

Manchester City Council

**Victoria North Infrastructure
Works**

**Ground Investigation Interpretative
Report**

VNIF-ARP-ZZ-YYY-RP-CG-0009

P03 | 23 February 2022

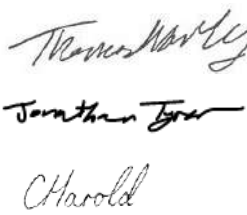
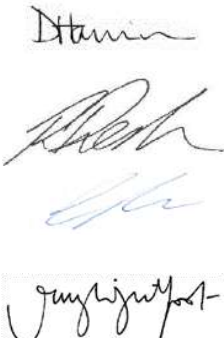
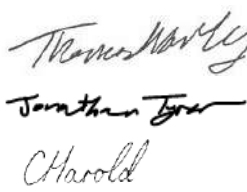
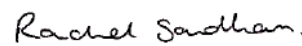
This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Executive Summary – HIF Infrastructure Works

General

Ove Arup and Partners Ltd (Arup) has prepared this report for BAM for the HIF Infrastructure Works at the Victoria North site. The works are being carried out to support a subsequent residential-led development incorporating park and public realm. This ground investigation interpretative report (GIR) builds on a previous (2019) desk study assessment and presents an interpretation of several phases of ground investigation. It is intended to support a planning application for the HIF Infrastructure Works.

The extent of the masterplan area for Victoria North has varied over phases of the project. Although this GIR assesses data for five areas of the site (**Figure 2**), three areas of Victoria North Masterplan will be taken forward under the HIF Infrastructure Works and planning application (Red Bank Plateau, Red Bank Viaduct (partial area) and St. Catherine's Wood) as shown in **Figure 1** and **Figure 3**.

The planning application site

The main area of the planning application site is the Red Bank Plateau (circa. 40mOD to 43mOD). The plateau was constructed by filling during the late 1800s to create railway sidings. From the plateau, wooded slopes (St Catherine's Wood) extend down to the banks of the River Irk at circa. 30mOD. Along the northern boundary, slopes extend down towards the adjacent P&P site beyond the site boundary. The plateau is proposed for residential development. The exception to this is in the north of the site where there is a proposed non-residential plot (RB05b, a proposed school development). The plateau is separated from the Red Bank Viaduct area to the south by a slope (circa 9m high). Red Bank Viaduct area is generally flat, circa 31mOD, and currently occupied by a variety of commercial operations. The area is also planned for residential plots and public realm.

Ground conditions

Variable made ground is present beneath most of the planning application site, locally up to 15.7m thick in Red Bank Plateau. Underlying the made ground, alluvium has been encountered at depths up to 5m, in association with the River Irk with glacial till identified in areas away from the river. Underlying bedrock includes Chester Pebble Beds, Manchester Marls and Collyhurst Sandstone. The depth to bedrock ranges from 18m beneath Red Bank Plateau and St. Catherine's Wood, to 1.8m bgl in Red Bank Viaduct.

Groundwater was encountered beneath the site at varying depths. It is likely that groundwater in made ground is perched on relict structures or on underlying natural cohesive deposits. Groundwater in alluvial deposits is likely to be in continuity with the river, as is groundwater in the underlying solid strata, particularly the Chester Pebble Beds Formation and Collyhurst Sandstone Formation, which are classified as Principal Aquifers.

Geotechnical considerations

The made ground is highly variable and underlain by alluvium and glacial till deposits of limited lateral extent. There is a potential for buried obstructions including former basements, foundations, walls and utilities within the made ground. The ground

investigation suggests that voids are unlikely to be a widespread hazard, however their presence cannot be discounted. Made ground may contain soft spots. Localised near surface soft spots may be present in some areas associated with alluvium or other natural superficial deposits.

The made ground, glacial till and alluvium are unlikely to provide sufficient strength for shallow building foundations and the use of bored piles is recommended, with pile lengths socketed into the underlying bedrock. Given the thickness and variability of the made ground deposits, the use of suspended floor slabs should be assumed.

Except for an area adjacent to Plots RB02 and RB03, the existing steep slopes within the planning application site are densely vegetated and at the steepest point, have gradients in the order of 1v to 1.6h. Analysis of the existing slope adjacent to Plots RB02 and RB03 has indicated a low factor of safety for large, deep seated slips. Stabilisation measures are recommended to mitigate risk associated with change in conditions/ground hazard.

Slopes adjacent to Plot RB05b also have a low factor of safety, however the consequence of failure is considered manageable. Therefore, a managed risk approach is proposed with identification of a 'risk zone to development' adopted in design approach. It is recommended that no development takes place in the risk zone. A similar risk-based approach has been developed for an additional area of sloping ground which extends beyond the northern site boundary into third party land. It is recommended that the loading conditions of the external slope are not altered without first assessing the potential impact.

A number of existing retaining walls exist within or form the boundaries of the planning application site. Once development proposals have been confirmed, the stability of existing walls affected by the development should be assessed.

Several new small retaining walls are proposed across the Red Bank Viaduct and Red Bank Plateau areas and a new c. 4m high retaining structure is required at Red Bank Viaduct. New retaining walls should be designed in accordance with BS8002: 2015.

Most of the material excavated from the planning application site during the site works will be made ground. Overall, between 45% and 63% of the made ground present on site is expected to be predominantly granular (however with a potentially significant cohesive component). A proportion of this material is likely to be suitable for use as general fill within the site works (subject to further geoenvironmental evaluation) and materials associated with removal of obstructions may be processed and suitable for use as engineering fill elsewhere in the works. It may however, be necessary to send unsuitable or surplus material off-site for disposal and depending on further assessments of cut/fill balance, imported engineering fills may be required to meet any shortfall in site-won material. Imported fill may be required for specific applications where material properties need to be tightly specified.

A CBR design value of 2% ($k_{762} = 22 \text{ MN/m}^3$) should be assumed for exposed in-situ made ground however, some soft-spot treatment may be required to achieve this. In areas of engineered fill (using recovered, site-won general granular fill), a CBR design value of 5% ($k_{762} = 37 \text{ MN/m}^3$) should be assumed.

Once development proposals are agreed, assessments of the likely settlement/heave magnitude and timescales will be required for any areas where current ground will be

changed. Movement monitoring may be required depending on the outcome of assessment and the implications on design.

Excavations in made ground and glacial till are likely to encounter perched groundwater which will require appropriate management. Note that groundwater in alluvium may be in continuity with surface water and/or groundwater in the underlying solid strata.

The presence of contaminants in the made ground is likely to preclude the use of soakaways for surface water drainage in most areas of the site. However, soakaways and other infiltration systems may be possible in areas close to the River Irk where sandstone is relatively shallow. Further detailed studies will be required to investigate the viability of soakaways and other infiltration systems at the site as design develops.

Geoenvironmental considerations

Soils

The potential risks to human health and the environment have been considered in the context of a conceptual source-pathway-receptor model (**Section 6**). Potential contaminant linkages identified in the 2019 desk study have been considered.

For the Red Bank Plateau and Red Bank Viaduct areas, when compared to human health generic assessment criteria (GAC) for a residential end use with plant uptake, a number of elevated samples have been identified. Volatile contaminants are generally absent, consequently there are not considered to be risks to future site users where re-used made ground is located beneath hardstanding. In areas of soft landscaping however, a risk to future site users could arise from exposure to exposed made ground soils (either in-situ made ground or made ground re-used as fill).

For the non-residential areas (St Catherine's Wood and Plot RB05b) analysis data has been compared to human health GACs for a public open space end use (parks) and no exceedances have been identified. Evidence of possible contaminant risks was, however, reported during the excavation of trial pits in the area of a former gas works in Plot RB05b. Additional ground investigation is recommended to delineate the area of contamination and monitor groundwater quality downgradient of the gasworks. Further controlled waters risk assessment is also recommended to determine the need for remediation in this area.

Across all site areas, visual evidence of asbestos containing materials (ACM) was recorded in 16 of 121 soil samples, with the maximum record fibre concentration being 0.012%. The presence of asbestos fibres does not necessarily pose a risk to human health, provided that the fibres are not easily released from the soil.

Many of the potential contaminant linkages in the construction phase can be addressed by the adoption of appropriate mitigation measures and the provision of appropriate working methods and PPE.

Post construction, a risk to users of the planning application site and site neighbours has been identified associated with the presence of contaminants in site-won soils exposed at the surface of the site. Appropriate mitigation measures will need to be applied to protect against this risk. The majority of the potential contaminant linkages will be addressed by the adoption of appropriate measures as part of the HIF Infrastructure works or during the development of the site.

Controlled waters

Screening has identified the presence of a range of potential contaminants in groundwater samples recovered from across the site, together with a number of potential pollutant linkages between specific contaminated areas and groundwater. Further detailed quantitative controlled waters risk assessments are required to determine whether the presence of these contaminants or the identified potential pollutant linkages present demonstrable risks and to what extent remediation is required. The potential linkages that have been identified do not appear to be having a significant impact on the quality of the River Irk at present; similar concentrations of the metals of concern are present in the river water upstream and downstream of the site. Development proposals will increase the extent of hardstanding and buildings across the site which in turn, will reduce infiltration through the made ground in the longer term.

Hazardous ground gas

Gas monitoring indicates that the planning application site is characterised by CS1 conditions, for which no special measures will need to be adopted during development. This conclusion is to be validated as part of a further programme of ground investigation. Given that construction details associated with proposed development are as yet unknown, it is recommended that future developers conduct their own assessment of ground gas risk and, if appropriate, undertake additional gas monitoring.

Aggressive ground conditions

An assessment of the potential for aggressive ground conditions to result in the degradation of buried concrete has been undertaken. The available data indicates that for the design of buried concrete in made ground DS-2 and AC-1 conditions should be assumed. For the design of buried concrete in other strata, DS-1 and AC-1 conditions should be assumed.

Remediation measures

The following recommendations are made:

- Removal of the remains of former rail infrastructure (the remains of up to two former rail turntables and a former carriage shed). Once excavations are complete, these areas may require validation and will require reinstatement to an appropriate specification. Validation requirements will be assessed as part of the further detailed quantitative controlled waters risk assessments that are to be undertaken.
- A programme of further ground investigation in the area of the former gas works (Plot RB05b) to allow further assessment of risks to human health and to controlled waters. If necessary, following this further investigation, remedial works may be required in this part of the site.
- Steep slopes adjacent to plots RB02 and RB03 are to be regraded to target gradients of 1v to 2.5h. Ground levels beneath plots RB02 and RB03 are to be lowered to a reduced level of 38.5m AOD to maximise the developable area in these plots.
- For other areas of the planning application site (excluding St Catherine's Wood and plots RB06, RB07 and RB08), in-situ soils are to be turned over to an average depth of 500mm to identify any obstructions present. In cases where obstructions are encountered at the resulting sub-formation (i.e. at the base of the 500mm turnover),

these obstructions will be removed to a depth of 1m below sub-formation level. Soils disturbed by this operation will need to be reinstated to an appropriate specification.

- Using site won materials, earthworks are to be undertaken across the site to achieve target remediation formation levels. Geotechnical testing and assessment will be required to confirm that site won materials will be suitable for re-use. In addition, it will be necessary to establish chemical acceptability criteria and a verification plan for all site-won materials that are intended for re-use on site.
- Place a suitable thickness of clean cover soils (nominally up to 600mm, subject to further detail design) to break any pathways between made ground soils and users of the site in areas of landscaping which are to be completed during the HIF Infrastructure works.
- Areas of exposed made ground should be covered with a temporary 200mm thick clean cover layer on completion of the HIF remediation works.
- Plot developers will be required to determine the appropriate thickness of clean cover soil required in areas of soft landscaping, depending on the distribution of contaminants in near surface soils (following earthworks) and the intended end use of the development plot. As an initial indication, clean cover soils in the order of 600mm thick may be required in areas of proposed private garden where plants may be grown for human consumption.

Excavation arisings

Acceptability criteria should be established for excavation arisings to be reused within the works for both geotechnical and chemical properties. Determination of relevant geochemical re-use criteria will require further detailed quantitative controlled waters risk assessments.

There is potential for surplus soil arising from earthworks, or materials which are geotechnically or geochemically unsuitable for use, to require offsite disposal. Preliminary WAC analysis and other supporting hazardous waste assessments suggests that a significant proportion of the material may be classified as non-hazardous waste and meet the requirements for disposal at inert waste landfills.

Recommended further works

On the basis of the assessment presented above, it is recommended that further assessments and a further phase of ground investigation is undertaken. The recommended further works include:

- Further detailed quantitative controlled waters risk assessments to determine the risks to controlled waters and to derive validation and re-use criteria for site won soils.
- Further investigation of human health and controlled waters risks in the vicinity of the former gas works in Plot RB05b.
- Confirmation of the initial design assumptions used in slope stability assessments.

- Confirmation of the conditions adjacent to existing retaining walls and boreholes at proposed bridge abutment locations.
- Further investigation of groundwater and surface water conditions to assist with subsequent controlled waters risk assessment.
- Additional chemical analysis of soil and water samples to confirm the conclusions reached in this GIR. The suites of analysis will reflect the previous recorded uses of the site.
- Additional geotechnical sampling and testing in areas of proposed excavation to confirm suitability of arisings for re-use and likely disposal requirements for surplus soils.
- Design studies to determine the most appropriate retaining structure to support a proposed embankment (Plot RB12b).
- Assessments to determine the likely settlement magnitude and settlement timescales across the site.

1 Introduction

1.1 Context

Manchester City Council (MCC) has appointed BAM to design and construct the Victoria North Infrastructure Works which will be funded by the Homes England Housing Infrastructure Fund (HIF). Ove Arup and Partners Ltd (Arup) has prepared this report on behalf of BAM. The proposed development is part of the wider Victoria North Strategic Regeneration Framework (SRF) redevelopment to the north of Manchester city centre. The Infrastructure Works are being carried out to support a subsequent residential led development being planned by a Joint Venture of Manchester City Council (MCC) and the Far East Consortium (FEC).

The Infrastructure Works comprise enabling works to create several plots for development, accessed via both existing highways and new highway connections, together with new utility and services connections, remediation and earthworks, demolition of existing structure and the provision of green infrastructure including the creation of green links and the first phase of the new City River Park. Although not part of the Infrastructure Works delivery, the proposed future development of the site will be a combination of residential, public open space and some retail and commercial development.

1.2 Objectives

Drawing on the findings of a 2019 Arup Desk Study [1] this ground investigation interpretative report (GIR) presents an interpretation of several intrusive investigations that have been undertaken within and adjacent to the planning application site, with particular focus on 2019 and 2021 investigations.

This GIR provides an understanding of the implications of ground conditions for development, including issues associated with ground stability, constraints associated with previous development, together with an assessment of risks associated with soil and groundwater contamination and ground gas. This understanding is required to inform the design of future remediation and development of the site.

This GIR is also intended to support a planning application for the HIF Infrastructure Works (IW).

1.3 Scope of report

The scope and structure of this report is outlined below:

- A synopsis of the desk-based information concerning the site and the environmental setting (**Section 2**).
- Review of previous ground investigations and the recent 2021 ground investigation (**Section 3**).
- A description of the ground conditions encountered and the ground model developed (**Section 4**).

- An evaluation of geotechnical parameters, material properties and groundwater conditions (**Section 5**).
- An evaluation of the soil and groundwater contamination and ground gas data and risk assessment (**Section 6**).
- Identification and discussion of geotechnical constraints to development (**Section 7**).
- Discussion of contamination-related and geoenvironmental constraints to development and presentation of an outline strategy for remediation to address the constraints (**Section 8**).
- Conclusions of the geotechnical and geoenvironmental assessments (**Section 9**).
- Recommended next steps to address constraints identified and progress the remediation strategy (**Section 10**).

1.4 Use of report and limitations

This report was prepared by Arup on behalf of BAM. It takes into account our Client's particular instructions and requirements. This report was not intended for, and should not be relied on by, any third party and no responsibility is undertaken to any third party in relation to it.

All reasonable skill, care and diligence have been exercised within the timescale available and in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team in preparing the report, it is possible that other ground contamination or ground conditions as yet undetected, may exist and consequently reliance on this report must be limited accordingly.

2 Proposed development and site setting

2.1 Site extent and site areas

For the purposes of this report, the term ‘planning application site’ has been used to refer to the planning boundary as proposed at the time of writing (the area outlined in red on **Figure 1**). The term ‘wider site area’ has been used when referring to parcels of land that have been subject to various stages of ground investigation (the area outlined in green on **Figure 1**). It can be seen from **Drawing 01**, that GI data is available for all areas of the planning application site. In addition, GI data is available for adjacent parcels of land. For completeness this GIR has considered all GI data within the wider site area (green line) and has adopted the following strategy:

- Data from all previous phases of ground investigation is presented and assessed regardless of whether the data sits within the HIF Infrastructure Works planning boundary (**Sections 2 to 6**).
- Given that development proposals are only known for areas inside the proposed HIF Infrastructure Works planning boundary, **Sections 7 to 10** of this report refer only to the planning application site.

