 [ref 7] be followed at every key stage.

HD 22/08 [ref 7] sets out the procedures to be used during the process of planning and reporting of all Geotechnical Works, ensuring that the Geotechnical Risk is correctly managed. At key stage 1 and 2 a Statement of Intent (SoI) Report and Preliminary Source Study Report (PSSR) should be prepared. The objective of these reports is to provide preliminary information, form a basis of the understanding of the scheme, and identify the potential geotechnical risks to the existing road infrastructure and of the scheme itself.

Once key stage 1 is certified it is recommended that intrusive ground investigation work be carried out in order to further assess the potential geotechnical and geo-environmental constraints identified within this feasibility assessment.

Based on the findings of this report the following scope of ground investigation is considered suitable:

- Cable percussive boring with rotary follow-on – to provide information on the ground profile (including weathered materials and weaker upper layers of bedrock) and to retrieve appropriate soil and rock samples for laboratory testing;
- Trial pitting – To provide information for near surface ground conditions and retrieve samples for laboratory testing;
- Surface and groundwater monitoring/sampling – To provide information on the surface and groundwater conditions and retrieve samples for laboratory testing.
- In situ testing – Standard Penetration Tests (SPT's) and hand shear vanes in trial pits to determine shear strength, photo ionisation detector (PID) testing to detect levels of volatile organic chemicals in trial pits & boreholes, and in situ CBR tests at formation level for pavement design;
- Laboratory testing – A comprehensive range of geotechnical testing to include classification, strength, consolidation, compaction and chemical aggressivity tests. In addition a programme of chemical contamination testing may be required in selected samples.

The ground investigation works should obtain information on the following:

- The depth, nature and variability of any Made Ground and the underlying superficial deposits beneath the

site;

- The detailed engineering description of ground materials to assist geotechnical design;
- The provision of geotechnical engineering parameters to assist pavement, earthworks and foundation design.
- The geo-environmental condition of the Made Ground and underlying superficial deposits through soil sampling and subsequent chemical analysis for key determinants.
- The ground gas and groundwater regime at the site via a programme of monitoring of standpipe installations, and sampling and subsequent chemical analysis of groundwater (where encountered); and
- The characterisation of the aggressivity conditions at the site with respect to buried construction materials.

It should be noted that depending on the findings of the ground investigation, additional investigations may be required.

Subsequent to receipt of the findings from the proposed ground investigations, the level of geotechnical risk will be re-assessed and identified within a Ground Investigation Report (GIR) and Geotechnical Design report (GDR), in accordance with Key Stage 2 and 3 of HD22-08 [ref 7].

The core objectives to achieve geotechnical certification and satisfy the geotechnical design requirements of the scheme are as follows:

- Review all the available desk study information, deemed relevant to the proposed scheme.
- Complete adequate intrusive ground investigation to facilitate all design works
- Prepare a Preliminary Sources Study Report and a combined Geotechnical Investigation/Geotechnical Design Report in accordance with HD 22/08 [ref 7].
- Concurrently undertake design of the necessary earthworks (cut slopes and embankments), pavement and structures for the proposed new alignment carriageway section.

Table 4: Geotechnical Design Risk Register								
Hazard	**Consequence**	**Risk before control**			**Response**	**Risk after control**		
		(L)	**(S)**	**(R)**		**(L)**	**(S)**	**(R)**
Ground conditions different to those anticipated / unforeseen ground conditions	Inadequate Geotechnical design and material instability. Implications for remedial design. Delay to programme and additional costs.	**3**	**3**	**9**	Pass all appropriate ground investigation information to the design team and appointed contactor. Have geotechnical representative on-site to monitor works.	**1**	**3**	**3**
Weak and / or compressible ground.	Unacceptable serviceability settlements, localised areas of soft materials causing embankment / excavation instability.	**3**	**3**	**9**	Develop robust ground investigation and ground model. Pass all site investigation information to design team and appointed contractor. Adopt appropriate design parameters and adequate factors of safety.	**2**	**2**	**4**
Worse than anticipated groundwater tables, perched groundwater and surface water flooding.	Embankment instability during construction, short term and throughout design life. Collapse of temporary excavations due to groundwater during construction. Groundwater inflow into excavations and/or perched groundwater table or water egress from granular horizons resulting in softening of finer materials. Waterlogged conditions leading to softening of subgrade. Immediate and future damage to pavement surface. Increase cost of scheme / delay during construction. May require pumping to remove water during construction and inclement weather.	**4**	**3**	**12**	PSSR, GIR and GDR (HD22/08) to suitably consider hydrology and hydrogeology of the area. Desk study and GI proposed to assess groundwater regime. Groundwater monitoring required. Design and installation of earthworks drainage - standard drainage pipes, open ditches, granular fill and filter fabrics. Provision of appropriate dewatering techniques, balancing pond and slope protection measures during construction. Installed drainage subject to regular inspections to ensure efficiency. Routine maintenance to comprise clearing of vegetation and cleaning of drains. Drainage design to consider access and maintenance issues.	**2**	**2**	**4**