As shown on **Figure 1**, the wider Victoria North site area is bounded to the east and south east by Collyhurst Road, a section of Dalton Street and an active railway viaduct. In the west, it is bounded by Red Bank (a public road) and the rear of existing commercial property off Honey Street and Collingham Street. In the north east, it is bounded by an historical pedestrian railway bridge. The River Irk and Dantzic Street cross the area.

As shown on **Figure 2**, for the purposes of this GIR, the wider site area has been divided into the five areas listed below:

- Red Bank Plateau;
- Red Bank Viaduct;
- St Catherine’s Wood;
- Travis Island;
- New Town Plots.

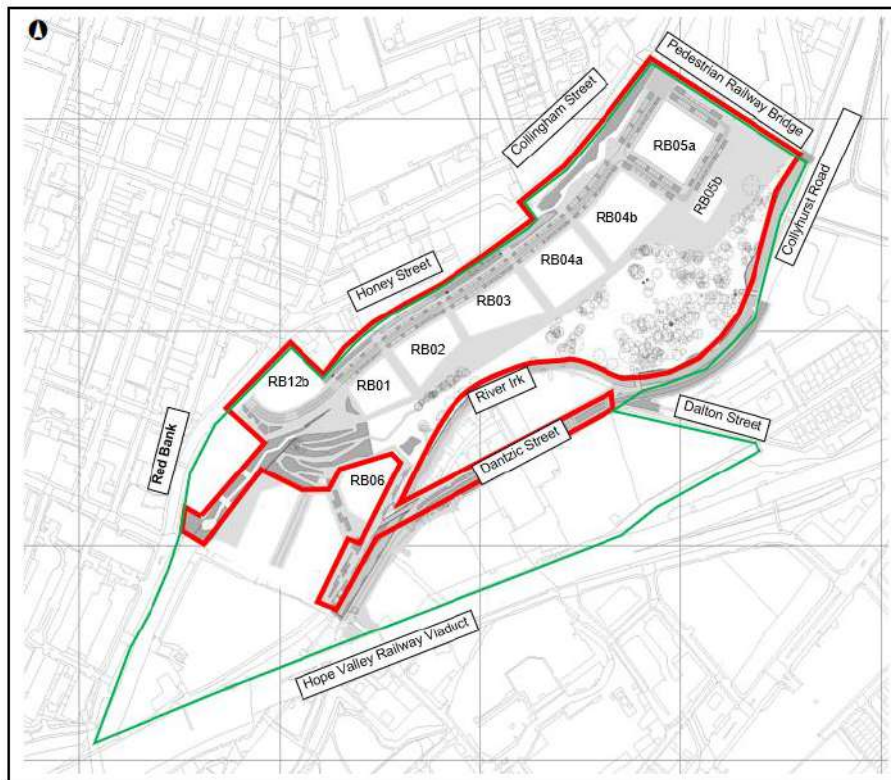


Figure 1: Victoria North wider site area (green outline) and planning application boundary (red outline). Site masterplan shown in grey with plot references.



Figure 2: The site areas as discussed in the GIR.

2.2 Proposed HIF Infrastructure Works development

The HIF Infrastructure Works proposals will be submitted as a full planning application to MCC and will comprise:

- Earthworks and remediation to create suitable development platforms (**Figure 1**);
- The construction of new internal access roads;
- New utility and services connections;
- Provision of green infrastructure including green links and the first phase of a new city river park.

Ultimately, the HIF IW planning application site is to be developed for a predominantly residential use with landscaped areas of public open space. The development plot areas and the landscaping are described in the current proposed masterplan presented in **Figure 3**.



Figure 3: HIF Infrastructure Works masterplan

The proposed follow-on development in each of the five site areas is as follows:

- Red Bank Plateau and the north eastern section of Red Bank Viaduct – The current masterplan indicates that this will be the focus of proposed residential development within the site. Limited areas of private residential gardens are proposed within the

developed site and areas of formal public open space are proposed in the south western area of Red Bank Plateau extending across the section of Red Bank Viaduct that lies within the proposed HIF IW site (**Figure 1**).

- St. Catherine's Wood - The current masterplan indicates that this area will be generally non-residential, with a school proposed in the north of the area (Plot RB05b) and areas of public open space elsewhere. Outside Plot RB05b, existing vegetation is to be preserved as fully as possible with limited areas of enhancement to facilitate the proposed POS use.
- Travis Island and New Town Plots – although these areas of the site formed part of the 2019 and 2021 ground investigations and the data is therefore included in this GIR, these site areas are not part of the proposed HIF IW site (**Figure 1** and **Figure 2**).

Full details of the HIF IW are in preparation. The follow-on developments on the plots prepared by the HIF IW, including residential and school developments, will be subject to separate planning applications.

Table 1 identifies how the proposed development plots shown in **Figure 1** correspond with the zones identified in **Figure 2**.

Table 1: Plots in each development area

Area	Development Plots
Red Bank Plateau To be developed principally for residential purposes with some areas of public open space.	RB01, RB02, RB03, RB04a, RB04b, RB05a and RB12b.
Red Bank Viaduct To be developed as a mix of residential and public open space areas.	RB06, RB07 and RB08 together with public open space.
St. Catherine's Wood To be developed for non-residential purposes – a school and public open space.	Plot RB05b (school) and public open space.
Travis Island	Excluded from proposed HIF IW planning application.
New Town Plots	Excluded from proposed HIFIW planning application.

2.3 Topography

The topography of the wider site area has been interpreted from both publicly available LiDAR data [2] and topographic survey drawings produced in September 2021 by Paragon Surveys Limited. The wider site area is centred on the valley of the River Irk, with the topographical low represented by the river channel. The River Irk flows from north-east to south-west through the site, with water levels between c. 29.5mOD to 26.6mOD.

The most elevated area of the site is the former Creamline Dairies site (Plot 12b - **Figure 1** and **Figure 4**), with ground levels at c. 45.5m AOD. The Creamline Dairies site is separated from the Red Bank Plateau by a c. 5m high retaining wall, with ground levels across the approximately 500m long Red Bank Plateau, ranging from 40.3m AOD in the south west to c. 43.4m in the north east.

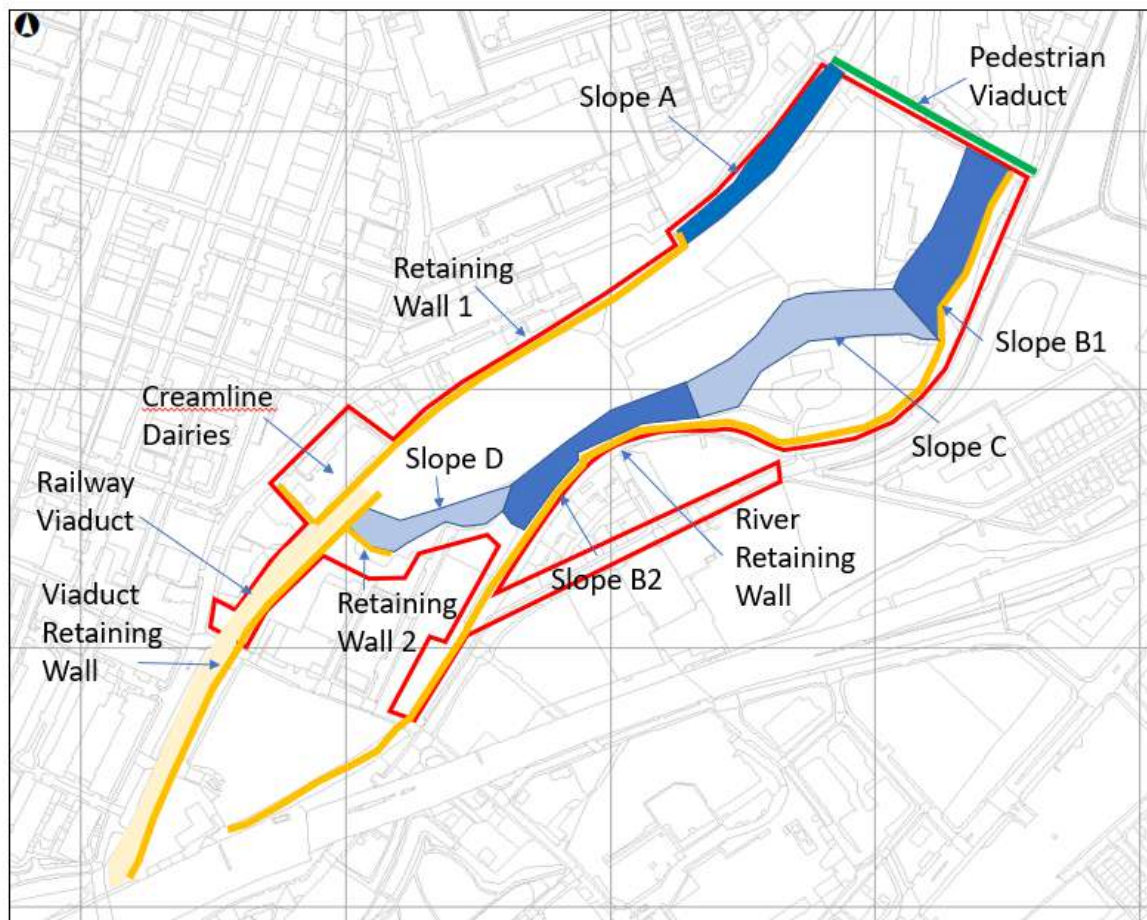


Figure 4: Key site features including retaining walls and slopes

The majority of the boundary between Red Bank Plateau and the St Catherine's Wood area (**Figure 2**) is marked by the crest of a series of steep slopes which are generally between 9m and 13m high and locally approach gradients of 1v to 1.6h (Slopes B1 and B2, **Figure 4**). The exception to this is in the north of St. Catherine's Wood adjacent to Slope B1, where Plot RB05b, is proposed in the area above and to the west of the existing steep slopes. Ground levels across the plot vary between c. 43m AOD in the south to c. 41.5m AOD in the north (over a distance of approximately 100m).

The steep slopes in the St. Catherine's Wood (Slope B1 and B2, **Figure 4**) area generally descend to the banks of the River Irk, at levels of c. 31m AOD in the north east and c. 29m AOD in the south west. In the areas adjacent to proposed development plots RB04a and 04b (**Figure 1**) however, the slopes (Slope C, **Figure 4**) descend initially to a wide, flat area at a level of c. 33m, descending to c. 30m AOD at the retaining walls that line the river channel.

The boundary between Red Bank Plateau and the Red Bank Viaduct area (**Figure 2**) is also marked by the crest of a slope (Slope D, **Figure 4**), which descends from c. 40.5m to 31m AOD. The gradient of this slope is generally in the order of 1 in 2.5. In areas along the toe of this slope, sections of masonry wall can be seen, which may be the remains of buildings or former retaining walls (Retaining Wall 2, **Figure 4**). Ground levels across the Red Bank Viaduct area are in the order of 32m AOD in the north east, falling to c. 29m AOD in the extreme south west. The boundary of the site along the boundary with the public highway however, is marked by a disused section of railway viaduct, some 7m high, which

formerly connected Victoria Station to Red Bank Plateau (Viaduct Retaining Wall, **Figure 4**). The top of the viaduct is c. 39m AOD.

Travis Island was not included in the September 2021 topographic survey, however the available LiDAR data[2] indicates this generally flat-lying area to be at c. 31m AOD. Original ground levels across the New Town Plots are generally at c. 30m AOD in the south west, rising to c. 34m AOD in the north east. On-going waste management operations in the north eastern half of the New Town Plots area have led to the formation of stockpiles of soils which locally reach up to c. 49m AOD.

2.4 Description of site areas

2.4.1 Red Bank Plateau

As shown on **Figure 2**, this area is situated north of the River Irk. Historically, a meander of the River Irk and a mill race were located within this area, together with two reservoirs. The present-day elevated plateau area at approximately 42m AOD was created by filling in the late 1800s. Until c. 1989 the area was occupied by extensive railway sidings and associated infrastructure, including a carriage shed, turntables and small gasworks. Following the suspension of rail operations at the site and the removal of most elements of rail infrastructure, large areas of Red Bank Plateau have become extensively vegetated, particularly in the south west.

Starting at the northern tip of the site, approximately 175m of the north-western boundary is marked by a cut slope up to approximately 7m high, which on the basis of the current ground model is likely to have been excavated in glacial till (Slope A, **Figure 4**). The gradient of this slope is approximately 1v to 3h (the off-site areas stand above Red Bank Plateau). From the south eastern end of Slope A, a c. 4m high brick retaining wall supports the elevated off-site areas and Plot RB12b (**Figure 1**) which at the time of the 2021 GI was occupied by Creamline Dairies.

Currently, the only vehicle access onto the Red Bank Plateau is from Collyhurst Road via a bridge over the River Irk. Development proposals include the provision of new site access off Red Bank, which will descend in shallow cutting through the former Creamline Dairies site, passing through Retaining Wall 1 (**Figure 4**) at approximately mid-height before descending on a low embankment to the Red Bank Plateau.

The north-eastern boundary is marked by a masonry pedestrian viaduct constructed in the late 1800s (**Figure 4**). This viaduct stands some 9m above ground levels across Red Bank Plateau and from its south east end, descends first via a series of steps and then via a sloping footpath to the River Irk.

2.4.2 Red Bank Viaduct

The Red Bank Viaduct area in the south west of the wider site area is relatively flat-lying (c. 30m AOD). The area has historically been occupied by various buildings and industries, including tanneries, an iron works, oil works, chemical works, dye works and a fireproof plate works. It is currently occupied by multiple independently-owned car parking businesses, a taxi service, a joinery warehouse, dry cleaners and food warehouse. Roger

Street passes under the disused railway viaduct (**Figure 4**) which marks the north western boundary of the Red Bank Viaduct area.

The boundary between Red Bank Plateau and Red Bank Viaduct consists of heavily vegetated slopes (Slope D, **Figure 4**) formed from fill materials largely placed as part of the former rail infrastructure development on the plateau. The lower sections of these slopes appear to have been supported by a masonry retaining wall or the remains of partly demolished buildings (Retaining Wall 2, **Figure 4**) however the alignment and condition of this masonry are largely obscured by vegetation and more recently placed fill materials.

2.4.3 St Catherine's Wood

This area of the proposed development site was historically occupied by a meander bend of the River Irk and a mill race, together with a corn mill (later starch and size mill), dye works, church, terraced housing and a school until the early 1970s. Today, the site is largely woodland with evidence of occasional fly tipping and limited areas of public footpath which run along the banks of the River Irk.

There are two generally flat parts of this area: a lower-lying area along the River Irk and at higher level a flat plateau which is proposed for school development (Plot RB05b). The St. Catherine's Wood area extends from the edge of the Red Bank Plateau in the north west to the River Irk in the south east. Steep slopes (reaching gradients up to 1v to 1.6h) generally with extensive tree cover, descend from Red Bank Plateau through the St Catherine's Wood area.

2.4.4 Travis Island

Travis Island is currently occupied by a travellers' site in the west and a large timber warehouse in the east.

2.4.5 New Town Plots

The New Town Plots lie between Dantzig Street and the Hope Valley Railway viaduct. The western-most plot (NT01) is currently under development. The plot to the east (NT02) is currently a disused warehouse with an adjoining events facility. The western section of the New Town Plots is occupied by a licensed waste recovery facility which processes waste soils.

2.5 Historical land use

The site history is discussed in the Ground Conditions Desk Study Report [1] issued in August 2019. The site history is not discussed in detail in this report, but summaries of the historical use and development have been provided in **Section 2.4**.

2.6 Published geology and hydrogeology

2.6.1 Superficial deposits

The 1:50,000 scale geological map indicates that glacial till underlies the area south-east of the River Irk and along the north-western site boundary (**Figure 5**). Although not indicated on published geological maps, as discussed subsequently in this report, ground investigation has established the presence of alluvial deposits in association with the River Irk.

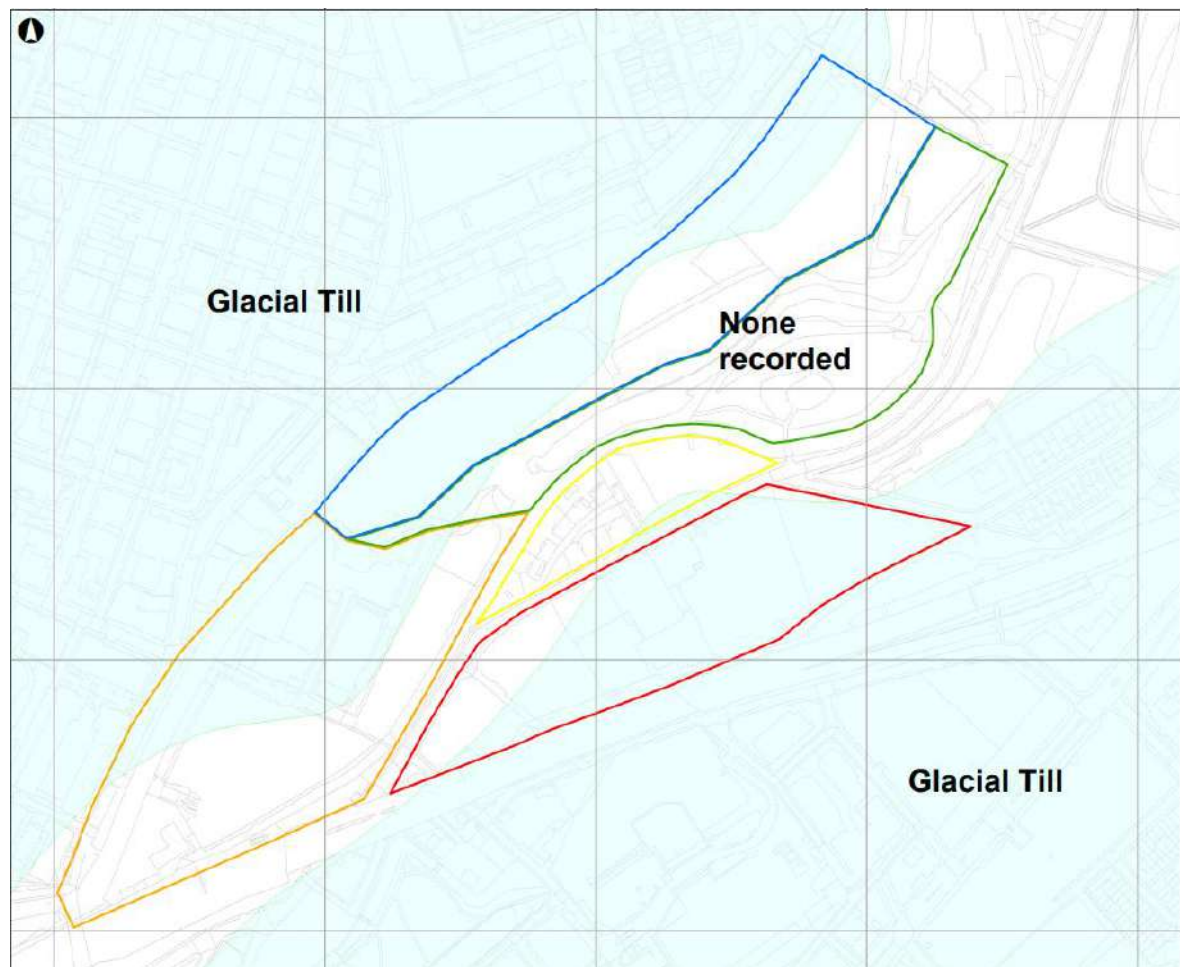


Figure 5: Superficial geology from 1:50,000 scale BGS map

2.6.2 Solid geology

Published sources of information indicate that the solid geology varies from east to west across the site, with the Chester Pebble Beds Formation in the west, Manchester Marls Formation in the centre of the site and the Collyhurst Sandstone Formation in the north-east (**Figure 6**). All three units are reported to be gently dipping (5 degrees) SSW.

A fault, trending NNW-SSE, cuts across the centre of the site, within the Manchester Marl Formation. The BGS map indicates that this is a normal fault, downthrown to the west, with limited displacement.

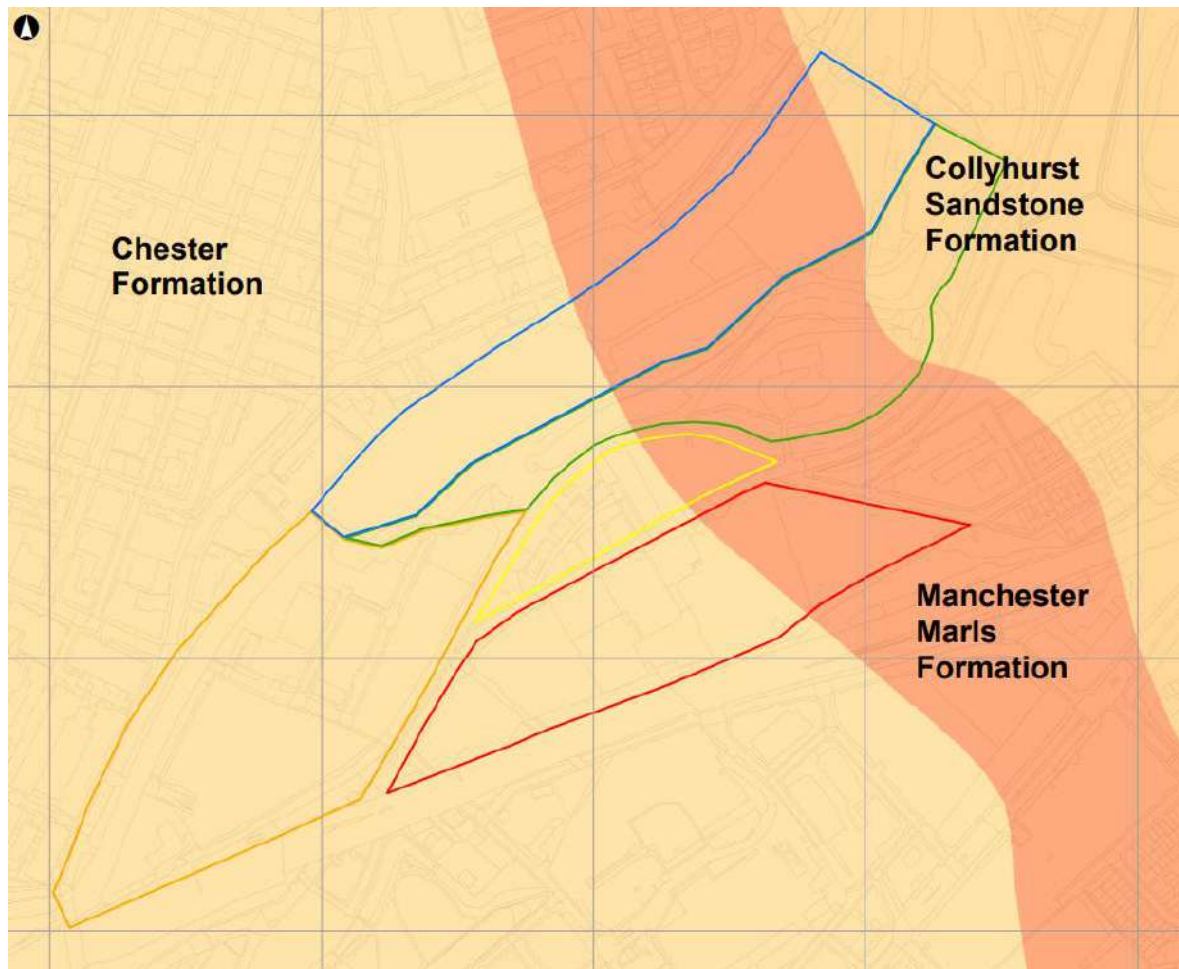


Figure 6: Bedrock geology taken from 1:50,000 scale BGS map

2.6.3 Hydrogeology & hydrology

The aquifer designations underlying the site and adjacent areas are discussed in the Ground Conditions Desk Study Report [1]. Alluvium is mostly classified as a Secondary (A) Aquifer and glacial till deposits as a Secondary (undifferentiated) Aquifer. Secondary Aquifers are defined as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The Manchester Marl is classified as a Secondary (B) Aquifer (Lower Permeability Layers), whereas the Chester Pebble Beds Formation and Collyhurst Sandstone Formation are classified as Principal Aquifers. Principal Aquifers are defined as strata of high intergranular and/or fracture permeability, usually providing a high level of water storage and may support water supply/river base flow on a strategic scale.

The BGS Hydrogeology map¹ describes the Manchester Marl as confining groundwater in the Collyhurst Sandstone. The Manchester Marl may act as a barrier to groundwater flow

¹ British Geological Survey Hydrogeology Map <https://largeimages.bgs.ac.uk/iip/hydromaps.html?id=clwyd-cheshire.jp2>

and the Collyhurst Sandstone and Chester Pebble Beds are likely to be separate aquifer units.

No Source Protection Zones are located within 500m of the site. No licensed groundwater or surface water abstractions are located within the site boundary, but there are three active abstraction licences located within 500m of the site boundary:

Abstraction reference	Distance from boundary	Purpose
Packaging Products Ltd, Collyhurst	270m north-east	General cooling
Derby Brewery, Cheetham	400m north-west	General cooling
Derby Brewery, Cheetham	400m north-west	Process water

The River Irk is classed as a heavily modified water body (HMWB) in recognition of physical modifications by human activity. The river is canalised through the majority of the HIF IW site. The Irk currently has an overall status of ‘moderate’ with an ecological potential of ‘moderate’ and a chemical status of ‘fail’. The reasons for not achieving ‘good’ status within the Irk catchment include ammonia due to continuous sewage discharges and diffuse sources including land contamination and landfill leachate, and phosphate due to sewage discharges and urban development [17].

The potential for modifications to the river are being addressed as part of a parallel study to alleviate flooding and where possible to re-naturalise sections of the watercourse.

3 Ground investigations

3.1 Background

A number of intrusive investigations have been undertaken across the wider site area. These include several historical ground investigations (**Section 3.2**) and two phases of ground investigation designed by Arup on behalf of FEC and undertaken in 2019 and 2021 by Allied Exploration and Geotechnics Limited (AEG) (**Section 3.3** and **Section 3.4**).

3.2 Historical ground investigation

Several historical ground investigations have been undertaken in the vicinity of the site. A summary of these investigations is presented in the Ground Conditions Desk Study Report [1] issued in August 2019. Although the historical ground investigations are not discussed further in this report, relevant data from these investigations has been used as appropriate, when assessing ground conditions at the site.

3.3 2019 ground investigation

A ground investigation was undertaken within the wider site area during January 2019 by Allied Exploration and Geotechnics Limited (AEG) on behalf of FEC. The investigation was designed to provide high-level information on ground conditions to inform an initial cost plan for the proposed development. The findings of the investigations were presented in a factual report produced by AEG [3].

The investigation included:

- Ten cable percussion boreholes;
- Twenty-one machine excavated trial pits;
- Seven windowless sample holes;
- In-situ standard penetration and hand shear vane testing;
- Geotechnical and specialist chemical sampling;
- Installation of gas and groundwater monitoring instrumentation;
- Groundwater monitoring, sampling and associated water quality parameter testing.

No rotary drilling was conducted as part of this work therefore penetration into rockhead was limited and no ground gas monitoring was carried out. Groundwater monitoring was undertaken in seven installations between 7th and 24th January 2019 on up to four occasions.

The locations of the exploratory holes completed as part of the 2019 ground investigation are presented in **Drawing 01** (labelled as BH1xx, TP1xx and WS1xx). The positions of the gas and groundwater monitoring installations are presented in **Drawing 02**. Interpretation of the 2019 data was presented in the Ground Conditions Desk Study Report [1].

3.4 2021 ground investigation

A further ground investigation was undertaken to provide information on the baseline geoenvironmental and geotechnical conditions within each development plot and the wider area, and to provide greater understanding of some of the abnormal ground conditions to support a future planning application for development. Part of the investigation scope targeted specific historical features within the wider site area; the rationale for the 2021 GI is included in **Appendix A**.

The ground investigation was carried out by AEG between 22nd March and 20th April 2021. The works were supervised by AEG with part-time site attendance by Arup. The findings of the investigations are presented in a factual report produced by AEG [4].

The fieldwork consisted of:

- Seventeen boreholes advanced using cable percussion methods;
- Six cable percussion boreholes were advanced into bedrock using rotary coring methods;
- Eighteen window sample boreholes;
- Twenty three mechanically excavated trial pits;
- Six horizontal concrete cores into the Red Bank Plateau retaining wall;
- In-situ standard penetration, hand shear vane, photo-ionisation detector, TRL cone penetrometer, hand penetrometer, water quality parameter and mexeprobe testing;
- Geotechnical and specialist chemical sampling;
- Installation of gas and groundwater monitoring instrumentation;
- Post site groundwater and surface water monitoring, sampling and associated water quality parameter testing.

A groundwater and soil-gas monitoring programme was also undertaken from twenty locations between 11th May and 10th August 2021, with groundwater samples recovered for laboratory analysis on two separate occasions.

The locations of the exploratory holes completed as part of the 2021 ground investigation are presented in **Drawing 01** (labelled as BH2xx, TP2xx and WS2xx). The positions of the gas and groundwater monitoring installations are presented in **Drawing 02**.

3.5 Summary of the 2019 and 2021 GIs

3.5.1 Exploratory holes

A summary of the fieldwork undertaken in 2019 and 2021 is presented in **Table 2**.

Table 2: Ground investigation summary

Ground investigation	Site area	Exploratory hole type*	No.	Min depth (mbgl)	Max depth (mbgl)
2019	Red Bank Plateau	CP	6	7.8	15
		TP	13	1.8	4.5
	Red Bank Viaduct	CP	2	4.3	7
		TP	4	3	3.7
		WS	2	1.5	5.45
	St. Catherine's Wood	TP	2	3.8	4.5
		WS	3	3.9	5.45
	Travis Island	WS	2	4.2	5
	New Town Plots	CP	2	3.5	3.95
		TP	4	2.8	4.5
2021	Red Bank Plateau	CP	6	6.8	16.1
		CP+RC	4	9.3	19.6
		TP	16	0.6	4.5
		WS	9	0.8	8.2
	Red Bank Viaduct	CP	3	1.2	5
		CP+RC	1	11.5	11.5
		TP	1	4.6	4.6
	St. Catherine's Wood	CP	2	3.5	16.5
		CP+RC	1	24	24
		TP	6	0.9	4.5
		WS	7	0.4	5.2
	Travis Island	WS	2	3.8	4.65
	New Town Plots	None			

*- CP = cable percussion borehole, TP = trial pit, WS = window sampler, RC = rotary coring.

3.5.2 Monitoring installations

A total of twenty-seven monitoring positions were installed as part of the 2019 and 2021 ground investigations. A summary of the monitoring installations is presented in **Table 3** and their locations are shown in **Drawing 02**.

Table 3: Borehole installations used for 2019 and 2021 monitoring

Borehole ID		Site area	Ground Level (mOD)	Response Zone depth (mbgl)		Response Zone Stratum
				Top	Bottom	
2019	BH101	Red Bank Plateau	43.38	1	5	Made ground
	BH102	Red Bank Plateau	42.93	1.9	6.7	Made ground/glacial till
	BH103	Red Bank Plateau	42.57	1	3.5	Made ground
	BH104	Red Bank Plateau	41.59	1.8	9.2	Made ground
	BH105	Red Bank Plateau	40.67	3	9.5	Glacial till
	BH106	Red Bank Plateau	40.67	2	10	Made ground/glacial till
	BH112	Red Bank Viaduct	32.25	0.5	4	Made ground/weathered Chester Pebble Beds
2021	BH201	Red Bank Plateau	43.40	3	5	Bedrock (mudstone)
	BH202	Red Bank Plateau	42.66	4	9	Glacial till
	BH203	St Catherine's Wood	41.89	18	24	Collyhurst Sandstone
	BH204	St Catherine's Wood	43.28	1.5	10	Made ground/possible made ground
	BH205	Red Bank Plateau	42.58	4.8	10.8	Manchester Marl
	BH206	Red Bank Plateau	42.69	2	6	Glacial till

Borehole ID	Site area	Ground Level (mOD)	Response Zone depth (mbgl)		Response Zone Stratum
			Top	Bottom	
BH207	Red Bank Plateau	41.64	1.5	15.5	Made ground
BH208	Red Bank Plateau	40.66	3	13	Made ground
BH209	Red Bank Plateau	41.21	11	17	Manchester Marl
BH210	Red Bank Plateau	40.45	14	19.6	Chester Pebble Beds
BH211A	Red Bank Plateau	40.44	5	10.5	Made ground
BH212	Red Bank Viaduct	30.38	5.5	9	Chester Pebble Beds
BH213	St Catherine's Wood	31.94	1.5	3	Made ground
BH214A	Red Bank Viaduct	30.03	3	4	Glacial till/alluvium
WS201B	Red Bank Plateau	43.55	0.5	1.3	Made ground
WS207	Red Bank Plateau	41.91	0.9	4.9	Made ground
WS208	Travis Island	30.17	1	4.1	Made ground (gasholder infill)
WS209	Travis Island	29.95	2.8	3.8	Made ground
WS210	Red Bank Plateau	40.88	1.5	2.5	Made ground
WS212	St Catherine's Wood	39.89	0.5	2.5	Made ground

3.5.3 Groundwater and ground gas monitoring

Following completion of ground investigation, gas and groundwater monitoring was undertaken to establish groundwater levels and ground gas conditions. Monitoring records are presented in both factual reports [3][4] and the results of monitoring are described in subsequent sections of this report.