Table 4: Geotechnical Design Risk Register								
Hazard	**Consequence**	**Risk before control**			**Response**	**Risk after control**		
		(L)	**(S)**	**(R)**		**(L)**	**(S)**	**(R)**
Earthworks / Excavation failure during construction	Health and safety implications. Additional works to repair failure. Delay to programme and additional costs.	**2**	**3**	**6**	Develop robust ground investigation and ground model. Pass all site investigation information to design team and appointed contractor. Adopt appropriate design parameters and adequate factors of safety.	**2**	**2**	**4**
Aggressive chemicals/compounds present in site soils/water	Chemical attack on concrete, leading to structural failure over time.	**2**	**3**	**6**	Undertake chemical testing as detailed in BRE SD1 and specify concrete in accordance with findings.	**1**	**3**	**3**
Encountering contaminated materials.	Health and safety implications for site personnel. Additional costs and delays to program whilst contamination is quantified and remedial measures implemented.	**2**	**3**	**6**	Pass all appropriate ground investigation information to the design team and appointed contractor. Any visual or olfactory evidence of contamination to be recorded and appropriate personnel notified. Remedial works may be required if contaminated materials are encountered. Appropriate PPE to be worn at all times.	**1**	**3**	**3**

Figures

Figure 1: Superficial Geology [ref 1]