3.6 Field observations

Field observations of conditions that may be indicative of contamination, recorded during the 2019 and 2021 ground investigations, are summarised in presented in **Table 4**.

A summary of obstructions encountered in exploratory holes is presented in **Table 5**.

Table 4: Summary of visual and olfactory evidence of contamination encountered during the ground investigations

Location ID*	Site area	Evidence of contamination	Sample taken for laboratory analysis (Y/N)
BH103	Red Bank Plateau	Hydrocarbon odour at 0.1 – 1.3mbgl	Y
WS106	Travis Island (within former gasholder base)	Hydrocarbon (benzene) odour at 2.8mbgl	N
TP101	Red Bank Plateau	Slight hydrocarbon odour at 0.8 – 0.9mbgl	N
TP120	Red Bank Viaduct	Strong hydrocarbon odour at 0.7 – 1.8mbgl	Y
BH203	St. Catherine's Wood (in area of former railway gasworks)	Moderate hydrocarbon odour at 5.5 – 7.5mbgl	Y
BH207	Red Bank Plateau	Moderate hydrocarbon odour at 13 – 15.7mbgl	Y

Location ID*	Site area	Evidence of contamination	Sample taken for laboratory analysis (Y/N)
BH211A	Red Bank Plateau (in area of former reservoir)	Strong hydrocarbon odour at 10.1 – 10.5mbgl	Y
TP202B	Red Bank Plateau (in area of former carriage shed)	Oily groundwater within foundations at 0.1 – 0.6mbgl	Y
TP202C	Red Bank Plateau (in area of former carriage shed)	Oily groundwater within foundations at 0.5 – 1.2mbgl	Y
TP204	St. Catherine's Wood (in area of former railway gasworks)	Metallic dark blue sand with strong hydrocarbon odour at 2.4 - 4.5mbgl, sheen on groundwater	Y
TP205	St. Catherine's Wood (in area of former railway gasworks)	Metallic dark blue sand and gravel with strong hydrocarbon odour at 1.9 – 4.2mbgl, sheen on groundwater	Y
TP206A	St. Catherine's Wood (in area of former railway gasworks)	Metallic dark blue sand with strong hydrocarbon odour at 1.7 – 4.5mbgl, sheen on groundwater	Tested for asbestos presence only
TP213	Red Bank Plateau	Strong hydrocarbon odour at 1.2 – 4.5mbgl	Y
TP216	Red Bank Plateau	Mild hydrocarbon odour at 1.1 – 1.2mbgl	N

*- 100 series exploratory holes were advanced during the 2019 GI with 200 series exploratory holes advanced during the 2021 GI.

The visual and olfactory evidence for contamination identified in TP202B and TP202C is considered to be associated with below ground remains of a former carriage shed. The visual and olfactory evidence for contamination identified in BH103, BH203, TP204 TP205, TP206A and TP213 may be associated with below ground remains of a former gas works. Both these historical features are part of the former rail infrastructure – **Drawing 04**).

Table 5: Summary of evidence of below ground obstructions encountered during the ground investigations

Location ID*	Site area	Evidence of below ground obstructions
TP102	Red Bank Plateau	Terminated due to cobble obstruction at 4.1mbgl
WS103	St. Catherine's Wood	Terminated due to concrete obstruction at 3.9mbgl
WS105	Red Bank Viaduct	Terminated due to refusal at 1.5mbgl
TP206	St. Catherine's Wood	Terminated due to concrete foundations at 0.9mbgl
TP202	St. Catherine's Wood	Terminated due to brick foundations at 1.4mbgl
TP202A	St. Catherine's Wood	Terminated due to brick foundations at 1.2mbgl
TP202B	St. Catherine's Wood	Terminated due to brick foundations at 0.6mbgl
TP202C	St. Catherine's Wood	Terminated due to brick foundations at 1.2mbgl

*- 100 series exploratory holes were advanced during the 2019 GI with 200 series exploratory holes advanced during the 2021 GI.

The obstructions identified in TP102, TP202, TP202A, TP202B and TP202C are considered to be associated with below ground remains of a former carriage shed (part of the historical rail infrastructure – **Drawing 03**).

4 Ground conditions

The findings from the 2019 and 2021 ground investigations have been used to develop stratigraphic models, as summarised below. Selected geological cross sections are presented as **Drawing 05**, **Drawing 06** and **Drawing 07** and should be read in conjunction with this section, together with **Figure 6** showing the approximate boundaries of the three bedrock types (Manchester Marl, Chester Pebble Beds and Collyhurst Sandstone). In this section the ground conditions are presented based on the five areas identified in **Section 2.1** and **Figure 2**.

4.1 Red Bank Plateau

The stratigraphy in the Red Bank Plateau area is summarised in **Table 6**.

Table 6: Summary of the stratigraphy encountered in the Red Bank Plateau area.

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
Made ground	Ground level (39.89 to 43.55)	0.8 to 15.7	Tarmacadam
			Concrete and brick
			Made ground is variable at shallow depths up to 1m. However, it generally comprises sandy gravel with low cobble content. Gravel is of concrete, brick, tarmac, plastic, glass, clinker, sandstone, ceramic, rubber. The deeper made ground (at depths >1m) is also highly variable but has a more cohesive component and is generally described as sandy slightly gravelly clay, clayey sand and gravel or gravelly sand with a low cobble content and gravels of clinker, slag, tarmac, brick, mudstone, sandstone, limestone. The cohesive soils are generally soft to firm becoming stiff at depth.
Glacial till	0.8 to 15.7 (25.94 to 42.38)	0.3 to 9.5	Generally described as soft to firm, becoming stiff at depth slightly sandy gravelly clay. Granular bands are recorded, described as medium dense to very dense brown slightly clayey sandy gravel and gravelly sand. With a low to moderate cobble content and gravel of sandstone, limestone and mudstone.
Alluvium	0.8 to 10 (42.38 to 31.59)	0.3 to 4.7	Generally described as medium dense slightly gravelly sand. Cohesive bands are described as soft to firm slightly sandy slightly gravelly clay.
Chester Pebble Beds	8.8 to 13.6 (26.85 to 31.87)	Unproven	Generally described as extremely weak to weak red brown slightly clayey coarse grained weathered sandstone
Manchester Marls	4 to 15.7 (25.94 to 38.8)	Unproven	Generally described as extremely weak thinly laminated clayey mudstone (weathered).
Collyhurst Sandstone	7 (36.38)	Unproven	Limited in extent, encountered in one location (BH101). Described as extremely weak to very weak fine to coarse grained sandstone with lenses of red marl.

4.2 Red Bank Viaduct

The stratigraphy of the Red Bank Viaduct area is summarised in **Table 7**.

Table 7: Summary of the stratigraphy encountered in the Red Bank Viaduct area.

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
Made ground	Ground level (29.45 to 32.25)	1.8 to 6.4	Tarmacadam
			Concrete with rebar
			Generally red brown and grey sandy gravel and gravelly sand with gravels of brick, concrete sandstone and clinker. A low to moderate cobble content is also noted. In some areas of this area of the site, made ground is encountered as a clayey material, described as to soft firm sandy gravelly clay containing gravels of brick, coal clinker and sandstone
Glacial till	3 (27)	1.1	Generally limited in extent. Described as medium dense brown, slightly clayey gravelly sand with gravels of mudstone, limestone and sandstone.
Alluvium	4 (25.45)	Unproven	Very limited in extent, encountered in only one location (WS105A). Described as loose dark brown clayey slightly gravelly sand with gravels of sandstone, limestone and quartzite.
Chester Pebble Beds	1.8 to 6.4 (24.68 to 30.15)	Unproven	Generally described as extremely weak to weak weathered to unweathered red brown fine grained sandstone. Generally recovered as sand and gravel due to weathering.
Manchester Marls	Not encountered		
Collyhurst Sandstone	Not encountered		

4.3 St. Catherine's Wood

The stratigraphy of the St. Catherine's Wood area is summarised in **Table 8**.

Table 8: Summary of the stratigraphy encountered in St. Catherine's Wood.

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
Made ground	Ground level (31.94 to 43.38)	3 to 7.5	Topsoil
			Concrete with rebar
			At shallow depths (up to 1m) made ground is variable but generally described as sandy clay, gravelly sand and sandy gravelly topsoil. Gravel recorded include roadstone, slag, ash, brick, concrete, clinker, coal, mudstone, sandstone, limestone and cinder. At depths >1m, made ground is variable but generally described as loose medium dense clayey sandy gravel and soft to stiff sandy gravelly clay. With gravels of concrete, brick, mudstone, cinder, macadam, slag, sandstone and coal.
Glacial till	7.5 (34.39 to 35.78)	10.5	Generally described as soft to firm brown sandy very gravelly clay with gravels of sandstone,

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
			mudstone and limestone. Also, granular bands described as medium dense brown slightly clayey sandy gravel and gravelly sand.
Alluvium	3 to 4.3 (28.51 to 29.2)	Unproven	Generally described as soft brown very sandy clay and loose brown slightly clayey sand
Chester Pebble Beds	3.3 (28.64)	Unproven	Encountered in one location (BH213). Described as extremely weak fine grained red sandstone, distinctly weathered
Manchester Marls	Not encountered		
Collyhurst Sandstone	18 (23.89)	Unproven	Generally described as extremely weak red brown coarse grained distinctly weathered sandstone.

4.4 Travis Island

The stratigraphy of the Travis Island area is summarised in **Table 9**.

Table 9: Summary of the stratigraphy encountered in the Travis Island area

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
Made ground	Ground level (29.95 to 31.52)	4 to unproven >4.65	Tarmacadam
			Topsoil
			At shallow depths up to 1m, generally described as brown clayey sandy gravel with a low cobble content and gravels of brick, concrete, slag, sandstone, mudstone and macadam. At depths >1m the made ground is generally described as soft to firm black sandy gravelly clay with a low cobble content and gravels of brick, concrete, slag, sandstone, mudstone, macadam.
Glacial till	Not encountered		
Alluvium	4 (27.52)	Unproven	Encountered in one location (WS106). Described as soft brown sandy clay.
Chester Pebble Beds	Not encountered		
Manchester Marls	Not encountered		
Collyhurst Sandstone	Not encountered		

4.5 New Town Plots

The stratigraphy of the New Town Plots area is summarised in **Table 10**.

Table 10: Summary of the stratigraphy encountered in the New Town Plots area.

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
Made ground	Ground level (30.69 to 41.29)	2.1 to 3	At shallow depths up to 1m, described as brown clayey sandy gravel and gravelly sand with a moderate to high cobble content. Gravel of clinker, sandstone, coal, slag, concrete, brick and fragments of metal and plastic.

Stratum	Top of stratum mbgl (mOD)	Thickness range (m)	Description
			At depths >1m generally described as soft to firm brown sandy slightly gravelly clay with gravels of sandstone, siltstone, coal, clinker and brick
Glacial till	2.1 to 2.8 (29.07 to 39.19)	0.2 to unproven (>1.8)	Very limited in extent. Where encountered the glacial till is described as firm red brown very sandy slightly gravelly clay with gravel of sandstone
Alluvium	Not encountered		
Chester Pebble Beds	2.9 to 3.1 (28.27 to 28.48)	Unproven	Generally described as extremely weak to weak weathered to unweathered red brown fine grained sandstone. Generally recovered as sand and gravel due to weathering.
Manchester Marls	2.4 (38.89)	Unproven	Only encountered in one location (BH107), generally described as extremely weak red brown slightly sandy mudstone with interbeds of weak fine to medium grained sandstone.
Collyhurst Sandstone	Not encountered		

4.6 Distribution and classification of made ground

It is evident from **Table 6** to **Table 10** that significant deposits of made ground have been encountered across all areas of the wider site area. Areas of significantly deeper made ground noted within the Red Bank Plateau and St. Catherine's Wood areas are believed to be associated with the former channel of the River Irk, a mill race and a historic reservoir, which were shown on historical mapping but were buried when Red Bank Plateau was created.

The plateau area was created in the late 1800s to form a level area for railway sidings and is likely to have been constructed using locally-sourced materials available at the time. The relevant exploratory hole records indicate that the made ground varies in character both laterally and with depth, but it has not been possible to identify distinct zones within the made ground that are predominantly granular or predominantly cohesive in nature.

In order to assess this further, secondary soils categories have been applied to the made ground encountered by the exploratory holes. These secondary soil categories have been determined on the basis of the relevant BS5930 [5] soil descriptions presented on the exploratory hole records contained within the 2019 and 2021 factual GI reports [3][4]. The secondary soil categories adopted for this assessment are as follows:

- MG-G – soils described on the exploratory hole records as predominantly granular;
- MG-C – soils described on the exploratory hole records as predominantly cohesive;
- MG-TS – humic layers (topsoil) usually within the upper made ground;
- MG-O – other materials such as obstructions, masonry, voids etc.

A preliminary global assessment of the proportions of made ground falling into the broad classifications has been undertaken based on the soil descriptions on the exploratory hole records. Based on this assessment, the made ground appears to be predominantly granular with approximately 63% of the made ground soils encountered during GI categorised as

MG-G (see **Figure 7**). As identified in **Table 6** to **Table 10** however, even the predominantly granular made ground soils contain potentially significant proportions of cohesive material, which may affect material behaviour if for example, the made ground soils are recovered for re-use as engineering fill within the planning application site.

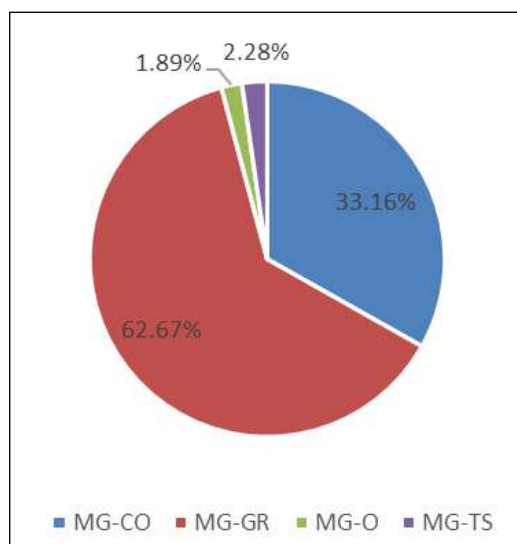


Figure 7: Approximate composition of made ground as determined from BS5930 soil descriptions presented on exploratory hole records.

Material that can be characterised as predominantly cohesive made ground (MG-C) was the next most abundant soil type encountered (approximately 33%), with approximately 2% topsoil and 2% other material.

The assessment of relative proportions of the various made ground materials identified in **Figure 7** is approximate and is based on the ground conditions encountered in the relevant exploratory holes. The data presented here therefore, is for general guidance purposes only. Suitability of excavated material for re-use within the HIF Infrastructure site is discussed further in **Section 5.1.1**.

4.7 Groundwater

4.7.1 Groundwater encountered during GI

During the ground investigation, groundwater was encountered at varying depths. The groundwater strike details recorded during the 2019 and 2021 ground investigation are listed below in **Table 11** and groundwater strikes from selected exploratory holes are shown on the geological long-section and cross-sections shown on **Drawing 05** to **Drawing 07**.

Table 11: Summary of groundwater encountered during the 2019 and 2021 GIs

GI	Intrusive location ID	Site area	Groundwater strike depth (mbgl)	Groundwater strike elevation (mAOD)	Strata
2019	BH103	Red Bank Plateau	0.6	42.0	Made ground
	TP104	Red Bank Plateau	3.5	39.6	Alluvium
	TP105	St. Catherine's Wood	2.0	39.1	Made ground
	TP107	Red Bank Plateau	0.6	42.2	Made ground
	TP110	Red Bank Plateau	1.8	39.6	Made ground
	TP112	Red Bank Plateau	2.8	38.0	Made ground
	WS10	St. Catherine's Wood	4.2	28.0	Alluvium
	WS104	Travis Island	2.2	29.3	Made ground
	WS105A	Red Bank Viaduct	4.2	25.2	Alluvium
	WS106	Travis Island	2.2	29.3	Made ground
2021	BH206	Red Bank Plateau	1.3	41.4	Made ground
	BH207	Red Bank Plateau	13	28.6	Made ground
	BH212	Red Bank Viaduct	5.6	24.8	Made ground
	TP201	Red Bank Plateau	2.4	40.6	Glacial till
	TP202	Red Bank Plateau	0.6	42.3	Made ground
	TP202A	Red Bank Plateau	0.6	42.4	Made ground
	TP202B	Red Bank Plateau	0.5	42.2	Made ground
	TP202C	Red Bank Plateau	0.4	42.2	Made ground
	TP203	Red Bank Plateau	2.9	40.4	Made ground
	TP204	St. Catherine's Wood	2.9	39.2	Made ground
	TP205	St. Catherine's Wood	2.7	38.3	Made ground
	TP206A	St. Catherine's Wood	3.5	38.5	Made ground
	TP207	Red Bank Plateau	2.7	40.6	Made ground
	TP208	St. Catherine's Wood	3.0	39.0	Made ground
	TP210	Red Bank Plateau	3.7	39.4	Glacial till
	TP211	Red Bank Plateau	0.55	41.1	Made ground
	TP212	St. Catherine's Wood	3.4	38.6	Made ground
	TP213	Red Bank Plateau	2.7	40.6	Made ground
	TP216	Red Bank Plateau	0.8	40.0	Made ground
	TP217	Red Bank Plateau	1.2	40.1	Made ground
	TP219	Red Bank Viaduct	3.0	27.7	Made ground
	WS201	Red Bank Plateau	1.1	42.4	Made ground
	WS204	St. Catherine's Wood	4.3	28.5	Made ground/ Alluvium
	WS205	Red Bank Plateau	5.0	37.1	Made ground
	WS206	St. Catherine's Wood	4.1	28.5	Made ground/ Alluvium
	WS207	Red Bank Plateau	0.6	41.3	Made ground
	WS208	Travis Island	1.2	29.0	Made ground
	WS210	Red Bank Plateau	2.8	38.1	Made ground

4.7.2 Groundwater monitoring

Groundwater monitoring equipment was installed in 27 exploratory holes. These installations comprised a 50mm standpipe within a gravel screen and bentonite seal in each case. A summary of the groundwater monitoring results is presented in **Table 12**.

Table 12: Summary of groundwater monitoring

GI	Location	Complete rounds	Response Zone (mbgl)	Response zone stratum	Groundwater depth range (mbgl)	Groundwater Level (mOD)
2019	BH101	4	1 to 5	Made ground	4.81 to 4.95	38.43 to 38.57
	BH102	3	1.9 to 6.7	Made ground/ glacial till	Dry	Dry
	BH103	3	1 to 3.5	Made ground	0.91 to 3.4	39.17 to 41.66
	BH104	2	1.8 to 9.2	Made ground	8.1 to 8.95	33.49 to 32.64
	BH105	2	3 to 9.5	Glacial till	4.52	36.15
	BH106	2	2 to 10	Made ground/ glacial till	Dry	Dry
	BH112	2	0.5 to 4	Made ground/ Bedrock (Chester Pebble Beds)	Dry	Dry
2021	BH201	5	3 to 5	Bedrock (Manchester Marl)	4.95 to 5.46	37.94 to 38.45
	BH202	3	4 to 9	Glacial till	4.19 to 4.94	37.72 to 38.47
	BH203	5	18 to 24	Bedrock (Collyhurst Sandstone)	12 to 12.17	29.89 to 29.72
	BH204	6	1.5 to 10	Made ground/ possible made ground	2.29 to 2.67	40.61 to 40.99
	BH205	3	4.8 to 10.8	Bedrock (Manchester Marl)	5.68 to 6.11	36.47 to 36.9
	BH206	5	2 to 6	Glacial till	2.71 to 3.1	39.59 to 39.98
	BH207	6	1.5 to 15.5	Made ground	12.25 to 12.8	28.84 to 29.39
	BH208	5	3 to 13	Made ground	11.8 to 12.01	28.65 to 28.86
	BH209	3	11 to 17	Bedrock (Chester Pebble Beds)	12.39 to 12.47	28.74 to 28.82
	BH210	5	14 to 19.6	Bedrock (Chester Pebble Beds)	7.63 to 11.21	29.25 to 32.82
	BH211A	6	5 to 10.5	Made ground	6.86 to 7.73	32.71 to 33.58
	BH212	2	5.5 to 9	Bedrock (Chester Pebble Beds)	3.35	27.03
	BH213	6	1.5 to 3	Made ground	2.99 to 3.1	28.84 to 28.95
	BH214A	4	3 to 4	Glacial till	3.24 to 3.38	26.65 to 26.79
	WS201B	6	0.5 to 1.3	Made ground	0.78 to 1.17	42.38 to 42.77
	WS207	6	0.9 to 4.9	Made ground	0.27 to 1.22	40.69 to 41.64
	WS208	3	1 to 4.1	Made ground	1.3 to 1.38	28.87 to 28.79
	WS209	3	2.8 to 3.8	Made ground	Dry	Dry
	WS210	4	1.5 to 2.5	Made ground	2.2 to 2.54	38.34 to 38.68
	WS212	6	0.5 to 2.5	Made ground	Dry	Dry

The main groundwater-bearing units within the site are the Collyhurst Sandstone in the east and the Chester Pebble Beds sandstone in the west. These two units are likely to be hydraulically separated from each other by the Manchester Marl which is present in the

central part of the site (see **Figure 6**). Average monitored groundwater levels in the Manchester Marls were around 37 to 38mOD, in the Collyhurst Sandstone 30mOD and in the Chester Pebble Beds 27 to 30mOD. Observed groundwater levels in the bedrock are shown in **Drawing 08**.

River levels measured during the 2021 topographical survey were between 29.5mOD in the east (where the Collyhurst Sandstone is present) and 26.6mOD in the west (where the Chester Pebble Beds are present). The similarity between groundwater and river levels suggests that the groundwater in the sandstone is discharging into the River Irk.

Groundwater was also observed in the made ground, glacial till and alluvium during drilling and in subsequent water monitoring. The made ground is considered likely to contain a perched but discontinuous body of groundwater in the Red Bank Plateau area, separated from the underlying bedrock aquifers in most areas by the glacial till. The glacial till has been noted to be absent in parts of Red Bank Plateau, for example where a former river channel was located.

In the lower-lying areas; Travis Island, Red Bank Viaduct, and the lower part of St. Catherine's Wood, where glacial till is absent, made ground has been observed to directly overlie alluvium or bedrock, and groundwater in these areas is likely to be in continuity with the river unless it is perched on relic features such as old floor slabs or cellars.

Alluvium was not encountered in many exploratory holes and is interpreted to be confined to a narrow zone along the river channel. The groundwater within the alluvium is assumed to be in continuity with the River Irk.

Glacial till is not continuous and appears to be absent in a zone along the river valley. The groundwater monitoring data in the glacial till suggests that there is not a continuous water body within these deposits, but that any groundwater is present within granular layers/lenses.

5 Geotechnical assessment: Material properties

A summary of the geotechnical in-situ and laboratory testing undertaken in each of the five development areas is presented below. The data is presented based on the test type, strata type and site area. This section also includes an assessment of geotechnical material properties, interpreted from data plots provided in **Appendix B**. A combination of the directly measured and derived material parameters was established to describe and classify the material, outline strength parameters, and discuss potential impacts to future Infrastructure Works within the planning application site.

5.1 Classification

5.1.1 Particle size distribution

Interpretation of material descriptions based on particle size distribution test results are carried out in accordance with BS 5930 [5]. **Appendix B, Charts 1A to 1D** show PSD results for made ground and superficial deposits. Three PSD tests undertaken on samples of Manchester Marl are considered to represent residual soils/highly weathered samples of solid strata and may not be typical of the Manchester Marl in general.

Table 13: Particle size distribution

Red Bank Plateau		
Stratum	No. of samples	Typical description
Made ground	53	Silty gravelly medium to coarse SAND
Glacial till	23	Silty sandy fine GRAVEL
Alluvium	No data	
Manchester Marl	2	Silty sandy GRAVEL
Red Bank Viaduct		
Stratum	No. of samples	Typical description
Made ground	11	Material can be described as a silty gravelly medium to coarse SAND
Glacial till	2	Material can be described as a silty sandy fine GRAVEL
Alluvium	No data	
St. Catherine's Wood		
Stratum	No. of samples	Typical description
Made ground	21	Silty gravelly medium to coarse SAND
Glacial till	4	Silty sandy fine GRAVEL
Alluvium	No data	
Travis Island		
Stratum	No. of samples	Typical description
Made ground	4	Silty gravelly medium to coarse SAND
Glacial till	No data	
Alluvium	No data	
New Town Plots		
Stratum	No. of samples	Typical description
Made ground	3	Silty gravelly medium to coarse SAND
Glacial till	1	Silty sandy fine GRAVEL

New Town Plots		
Stratum	No. of samples	Typical description
Alluvium	No data	
Manchester Marl	1	Silty sandy GRAVEL

As discussed in **Section 4.6**, assessments of the made ground encountered across the wider site area based on BS5930 descriptions of the soils encountered in exploratory holes suggest that approximately 63% of made ground will be predominantly granular. The exploratory hole logs however, suggest that these predominantly granular made ground soils contain a potentially significant cohesive component.

The Specification for Highway Works (SHW) [6] differentiates between general cohesive and granular materials intended for use as engineering fill partly on the basis of PSD data. Further assessment of the PSD data from 92 tests on samples of made ground has identified that 41 samples (45%) had less than 15% passing the 63 micron sieve, suggesting that when classified in accordance with the SHW, made ground recovered from across the wider site area may contain in the order of 45% granular material (note however that fill classification in accordance with the SHW is dependent on a range of parameters, not just PSD data). PSD data for specific areas of proposed excavation and implications for material re-use are assessed further in **Section 7.3.2** below.

As discussed in **Section 4.6**, assessments of relative proportions of various made ground components such as this are approximate and are based on the composition of the relevant samples recovered for testing. Ground conditions may vary between sample locations. In addition, the above assessment of PSD data is a global assessment and given the variability of made ground across the site, the composition of made ground in specific areas may differ.

On the basis of the assessments presented in **Section 4.6** and above, it is concluded that when considered globally across the site, made ground is likely to contain in the order of 45% to 63% predominantly granular material, however this predominantly granular fill may contain a potentially significant cohesive component. Given the variability of made ground across the site, the composition of made ground in specific areas may differ from this range and therefore, this assessment is presented as preliminary guidance only.

5.1.2 Natural moisture content

Charts showing the natural moisture content (nmc) against elevation are shown in **Appendix B, Charts 2A to 2C** with a combined moisture content graph shown in **Chart 2D**. A summary of the results is presented in **Table 14**.

Table 14: Natural moisture content

Red Bank Plateau						
Stratum	No. of samples	No. of outliers	Lower bound nmc (%)	Upper bound nmc (%)	Average nmc (%)	Chart reference (see App B)
Made ground	63	2	14	57	22	Chart 2A
Glacial till	37	3	11	31.6	20	Chart 2B
Alluvium	No data					
Chester Pebble Beds	2	0	14	16	15	Chart 2C
Manchester Marl	3	0	17.2	25	21	Chart 2C
Collyhurst Sdstn	No data					
Red Bank Viaduct						
Stratum	No. of samples	No. of outliers	Lower bound nmc (%)	Upper bound nmc (%)	Average nmc (%)	Chart reference (See App B)
Made ground	9	1	14.5	35.4	22	Chart 2A
Glacial till	2	1			12	Chart 2B
Alluvium	No data					
Chester Pebble Beds	1	0			30.9	Chart 2C
Manchester Marl	No data					
Collyhurst Sdstn	No data					
St. Catherine's Wood						
Stratum	No. of samples	No. of outliers	Lower bound nmc (%)	Upper bound nmc (%)	Average nmc (%)	Chart reference (See App B)
Made ground	34	2	11	31	20	Chart 2A
Glacial till	9	2	15	28	23	
Alluvium	2	0	18.6	21	20	Chart 2B
Chester Pebble Beds	1	0			18	Chart 2C
Manchester Marl	No data					
Collyhurst Sdstn	No data					
Travis Island						
Stratum	No. of samples	No. of outliers	Lower bound nmc (%)	Upper bound nmc (%)	Average nmc (%)	Chart reference (See App B)
Made ground	5	1	19	40.1	25	Chart 2A
Glacial till	No data					
Alluvium	No data					
Chester Pebble Beds	No data					
Manchester Marl	No data					
Collyhurst Sdstn	No data					
New Town Plots						
Stratum	No. of samples	No. of outliers	Lower bound nmc (%)	Upper bound nmc (%)	Average nmc (%)	Chart reference (See App B)
Made ground	4		19.8	30.12	21	Chart 2A
Glacial till	1				19.8	Chart 2B
Alluvium	No data					
Chester Pebble Beds	No data					
Manchester Marl	No data					
Collyhurst Sdstn	No data					

5.1.3 Atterberg limits and plasticity index

Appendix B, Charts 3A to 3D present data for plasticity index against liquid limit of samples of made ground, superficial deposits and bedrock plotted on Casagrande A-line plasticity charts. **Charts 3A and 3B** indicate the cohesive made ground to be typically low to intermediate plasticity clay based on a total of 59 results, whilst **Charts 3C and 3D** indicate the superficial deposits and Manchester Marl to be typically low to intermediate plasticity clay based on 28 and 4 results respectively.

Charts 3E and 3F show plots of natural moisture content and plasticity range (PL-LL) against depth for made ground and superficial deposits at Red Bank Plateau. The charts show that the natural moisture content of the cohesive made ground is typically close to the plastic limit, and based on plasticity characteristics alone, the material would generally fall in Class 2A (wet cohesive material) of the SHW if used as general fill. The natural moisture content of the glacial till within approximately 5m of ground level beneath the Red Bank Plateau is also typically slightly above the plastic limit, and would also result in a Class 2A classification in accordance with SHW. Note that criteria other than the relationship between moisture content and plasticity will need to be taken into consideration when assessing the acceptability of re-use, including strength and compaction characteristics.

Charts 3G to 3J show plots of natural moisture content and plasticity range (PL-LL) against depth for made ground only across the remaining site areas (no plots are available for glacial till). Two of three samples from Red Bank Viaduct (Chart 3G) exhibit natural moisture content close to the liquid limit. Such materials are unlikely to be suitable for re-use without conditioning to reduce the moisture content, however caution should be exercised in drawing conclusions from such limited data. The samples from the St Catherine's Wood area (Chart 3H) exhibit a range of moisture content either-side of the plastic limit, however it appears that most of the cohesive material tested from this area would fall in Class 2A, wet cohesive material.

Charts 3K to 3P show individual plots of plastic limit and liquid limit against depth for made ground, superficial deposits and Manchester Marl.

A summary of the Atterberg limit results and average natural moisture content data (from **Table 14**) is presented in **Table 15**.

Table 15: Plasticity Index

Red Bank Plateau						
Stratum	No. of samples	Plasticity index	Plastic Limit (%)	Liquid Limit (%)	Average Natural moisture content (%)	Soil classification
Made ground	31	7 - 24	15 – 25	25 - 45	22	Low to intermediate plasticity clay soil
Glacial till	21	6 - 26	13 – 19	17 - 45	20	Low to intermediate plasticity clay soil
Alluvium	No data					
Manchester Marl	3	16 -23	13-24	36 – 40	21	Intermediate plasticity clay soil

Red Bank Viaduct						
Stratum	No. of samples	Plasticity index	Plastic Limit (%)	Liquid Limit (%)		Soil classification
Made ground	5	8 – 16	12 – 25	25 – 45	20	Low plasticity clay soil
Glacial till	No data					
Alluvium	No data					
St. Catherine’s Wood						
Stratum	No. of samples	Plasticity index	Plastic Limit (%)	Liquid Limit (%)		Soil classification
Made ground	18	5 – 22	15 – 25	25 – 45	20	Low to intermediate plasticity clay soil
Glacial till	3	16 – 19	13 – 19	17 – 45	20	Low plasticity clay soil
Alluvium	2	13	15-16	28	20	Low plasticity clay soil
Travis Island						
Stratum	No. of samples	Plasticity index	Plastic Limit (%)	Liquid Limit (%)		Soil classification
Made ground	2	12 – 19	15-25	25 – 45	20	Low plasticity clay soil
Glacial till	No data					
Alluvium	No data					
New Town Plots						
Stratum	No. of samples	Plasticity index	Plastic Limit (%)	Liquid Limit (%)		Soil classification
Made ground	3	11 – 18	15 -25	25 – 45	21	Low plasticity clay soil
Glacial till	1	15	16	31	19.8	Low plasticity clay soil
Alluvium	No data					
Manchester Marl	1	15	18	33	19.8	Low plasticity clay soil

5.1.4 Bulk unit weight

No specific laboratory tests were carried out to determine material unit weights. Inferred bulk unit weights based on standard penetration test (SPT) results are provided in **Table 16**: Inferred unit weights based on correlation with SPT N results and estimations from Look (2007). **Table 16** based on recommendations provided by Look (2007) [7] assuming a typical range for dry to saturated conditions.

Table 16: Inferred unit weights based on correlation with SPT N results and estimations from Look (2007).