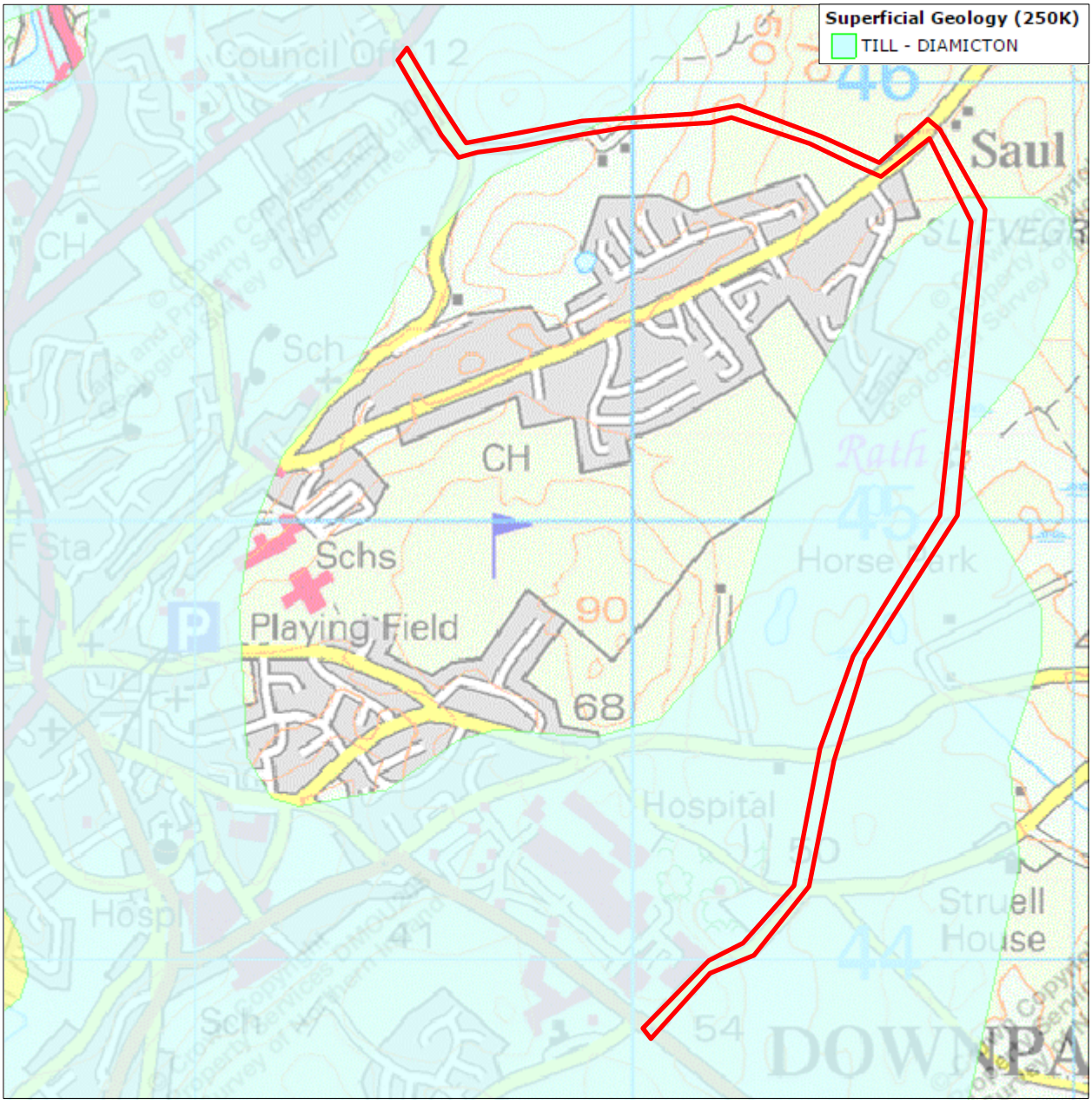
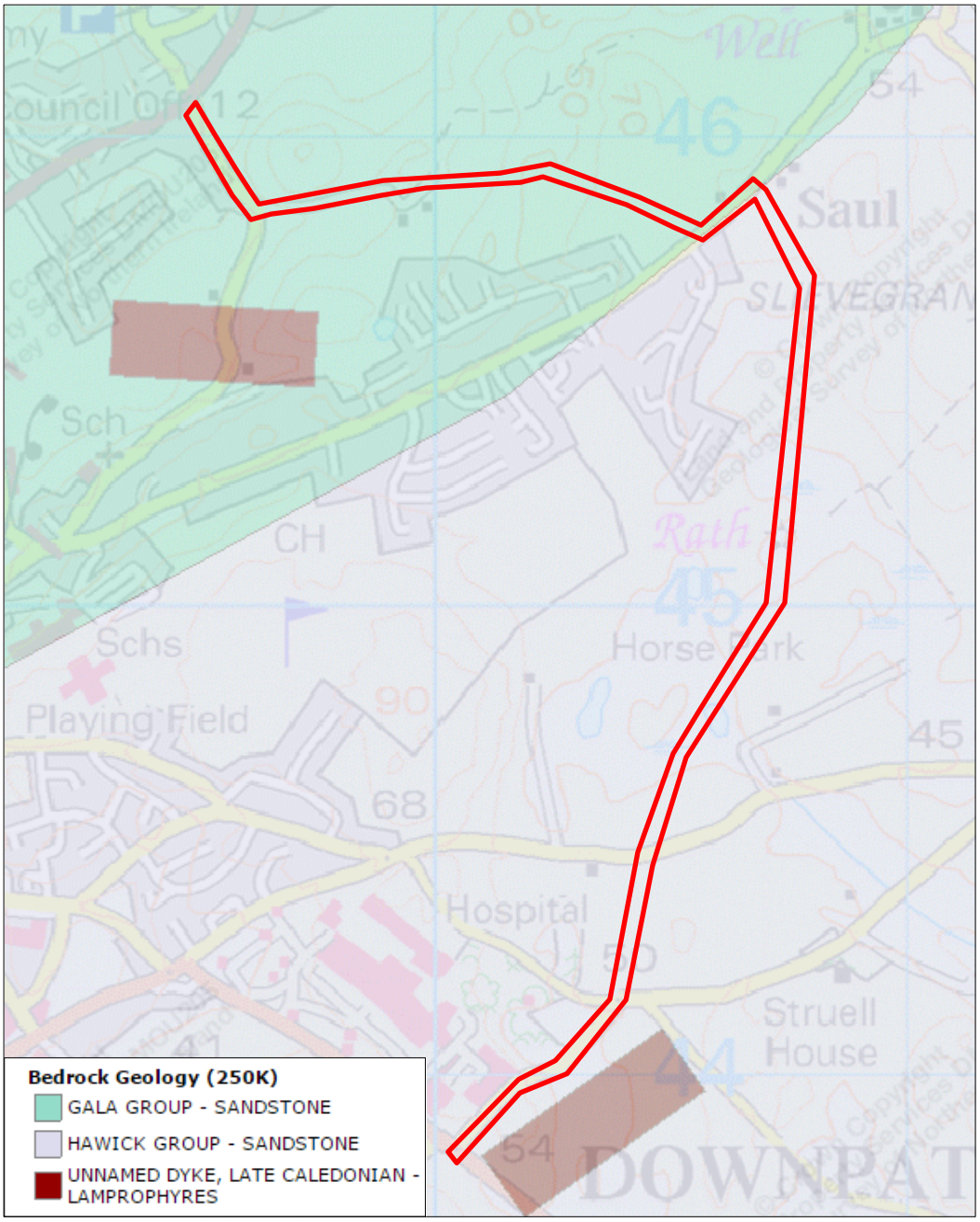


Figure 2: Bedrock Geology [ref 1]



Approx. Proposed Scheme Extents