Red Bank Plateau		
Stratum	Bulk unit weight (kN/m³)	Description and justification
Made ground	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Glacial till	19-21	Dense based on SPT (Table 19) and estimations from Look (2007)
Alluvium	-	No data
Red Bank Viaduct		
Stratum	Bulk unit weight (kN/m³)	Description and justification
Made ground	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Glacial till	-	No data
Alluvium	-	No data
St Catherine's Wood		
Stratum	Bulk unit weight (kN/m³)	Description and justification
Made ground	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Glacial till	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Alluvium	15-18	Loose sand based on SPT (Table 19) and estimations from Look (2007)
Travis Island		
Stratum	Bulk unit weight (kN/m³)	Description and justification
Made ground	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Glacial till	-	No data
Alluvium	-	No data
New Town Plots		
Stratum	Bulk unit weight (kN/m³)	Description and justification
Made ground	17-20	Medium dense based on SPT (Table 19) and estimations from Look (2007)
Glacial till	-	No data
Alluvium	-	No data

5.2 Strength

5.2.1 Laboratory undrained shear strength

Nine undisturbed samples were tested to determine their undrained shear strength by use of triaxial compression in accordance with BS1377:7. The results are summarised in **Table 17**. The average undrained shear strength for the made ground from triaxial testing is 25 kPa (excluding a sample from BH204B which produces an outlier result), and the average undrained shear strength for glacial till is 24 kPa (excluding an outlier of 146kPa associated with BH215). Except for BH204A and BH204B, there is no obvious increase in shear strength with depth evident in the available data.

Table 17: Undrained Triaxial test results

Red Bank Plateau						
Stratum	BH ID	Sample depth	Corrected deviator stress (kPa)	Failure strain (%)	Mode of failure	c_u (kPa)
Made ground	BH101	3.5	63	20	Compound	31
Made ground	BH104	5.3	54	20	Compound	27
Made ground	BH202	1.5	127	5	Plastic	64
Glacial till	BH106	8.5	48	19.5	Plastic	24
Glacial till	BH215	3.5	652	13.5	Brittle	325
Redbank Viaduct						
Stratum	BH ID	Sample depth	Corrected deviator stress (kPa)	Failure strain (%)	Mode of failure	c_u (kPa)
Made ground	BH110	4.8	23	20	Plastic	12
St Catherine's Wood						
Stratum	BH ID	Sample depth	Corrected deviator stress (kPa)	Failure strain (%)	Mode of failure	c_u (kPa)
Made ground	BH203	7	72	16	Plastic	36
Made ground	BH204A	6	29	11	Plastic	15
Made ground	BH204B	13.5	293	10	Brittle	146

5.2.2 Hand shear vane tests

A total of 26 No. hand shear vane (HSV) tests were recorded as having been undertaken across the site. A summary of the results is presented below in **Table 18**.

Table 18: Hand shear vane testing

Red Bank Plateau			
Stratum	No. of tests	Range (kPa)	Average c _u (kPa)
Made ground	13	28 to 127	71
Glacial till	4	32 to 130	68
Alluvium	No results		
Red Bank Viaduct			
Stratum	No. of tests	Range (kPa)	Average c _u (kPa)
Made ground	3	21 to 23	22
Glacial till	No data		
Alluvium			
St. Catherine's Wood			
Stratum	No. of tests	Range (kPa)	Average c _u (kPa)
Made ground	6	19 to 86	54
Glacial till	No data		
Alluvium			
*Note – no data obtained from Travis Island and New Town Plots areas as material encountered was not suitable for testing			

Direct shear strength results from the triaxial tests and ex-situ hand shear vane tests have been plotted against depth in **Figure 8** and **Figure 9** for made ground and glacial till respectively. The data shows a wide scatter with no clear trends.

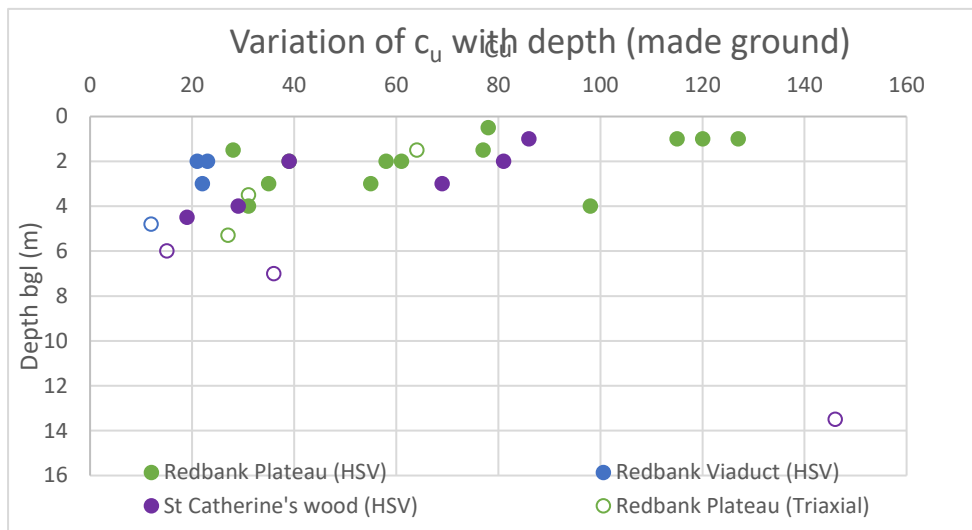
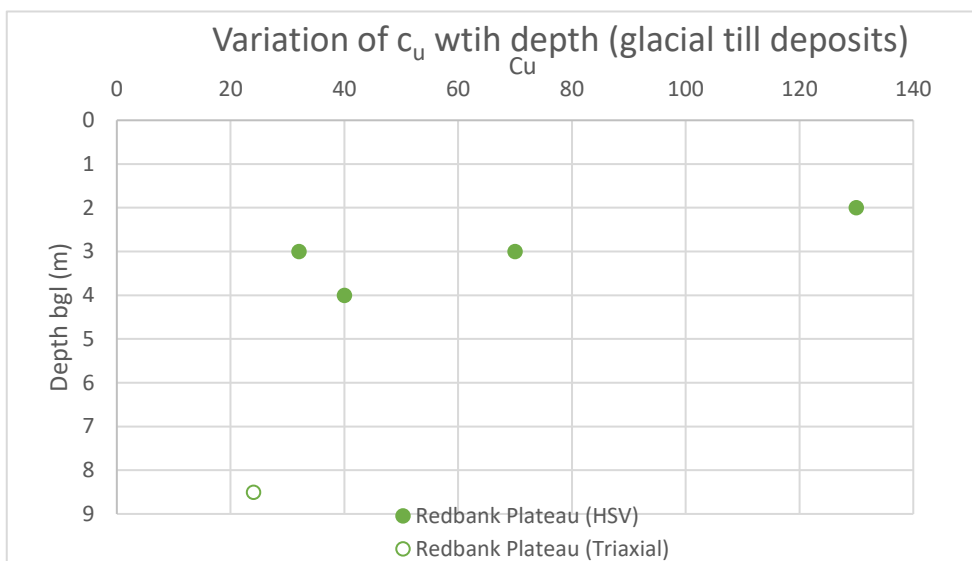


Figure 8: Variation of c_u with depth (made ground)



5.2.3 Derived strength

Standard penetration tests

Appendix B, Charts 4A to 4E, present plots of SPT N value with depth below ground level each of the strata types. A summary of the data is presented in **Table 19**. A number of instances where SPT results exceeded 150 were recorded across the full depth of the made ground material, which may indicate the presence of obstructions within the fill. Depending on their depth, nature and size, such obstructions may represent remediation and/or development constraints.

From Chart **4A**, the made ground shows a wider scatter of SPT N values near to the surface with values between 1.5mbgl and 4mbgl ranging from N = 0 to N = 42 (excluding outliers >N = 50) which is likely to be due to localised compaction. However, within the deeper made ground (below 4m) the range is lower, from N = 2 to N = 22.

Chart **4B**, related to glacial till deposits, appears to show a cluster of SPT N values typically in the range N 10 – 12 to around 8mbgl, which may represent weathered or reworked till, and typical values of around 20 SPT N is likely to represent un-weathered undisturbed till.

For bedrock (Manchester marl and Chester bed formations), outliers are distinguished based on engineering judgement regarding a significant difference from the data set. The Collyhurst formation produced SPT N refusals.

Table 19: Summary of standard penetration test results

Red Bank Plateau						
Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Data plot reference (See Appendix B)
Cohesive made ground	23	2	2	23	11	Chart 4A
Granular made ground	60	4	2	29	11	Chart 4A
Glacial till	50	12	5	55	22	Chart 4B
Alluvium	No Data					
Chester Pebble Beds	12	3	130	1364	573	Chart 4D
Manchester Marl	19	5	203	1071	493	Chart 4C
Red Bank Viaduct						
Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Data plot reference (See Appendix B)
Cohesive made ground	8	0	3	22	12	Chart 4A
Granular made ground	12	3	5	28	12	Chart 4A
Glacial till	No Data					
Alluvium	No Data					
Chester Pebble Beds	12	4	238	556	380	Chart 4D
Manchester Marl	No Data					
St. Catherine's Wood						
Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Data plot reference (See Appendix B)
Cohesive made ground	16	1	1	19	9	Chart 4A
Granular made ground	25	1	0	16	8	Chart 4A
Glacial till	11	0	14	28	19	Chart 4B
Alluvium	9	0	3	22	9	Chart 4B
Chester Pebble Beds	No Data					
Manchester Marl	No Data					

Travis Island						
Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Data plot reference (See Appendix B)
Cohesive made ground	5	1	1	3	2.25	Chart 4A
Granular made ground	9	0	1	18	10	Chart 4A
Glacial till	No Data					
Alluvium	No Data					
Chester Pebble Beds	No Data					
Manchester Marl	No Data					
New Town Plots						
Stratum	No. of tests	No. of outliers	Lower bound SPT N	Upper bound SPT N	Average SPT N (excluding outliers)	Data plot reference (See Appendix B)
Cohesive made ground	1	0	29	29	29	Chart 4A
Granular made ground	2	0	7	20	13.5	Chart 4A
Glacial till	No Data					
Alluvium	No Data					
Chester Pebble Beds	2	N/A	158	750	454	Chart 4D
Manchester Marl	2	N/A	28	37	32.5	Chart 4C

The SPT results have been used to derive indicative values for strength of the various strata encountered (**Table 20**). It is noted that SPT results vary widely. Consequently, the use of site wide properties is not recommended, and further location specific interpretation of available investigation and test data should be carried out for area specific design scenarios.

Estimations of phi values for granular soils from SPT N are provided based on Wolff 1989 [8]. For estimating undrained shear strength from SPT for the cohesive made ground and glacial till, an f_1 constant value of 5 has been derived based on results of $SPT < 200$ and the reporting of a low to intermediate plasticity. This is used to establish the relationship $c_u = SPT N * f_1$. The strength results derived from the SPT tests (**Table 20**) have also been compared with the estimated shear strength values derived from the hand shear vane test (**Table 18**), which suggest similar ranges. However, both of the indirect test methods suggest greater values than those produced by the undrained triaxial test data (**Table 17**).

SPT results from the weaker part of the bedrock (Chester Pebble Bed formation and Manchester Marl) have been used to estimate compressive strength and shear strength values using compressive strength of weak rock estimations set by Stroud, 1988 [9]. However, the estimations describe the compressive strength of the rock mass rather than the intact rock which is likely to be greater due to confinement.

Table 20: Estimated strength parameters from SPT N results

Stratum	Average SPT N result	ϕ' (degrees) (Wolff,1989)	c_u (kPa)	σ_c (MPa)
Cohesive made ground	15	-	75	-
Granular made ground	11	30	-	-
Glacial till (granular)	20	33	-	-
Weathered/reworked glacial till (cohesive)	11		55	
Unweathered/undisturbed glacial till (cohesive)	20		100	
Alluvium	9	30	-	-
Chester Pebble Beds	469	-	4500	9
Manchester Marl (excluding residual)	493	-	5000	10

Drained strength

No drained triaxial test data is available from the 2019 or 2021 GIs from which effective stress strength parameters can be determined. Plasticity index data has therefore been used to derive approximate strength parameters using a correlation graph produced by Holtz and Kovacs [10]. Using the upper and lower bound plasticity index values for made ground and glacial till given in **Table 15** allows values for upper and lower bound effective friction angle to be derived (**Table 21**).

Table 21: Estimated effective friction angle from Plasticity Index values

Stratum	PI % (Lower)	PI % (Upper)	ϕ' (degrees)
Made ground (cohesive)	7	24	30 - 34
Glacial till	6	26	29 -35

5.2.4 Rock strength

The uniaxial compressive strength of the bedrock has been measured directly by a limited number of laboratory tests and derived from point load index test results and SPT test results. As shown in **Appendix B, Charts 5A to 5B**, point load test results on samples of bedrock exhibit no clear trend and vary typically between 0.03MPa and 0.3Mpa. There is insufficient data available to derive reliable site-specific correlations between point load index and UCS, therefore published correlations of $k(a) = 15$ for sandstone (Forster, 1983) and $k(a) = 8$ for mudstone (Wilson, 1976) have been used to derive approximate strength values.

On the basis of the assessments summarised above, the strata encountered can generally be classed as a moderately weak rock.

Uniaxial compressive strengths measured directly and derived from point load tests are summarised in **Table 22**.

Table 22: Uniaxial compressive strength for the bedrock beneath the site

Derivation	Strata	No. of tests	UCS (MPa)	Description and justification
UCS from direct tests	Chester Pebble Beds	2	6.5 to 15.1	Typical range based on two results
	Manchester Marls	No data		
	Collyhurst Sandstone	1	1.4	One result only
UCS derived from point load index	Chester Pebble Beds	54	0.37 to 7.98	Typical range of point load test results $I_{s(50)}$ between 0.1Mpa to 0.3Mpa
	Manchester Marls	61	0.056 to 4.32	Typical range of point load test results $I_{s(50)}$ between 0.03Mpa to 0.3Mpa
	Collyhurst Sandstone	47	0.25 to 7.95	Typical range of point load test results $I_{s(50)}$ between 0.03Mpa to 0.1Mpa

Uniaxial compressive strength tests are typically carried out on higher quality samples which may act to exaggerate the rock strength when compared to data derived from point load tests.

5.3 Compressibility

5.3.1 Laboratory consolidation test

The one-dimensional compressibility characteristics of selected soils samples have been determined on the basis of oedometer testing. Testing was carried out in accordance with clause 3 of BS 1377-5:1990. Samples from BH101, BH110 and BH215 were loaded to 400 kPa which doubled in increments from an initial 50 kPa. Samples from BH102, BH104, BH202, BH203 and BH204 were loaded to 200 kPa which doubled in increments from an initial 25 kPa.

Table 23: Oedometer test results

BH ID	Load range (kPa)	Sample depth	Stratum	Voids ratio (e)	m_v (m ² /MN)	c_v (m ² /yr)	Voids ratio (e)	m_v (m ² /MN)	c_v (m ² /yr)
Red bank Plateau									
				End of consolidation			After consolidation (unload)		
BH101	400	3.5	Made ground	0.440	0.113	2.96	0.448	0.018	Swelling
BH102	200	2.5	Made ground	0.487	0.211	7.68	0.493	0.024	Swelling
BH104	200	5.3	Made ground	0.620	0.253	1.28	0.634	0.060	Swelling
BH202	200	1.5	Made ground	0.379	0.116	11.78	0.379	0.002	Swelling
BH215	400	3.5	Glacial till	0.389	0.051	7.28	0.391	0.006	Swelling

BH ID	Load range (kPa)	Sample depth	Stratum	Voids ratio (e)	m_v (m ² /MN)	c_v (m ² /yr)	Voids ratio (e)	m_v (m ² /MN)	c_v (m ² /yr)
Red bank Viaduct									
				End of consolidation			After consolidation (unload)		
BH110	400	4.8	Made ground	0.383	0.063	12.86	0.382	0.001	Swelling
St Catherine's Wood									
				End of consolidation			After consolidation (unload)		
BH203	200	7	Made ground	0.519	0.175	3.61	0.523	0.022	Swelling
BH204	200	6	Made ground	0.420	0.152	10.37	0.421	0.005	Swelling
BH204	200	13.5	Made ground	0.452	0.197	10.49	0.456	0.023	Swelling

Table 23 identifies the coefficient of compressibility (m_v) and coefficient of consolidation (c_v) for each sample tested, both at the end of consolidation (fully loaded) and after consolidation during un-loading. The average m_v value based on the 200 kPa loading test after full consolidation for made ground is 0.184 m²/MN, and the average c_v value after full consolidation for made ground is 7.53 m²/yr. For the 400 kPa loading phase, the average m_v values after full consolidation for made ground is 0.088 m²/MN, and the average c_v after full consolidation for made ground is 7.91 m²/yr.

5.4 California bearing ratio

Equivalent CBR values for the shallow made ground encountered across the wider site area have been derived from mexeprobe and dynamic cone penetrometer testing. The results are summarised below. When assessing this data, the following definitions have been used:

Sub-formation - the surface exposed following site clearance and any excavation and prior to any filling operation.

Formation - the surface of the ground after completion of any filling operation.

5.4.1 Mexeprobe testing

During the 2021 GI, the mexeprobe method was used to obtain an equivalent CBR in selected trial pits. The tests were undertaken at a range of start depths from 0.2 to 0.8m bgl. The maximum depth the tests were completed to was 0.6m below the start depth. **Table 24** presents a summary of test results obtained from the made ground, with the data plotted against depth on **Figure 10**.

Table 24: Determination of equivalent CBR % by mexeprobe testing

Red Bank Plateau			Equivalent CBR %						
No. of locations	No. of tests	No. of failed tests	Max	Min	Average	No. <2.5%	No. 2.5 to 5%	No. 5-10%	No. 10-15%
12	49	11	15	0.5	4.4	17	11	7	3

Red Bank Viaduct			Equivalent CBR %						
No. of locations	No. of tests	No. of failed tests	Max	Min	Average	No. <2.5%	No. 2.5 to 5%	No. 5-10%	No. 10-15%
2	11	2	10	2	5.4	2	3	4	0
St. Catherine's Wood			Equivalent CBR %						
No. of locations	No. of tests	No. of failed tests	Max	Min	Average	No. <2.5%	No. 2.5 to 5%	No. 5-10%	No. 10-15%
6	27	6	0.5	11	3.65	10	8	3	0

The results in **Table 24** and **Figure 10** indicate a range of equivalent CBR of 0.5 to 13% with an average CBR from all available tests of 4.3%. It is inferred that all failed tests were due to obstructions of large cobbles causing early termination.

5.4.2 Dynamic cone penetrometer testing

During the 2021 GI, the Dynamic Cone Penetrometer (DCP) was used to obtain equivalent CBR values at a number of selected trial pit locations. The results of DCP testing are summarised in **Table 25** and **Figure 10**.

Table 25: Summary of equivalent CBR via DCP testing method.

Exploratory Hole ID	Stata	Start depth (mm)	Equivalent CBR reading (%) at ~500mm below start depth	Equivalent CBR reading (%) at ~1000mm below start depth	Equivalent CBR reading (%) at ~1500mm below start depth	Equivalent CBR reading (%) at ~2000mm below start depth
Red Bank Plateau						
TP201	Granular	800	-	12.5	26.5	-
TP203	Granular	300	8.5	8.5	8.5	-
TP207	Granular	300	10	6	12.5	-
TP209	Granular	300	-	-	-	-
TP210	Granular	800	-	55	-	-
TP211	Granular	250	26.5	-	-	-
TP213	Topsoil	400	3	6	6	12.5
TP214	Granular	500	4	26.5	17	26.5
TP215	Granular	700	-	2	1	4
TP216	Granular	300	12.5	8.5	17	-
TP217	Granular	450	12.5	26.5	-	-
Red Bank Viaduct						
TP218	Cohesive	450	12.5	12.5	4	-
TP219	Granular	700	-	55	-	-
St. Catherine's Wood						
TP204	Granular	400	5	8.5	12.5	-
TP205	Topsoil	250	6	8.5	-	-
TP206	Topsoil	300	17	-	-	-
TP206A	Granular	400	6	12.5	26.5	26.5

Exploratory Hole ID	Stata	Start depth (mm)	Equivalent CBR reading (%) at ~500mm below start depth	Equivalent CBR reading (%) at ~1000mm below start depth	Equivalent CBR reading (%) at ~1500mm below start depth	Equivalent CBR reading (%) at ~2000mm below start depth
TP208	Topsoil	600	2	17	26.5	-
TP212	Granular	800	-	3	2	3.5

At depths of 500mm, 1000mm, 1500mm and 2000mm below ground level the average equivalent CBR recorded are 9.7%, 16.8%, 13.4% and 14.6% respectively. Outlier results greater than 100% have been excluded from the data analysis. Values from the DCP tests show that the equivalent CBR of the made ground generally increases with depth, however it should be noted that at depth, several tests terminated early due to obstruction so data from depth is relatively limited. Plate load testing should be used to verify formation strength.



Figure 10: Equivalent CBR vs depth based on in-situ mexeprobe and DCP results

By inspection, on the basis of the in-situ test data presented in **Figure 10**, it is anticipated that a CBR value of 2% ($k_{762} = 22 \text{ MN/m}^3$) or greater can be anticipated across the sub-formation.

5.4.3 Laboratory CBR

During the 2019 and 2021 ground investigations a total of 32 laboratory derived CBR tests were completed on samples prepared by a variety of methods including 2.5kg compaction, 4.5kg compaction and vibrating hammer compaction. The tests were undertaken on samples obtained from depths ranging from 0.8 to 15m bgl. All samples were tested with as received moisture contents. A variety of seating loads were applied to the samples during the tests including 10kPa, 50kPa and 250kPa.

The full range of results from all tests completed was 0.98 to 98.5%. As it is anticipated that only the top 2m of the site will need to be reworked, all results from tests on samples taken deeper than 2m have been discounted from this assessment. Following this the seating loads were reviewed, and it is indicated that on tests where a high seating load (250kPa) was applied the CBR results were significantly higher than when a lower seating load (10kPa and 50kPa) was applied. The results from the high seating load tests are deemed to be unrepresentative and as a result have been discounted from the assessment.

Of the 32 results obtained, 5 were from ground level to 2m bgl and had a seating load of 10-50kPa applied. The derived CBR results ranged from 0.9 to 17% with the average being 7%.

By inspection, on the basis of the laboratory testing that has been undertaken, it is anticipated that for suitable general granular fill recovered from made ground, placed and compacted in accordance with the SHW, a CBR value of 5% ($k_{762} = 37 \text{ MN/m}^3$) or greater at formation level can be assumed for pavement design.

5.4.4 Summary of CBR tests

On the basis of both the in-situ testing and laboratory results, together with engineering judgement, it is recommended that following a programme of proof-rolling, (**Section 8.2.3**) a CBR value of 2% ($k_{762} = 22 \text{ MN/m}^3$) can be assumed for made ground exposed at sub-formation level. In areas of engineered fill (using recovered, site-won general granular fill), a CBR value of 5% ($k_{762} = 37 \text{ MN/m}^3$) can be assumed at formation level for pavement design.

5.5 Moisture content/dry density relationship

Twenty-nine laboratory compaction tests have been undertaken to establish the relationship between moisture content and dry density for a range of samples recovered from wider site area. Outliers have been removed to prevent skewing the data range. The compaction test results are summarised in **Table 26**.

Table 26: Summary of compaction test results

Red Bank Plateau			2.5kg		4.5kg		Vibro	
Stratum	No. of tests	No. Outliers	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)
Made ground (cohesive)	No data							
Made ground (Granular)	9	2	1.7–2.06	9-17	1.43–1.92	12-18	1.69 –1.83	10-14
Glacial till	12	0	1.74-1.97	11-18	2.05	9.5	-	-

Red Bank Viaduct			2.5kg		4.5kg		Vibro	
Stratum	No. of tests	No. Outliers	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)
Made ground (cohesive)	No data							
Made ground (Granular)	1		1.93	11.2	-	-	-	-
Glacial till	No data							
St Catherine's Wood			2.5kg		4.5kg		Vibro	
Stratum	No. of tests	No. Outliers	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)	Max Dry Density (Mg/m ³)	Optimum moisture content (%)
Made ground (cohesive)	3	0	1.8–1.82	14 – 16.7	1.97	11	-	-
Made ground (Granular)	4	1	1.97	11	1.95-2.01	10	-	-
Glacial till	1	0	2.14	8	-	-	-	-
Travis Island – No data								
New Town plots – No data								

An analysis of the moisture content/dry density relationship for made ground has been carried out for the 2.5kg rammer tests (**Appendix B, Charts 6A to 6Q**) and is summarised in **Table 27**. An interpretation of the test results has been undertaken to suggest allowable moisture content ranges that would satisfy requirements for structural and general fill material in accordance with SHW table 6/4 [6].

Thirteen of the individual test results presented in Appendix B, Charts 6A to 6Q, had natural moisture content within the range that is likely to be acceptable for material placed as class 1 general granular fill in accordance with the SHW. In three samples, natural moisture content was higher than the acceptable range. Typically, the natural moisture content of the material is very close to or at the upper limit of acceptability.

The data indicates that in some instances the natural moisture content is above the likely upper limit of acceptability for general granular fill, indicating that some material is likely to require conditioning. For material to be placed as a structural backfill, where a higher standard of compaction is likely to be required, more conditioning to reduce the moisture content is likely to be necessary.

Table 27: Summary of compaction test analysis

BH ID	Outliers	Average data values					
		Results of Proctor Testing					Natural moisture content
		Acceptable Moisture Content				Optimum moisture content	
		Lower bound - general fill	Upper bound - general fill	Lower bound - structural fill	Upper bound - structural fill		
Redbank Plateau							
TP103, TP201, TP207, TP211, BH205, BH209 A/B BH215B	TP215, TP209, BH215A	7	21	8	19	14.5	21.6
Redbank Viaduct							
TP121	n/a	6	18.5	8.5	15.5	11.2	No value
St Catherine’s Wood							
BH204 A/B, BH213, TP212	n/a	6.6	22.8	9.1	20.6	16.25	23.5
Travis Island							
No data							
New Town Plots							
No data							

5.6 Concrete aggressivity

Contaminants such as sulphates and acidic conditions generally present a low risk to human health but can result in aggressive ground conditions that may result in the degradation of buried concrete. Current UK good practice requires the assessment of this potential risk and appropriate design of buried concrete in line with BRE Special Digest SD1 [12]. An assessment in line with this guidance is presented below.

The design sulphate (DS) and aggressive chemical environment for concrete (ACEC) classes were assessed assuming that the site was classified as non-pyritic brownfield with mobile groundwater. A summary of the assessment results is provided in **Table 28** below.

The available data indicates that for the design of buried concrete in made ground DS-2 and AC-1 conditions should be assumed. For the design of buried concrete in other strata, DS-1 and AC-1 conditions should be assumed. This assessment does not take account of the potential impact of hydrocarbon contamination on the setting and curing of concrete. The potential impacts of such contamination should be taken account of during the development of the remediation strategy for the site and in designing concrete mixes.

Table 28: Summary of aggressive ground testing

Strata	No. of samples	Characteristic pH	Characteristic sulphate (mg/l)	Design sulphate class	ACEC class*
Made ground	24	10.9	1,019	DS-2	AC-1
Glacial till	2	8.2	97.4	DS-1	AC-1
Alluvium	No data				
Chester Pebble Beds	2	8.15	31.7	DS-1	AC-1
Manchester Marl	5	8.24	36.9	DS-1	AC-1
Collyhurst Sandstone	1	8.5	14.5	DS-1	AC-1
*Assumes mobile groundwater					

6 Contamination assessment

6.1 Initial conceptual site model

6.1.1 Approach

A conceptual model describes the scenario in which the risks to human health and the environment posed by land contamination are assessed. It describes the ground and surface conditions, the proposed ground works and the final form of the development. In particular, the model identifies and describes the sources of the potential contamination, the behaviour of the contamination in environmental media such as soil and groundwater, surface water and air. It also identifies and characterises potential human health and environmental receptors, and plausible pathways.

The potential risks to human health and the environment have been considered in the context of a conceptual source-pathway-receptor model of the wider site area, identifying:

- The principal pollutant hazards associated with the site (the sources);
- The principal receptors at risk from the identified hazards; and
- The existence, or absence, of plausible pathways which may exist between the identified hazards and receptor.

For risks to be present, all three elements (source-pathway-receptor) of a potential contaminant pollutant linkage must be present.

6.1.2 Potential sources

The 2019 desk study [1] identified the primary potential contamination sources within the planning application site as rail sidings (in Red Bank Plateau), historical works (across all site areas, including mills, dye works and chemical works) and gasworks and gasometers (in St Catherine's Wood). Potential sources external to the planning application site include former gasometers in Travis Island, the Rochdale Road gasworks, the former Queens Road Tip (landfill) and Sand Street landfill [1].

The 2019 desk study [1] included a review of potentially contaminating previous uses and a preliminary review of the findings of the 2019 GI across the wider site area. **Table 29** has been adapted from Arup desk study report and presents a summary of potential sources of contamination at the site based on the findings of both the desk-based review and the 2019 GI.

The 2021 GI was designed to provide more information on historical features identified by the desk study. The rationale for the GI, which sets out the purpose of each exploratory hole, is presented in **Appendix A**.

Table 29: Potential sources of contamination (based on desk study information and the preliminary findings of the 2019 GI)[1]

Potential Source	Potentially Contaminative Materials	Comments
Made ground from site historical site operations including: Rail sidings ¹ Historical works ^{2,3,4,5,6,7} Gasworks and gasometers ⁸	Organic compounds Metals and metalloids including lead, arsenic, mercury, nickel, copper, zinc, and iron Asbestos Polycyclic aromatic hydrocarbons (PAHs) Total petroleum hydrocarbons (TPH) including lubricating oils, heating oils, petrol and diesel range organics Solvents (VOCs and SVOCs) Cyanide (free and complex) Phenol Extremes of pH	The 2019 ground investigation identified material such as clinker in the made ground. Asbestos was identified in 16 positions and it may also be present in other areas of contaminated soil not yet identified Hydrocarbon odours were noted in 12 exploratory holes, including TP204, TP205 TP206A and BH203 in the area of a former gasworks. Metallic blue sand was also noted in this area. Hydrocarbon odours were also noted in WS106 which was drilled through a former gasholder in Travis Island. Oily groundwater was noted in TP202B and TP202C in the foundations of the former carriage shed in St. Catherine's Wood. Works include: chemical works, dye works, oil works, engineering works, garage, glass works, metal works, printing works, tannery, and timber works
Historical demolition rubble in made ground	Asbestos	Previous buildings within the site boundary may have contained asbestos, which may have become incorporated into the made ground during demolition
Perched groundwater within made ground/relic structures Leachate from adjacent landfill sites (predominantly Queens Road Tip landfill)	Potential for leachable contaminants from made ground	Hydrocarbon contamination of perched groundwater was identified in the area of the former carriage shed and railway gasworks. Monitoring wells were installed in BH201 and BH205 to check for the migration of contaminated leachate from Queens Road Tip.
Made ground containing degradable materials Former landfill sites (offsite, including Queens Road tip, Sand Street landfill and Fitzgeorge Street landfill)	Hazardous ground gases (methane, carbon dioxide, hydrogen sulphide, carbon monoxide)	Gas monitoring data is available from the 2021 investigation, with all but one position CS1. BH205, close to the edge of Queens Road Tip, was determined as CS2.
DoE Industrial Profile document titles: ¹ Railway Land ² Chemical works – coatings, paints and printing inks manufacturing works ³ Timber treatment works ⁴ Timber manufacturing works ⁵ Road vehicle fuelling, service and repair – garages and filling stations ⁶ Metal manufacturing, refining and finishing works – iron and steel works ⁷ Textile and dye works ⁸ Gas works, coke works and other coal carbonisation plants		

6.1.3 Potential receptors

Receptors both during the proposed HIF Infrastructure Works and following completion of the HIF IW and future development include:

- Construction workers and site neighbours during the HIF IW;
- Interim users of the site following HIF IW before follow-on plot development;
- Construction workers and site neighbours during future development of the site;
- Residents and workers in the proposed future buildings constructed on the site;
- Occupants of the proposed school (Plot RB05b);
- Future users of onsite public open space areas;
- Groundwater within the alluvium deposits (secondary A aquifer), glacial till (secondary (undifferentiated) aquifer), Manchester Marls Formation (secondary B aquifer) and Chester Formation and Collyhurst Sandstone Formation (principal aquifers);
- Surface water receptors – primarily the River Irk;
- Buried structures and services;
- Plants in new soft landscaped areas.

6.1.4 Potential pathways

Potential pathways that may be present during construction of HIF IW and following completion of the HIF IW, during construction of follow-on development and following completion of follow-on development include:

- Human health - ingestion of soils or dust;
- Human health - inhalation of dust, vapour or ground gas;
- Human health - dermal contact with soils, surface water and groundwater;
- Controlled waters - migration of dissolved or free phase contamination (preferential flow paths may exist such as former river channels);
- Vegetation - direct contact and uptake of contaminants in made ground;
- Ground gas - ingress of ground gas into the new development;
- Building and services - building materials such as concrete and plastic pipework may be subject to attack by aggressive ground conditions, where present.

6.1.5 Summary of initial conceptual site model

The 2019 Desk Study included a preliminary summary of potential contaminant linkages requiring assessment in relation to the wider site area, based on the findings of both the desk-based review and the 2019 GI. **Table 30** and **Table 31** have been adapted from Arup desk study report and present summaries of potential contaminant linkages both during the construction and operational phases of the planning application site.

Table 30: Conceptual site model for the HIF Infrastructure Works construction phase

Source		Pathway		Receptor	Linkage?
Made Ground (containing solid contaminants, asbestos fibres and hydrocarbons)	→	Dermal contact	→	Construction worker	Yes
		Ingestion of soil/ soil dust	→		Yes
		Inhalation of soil vapour	→		Yes
		Inhalation of soil and soil dust	→	Construction worker	Yes
			→	Site neighbours	Yes
Temporary stockpiles of excavated arisings Accidental leaks and spills during construction	→	Leaching and runoff	→	Relic surface water drainage network	Yes
			→	River Irk	Yes
		Leaching and infiltration	→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock River Irk	Yes
Impacted shallow groundwater, including groundwater entering the site from landfill to the north	→	Dermal contact	→	Construction worker	Yes
		Ingestion	→	Construction worker	Yes
		Lateral migration	→	River Irk	Yes
Ground gases/landfill gases	→	Ingress and accumulation of toxic, asphyxiating or explosive concentrations within excavations	→	Construction worker in deep trenches and chambers	Yes

Table 31: Conceptual site model post-completion of HIF Infrastructure works

Source		Pathway		Receptor	Linkage?
Made Ground (containing solid contaminants and possible hydrocarbons from historical spills)	→	Dermal contact	→	Future site user in public open space areas	Yes
		Ingestion of soil/ soil dust	→	Interim users of plots where no hardstanding exists prior to follow-on development	Yes
		Inhalation of soil vapour	→		Yes
		Inhalation of soil and soil dust	→	Pathways broken where hard surfacing and buildings present	Yes
		Leaching and infiltration	→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock River Irk	Yes
		Direct contact	→	Buried structural concrete	Yes
			→	Potable water supply pipes	Yes

Source		Pathway		Receptor	Linkage?
			→	New planting in public open space areas	Yes
Impacted shallow groundwater, (including groundwater if entering site from landfill to north)	→	Dermal contact	→	Future site resident	No
		Ingestion	→	Future site resident	No
		Lateral migration	→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock River Irk	Yes
Ground gases/landfill gases	→	Ingress and accumulation of toxic, asphyxiating or explosive concentrations within buildings	→	Future site user Building structures	Yes

6.2 Environmental risk assessment

6.2.1 Introduction

Several potential contaminant linkages have been identified within the planning application site (**Section 6.1.5**). An environmental risk assessment has been undertaken for each of the receptors for which a potential contaminant linkage has been identified. The process outlined in the Land Contamination Risk Management (LCRM) guidance [13] follows a tiered approach to assessing risk which begins with an initial screening assessment known as a generic quantitative risk assessment (GQRA). The GQRA makes use of published assessment criteria and when a soil/ groundwater concentration exceeds the screening value then further consideration is required. The GQRA is presented in the following sections.

The potential environmental risks have been considered in the context of a conceptual source-pathway-receptor (SPR) model of the site. A preliminary evaluation of the level of risk to each receptor from the identified plausible pathways and the level of mitigation that would be required for the proposed development is also provided.

For this assessment, the laboratory analysis results and field data collected during the 2019 and 2021 ground investigations have been screened against current published or internal guideline values in order to provide an initial assessment of the potential contamination status of the planning application site. The data for soil, groundwater and ground gas have been assessed separately, as presented below.

6.2.2 Human health soil screening assessment

6.2.2.1 Methodology

To simplify the assessment of ground contamination risks, the statutory guidance suggests that generic soil quality guideline values may be used for the initial screening of soil

contamination testing results. Generic assessment criteria (GAC) and site-specific assessment criteria (SSAC) can be calculated using the software version of the Contaminated Land Exposure Assessment (CLEA) model [14]. The model estimates human exposure (children and adults) to soil contaminants for those potentially living, working and/or playing on contaminated sites over long time periods (chronic exposure). The CLEA model does not consider short-term (acute) risks to humans, such as those which may arise during construction activities, or the risks posed by contaminated groundwater.

Soil guideline values (SGVs) generated using the CLEA software and accompanying toxicological reports have been issued by the Environment Agency (EA) for eleven contaminants. Arup has produced GACs using risk assessment software in accordance with the CLEA assessment framework for the six standard CLEA end uses (residential with plant uptake, residential without plant uptake, public open space (parks), public open space (residential), allotments, and commercial) and for soil organic matter (SOM) values of 1%, 2.5% and 6%. Land Quality Management Ltd (LQM) [15] and the AGS/EIC/CL:AIRE [16] have also produced and published GACs for the standard CLEA end uses, using the CLEA v1.07 software. Arup GACs have been benchmarked against the LQM and AGS/EIC/CL:AIRE GACs and both are similar with respect to the research carried out and the criteria developed.

The assessment of risks from asbestos in soils is presented in **Section 6.2.2.4**.

6.2.2.2 Soil screening results – residential end use

Only limited areas of private residential gardens are proposed as part of the follow-on development within the planning application site. For the Red Bank Plateau and Red Bank Viaduct areas, the soil results have been compared to human health generic assessment criteria (GAC) derived by Arup (**Appendix C**) for a residential end use with plant uptake, to provide a conservative assessment of the potential risks to human health. Full details on the input parameters and background research can be provided upon request. The GACs have been developed using a Soil Organic Matter (SOM) value of 6%, which has been selected based on the average SOM content of the soils sampled across the wider site area.

Although part of the 2019 and 2021 GI, Travis Island and the New Town Plots do not currently form part of the planning application site (**Figure 1**). For these areas of the site (for which development proposals are not currently known), data from both the 2019 and 2021 GIs has also been compared to the human health GAC for a residential end use with plant uptake. This screening has not been applied to St. Catherine's Wood (including Plot RB05b) as it is not intended for residential development (see **Section 6.2.2.3**).

The results of the human health screening assessment for the Red Bank Plateau, Red Bank Viaduct, Travis Island and New Town Plots are presented in **Appendix C** and summarised on **Drawing 10**. A total of 132 soil samples were screened across the two investigations. The screening identified several samples where contaminants exceeded the relevant human health GAC as summarised in **Table 32**.

Table 32: Soil samples exceeding human health GACs for residential development with plant uptake.

Contaminant	GAC (mg/kg)	No. of samples	Conc range (mg/kg)	Exceedances				
				No.	Location ID	Depth (mbgl)	Conc (mg/kg)	Area
Arsenic	37	128	1.9 to 180	13	BH106	0.3m	40	RB Plateau
					TP109	1.3m	71	RB Plateau
					TP112	2.3m	44	RB Plateau
					TP115	0.3m	40	RB Plateau
					TP115	3.3m	40	RB Plateau
					TP124	0.3m	61	New Town
					BH207	1.2m	53	RB Plateau
					BH211A	9m	50	RB Plateau
					BH211A	10.5m	40	RB Plateau
					TP219	1m	180	RB Viaduct
					WS201	1m	44	RB Plateau
					WS205	2m	65	RB Plateau
					WS209	2m	43	Travis Island
Beryllium	1.7	128	<0.2 to 3.9	24	BH104	0.7m	2.8	RB Plateau
					BH104	9.7m	2.1	RB Plateau
					TP109	0.3m	2.6	RB Plateau
					TP109	1.3m	2.1	RB Plateau
					TP109	3.3m	2	RB Plateau
					TP110	1.3m	1.9	RB Plateau
					TP112	0.3m	2.2	RB Plateau
					TP115	0.3m	2.2	RB Plateau
					TP115	1.3m	3.9	RB Plateau
					TP115	3.3m	2.3	RB Plateau
					TP120	1m	1.9	RB Viaduct
					TP124	0.3m	1.8	New Town
					BH207	1.2m	2.6	RB Plateau
					BH207	10.2m	3.9	RB Plateau
					BH208	0.3m	1.8	RB Plateau
					BH208	8.2m	2	RB Plateau
					BH209	1.2,	2.1	RB Plateau
					BH211A	2.2m	1.8	RB Plateau
					BH211A	5.2m	2	RB Plateau
					TP202	0.3m	1.9	RB Plateau
					TP219	1m	2.6	RB Viaduct
					WS201	1m	2	RB Plateau
					WS205	2m	2.3	RB Plateau
					WS209	2m	2.2	Travis Island
Copper	2430	128	8.9 to 4200	1	TP124	0.3m	4200	New Town
Lead	200	128	6.4 to 12000	39	BH102	0.3m	530	RB Plateau
					BH103	0.3m	230	RB Plateau
					BH103	1m	210	RB Plateau
					BH106	0.3m	370	RB Plateau
					BH106	3.3m	210	RB Plateau

Contaminant	GAC (mg/kg)	No. of samples	Conc range (mg/kg)	Exceedances				
				No.	Location ID	Depth (mbgl)	Conc (mg/kg)	Area
					BH110	3m	1900	RB Viaduct
					BH112	0.3m	300	RB Viaduct
					TP104	0.3m	210	RB Plateau
					TP109	0.3m	1300	RB Plateau
					TP109	3.3m	330	RB Plateau
					TP110	1.3m	520	RB Plateau
					TP112	0.3m	290	RB Plateau
					TP112	2.3m	210	RB Plateau
					TP115	0.3m	460	RB Plateau
					TP115	3.3m	520	RB Plateau
					TP120	0.3m	2100	RB Viaduct
					TP121	0.3m	440	RB Viaduct
					TP122	0.3m	730	RB Viaduct
					TP124	0.3m	12000	New Town
					TP125	0.3m	830	New Town
					WS104	1m	290	Travis Island
					WS105	0.3m	490	RB Viaduct
					BH207	1.2m	240	RB Plateau
					BH210	4.2m	260	RB Plateau
					BH211A	2.2m	490	RB Plateau
					BH211A	5.2m	600	RB Plateau
					BH211A	9m	460	RB Plateau
					BH212	0.4m	430	RB Viaduct
					BH212	2.2m	850	RB Viaduct
					BH212A	0.6m	370	RB Viaduct
					BH214	1.1m	870	RB Viaduct
					BH214A	2.2m	520	RB Viaduct
					TP202	0.3m	460	RB Plateau
					TP210	1m	420	RB Plateau
					TP213	0.3m	230	RB Plateau
					TP219	1m	430	RB Viaduct
					WS205	2m	1400	RB Plateau
					WS208	2m	240	Travis Island
					WS209	0.3m	230	Travis Island
Vanadium	410	128	7 to 640	1	BH207	5.2m	640	RB Plateau
Cyanide	1.4	128	<0.1 to 160	14	BH104	9.7m	2.4	RB Plateau
					TP115	3.3m	68	RB Plateau
					TP124	0.3m	89	New Town
					WS104	1m	8.5	Travis Island
					WS106	1m	4	Travis Island
					BH207	10.2m	9.1	RB Plateau
					BH207	13.2m	18	RB Plateau
					BH211A	2.2m	2.9	RB Plateau
					BH211A	5.2m	2.5	RB Plateau
					BH211A	9m	47	RB Plateau
					BH211A	10.5m	12	RB Plateau

Contaminant	GAC (mg/kg)	No. of samples	Conc range (mg/kg)	Exceedances				
				No.	Location ID	Depth (mbgl)	Conc (mg/kg)	Area
					BH212A WS208 WS209	0.6m 2m 0.3m	3.1 160 69	RB Viaduct Travis Island Travis Island
Dibenz-a-h-anthracene	0.305	99	<0.03 to 5	6	BH110 WS104 BH213 TP210 TP213 TP213	0.3m 1m 1.2m 0.3m 0.3m 2m	0.54 2.4 5 0.76 0.75 0.46	RB Viaduct Travis Island RB Viaduct RB Plateau RB Plateau RB Plateau
Benzo(a) anthracene	13.3	99	<0.03 to 43	2	WS104 BH213	1m 1.2m	19 43	Travis Island
Benzo(a) pyrene	3	99	<0.03 to 26	6	BH110 WS104 BH213 TP210 TP213 TP213	0.3m 1m 1.2m 0.3m 0.3m 2m	3.9 17 26 5.6 6.2 5	RB Viaduct Travis Island RB Viaduct RB Plateau RB Plateau RB Plateau
Benzo(b) fluoranthene	3.7	99	<0.03 to 37	5	BH110 WS104 BH213 TP210 TP213	0.3m 1m 1.2m 0.3m 0.3m	4.5 17 37 7.1 5.9	RB Viaduct Travis Island RB Viaduct RB Plateau RB Plateau
Chrysene	26.8	99	<0.03 to 50	1	BH213	1.2m	50	RB Viaduct

6.2.2.3 Soil screening results – public open space end use (parks)

The main focus of non-residential development in the current proposed masterplan is the St Catherine's Wood area (including Plot RB05b). Analysis data from both the 2019 and 2021 GIs for this part of the site has been compared to the human health generic assessment criteria (GAC) derived by Arup for a public open space end use (parks). The GACs have been developed using a Soil Organic Matter (SOM) value of 6%, which has been selected based on the average SOM content of the soils sampled across the wider site area.

The results of the human health screening assessment for the St. Catherine's Wood area are presented in **Appendix C**. A total of 38 soil samples were screened across the two investigations. The screening did not identify any samples where contaminants exceeded the relevant human health GAC (**Drawing 11**).

6.2.2.4 Soil screening results – asbestos

The methods used to assess the results of asbestos content of soil samples differ to those used for other contaminants. As a first step, soil samples undergo laboratory assessment for the presence of asbestos. As part of the 2019 and 2021 GI, samples which proved

positive for the presence of asbestos underwent a further quantification stage. The findings of this assessment are presented in **Table 33** and **Drawing 12**.

Table 33: Soil samples in which the presence of asbestos was identified.

No. of samples	% range	Exceedances				
		No.	Location ID	Depth (mbgl)	Type and %	Area
121	<0.001 to 0.012	16	TP210	1m	Chrysotile fibres - 0.011	RB Plateau
			WS207	1m	Chrysotile fibres - 0.012	RB Plateau
			BH110	0.3m	Amosite fibres - <0.001	RB Viaduct
			BH112	0.3m	Amosite fibres - <0.001	RB Viaduct
			TP120	1m	Chrysotile – microscopic ACM fragments – 0.002	RB Viaduct
			BH212A	0.6m	Chrysotile fibres - 0.005	RB Viaduct
			TP105	0.3m	Chrysotile – microscopic board fragments – 0.006	St. Catherine's Wood
			WS103	1m	Amosite fibres - <0.001	St. Catherine's Wood
			TP206	0.3m	Chrysotile fibres - 0.007	St. Catherine's Wood
			WS104	1m	Amosite fibres - <0.001	Travis Island
			WS106	1m	Amosite fibres - <0.001	Travis Island
			WS208	2m	Chrysotile and Amosite fibres - 0.004	Travis Island
			WS209	0.3m	Chrysotile fibres - <0.001	Travis Island
			TP125	0.3m	Chrysotile in microscopic bitumen and bundles of chrysotile and amosite in soil – 0.003	New Town
			TP126	0.3m	Amosite in loose fibrous asbestos debris and bundles of Chrysotile fibres in soil – 0.005	New Town
			TP127	0.3m	Bundles of Chrysotile and Amosite fibres - <0.001	New Town

Asbestos has been identified in all areas of the planning application site including the Red Bank Plateau, Red Bank Viaduct and St. Catherine's Wood areas. The asbestos identified was generally present as fibres, with both chrysotile and amosite identified. The possibility exists that asbestos may be present in soils between exploratory locations.

6.2.2.5 Summary of soil screening

Visible evidence of asbestos fibres or asbestos containing materials (ACM) was recorded in 16 of 121 samples across the wider site area, with the maximum recorded concentration of 0.012%. Appropriate measures will be required to mitigate the risks posed by asbestos both during construction and in the long term to protect future residents, neighbours of the site and maintenance workers.

In the St. Catherine's Wood area, no contaminants other than asbestos have been found to exceed the public open space (parks) GACs (**Section 6.2.2.3**).

In the Red Bank Plateau, Red Bank Viaduct, Travis Island, and New Town Plots, when the results of analysis have been screened against the selected residential with plant uptake GACs (**Section 6.2.2.2**), exceedances were identified at a range of depths, both in made ground and one sample of glacial till. The following contaminants have been found to be present at concentrations above their respective screening criteria:

- arsenic, beryllium, copper, lead, vanadium, cyanide, asbestos, and PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, and dibenz(ah)anthracene).

No exceedances of BTEX (benzene, toluene, ethylbenzene, xylene) or TPH have been identified.

Investigation has been undertaken in the area of a former small railway gas works indicated on historical maps in the St. Catherine's Wood area (Plot RB05b). The results of the soil screening have not identified any contaminants at concentrations that could pose a risk to human health when assessed in the context of the non-residential development that is proposed in this area (a school). Despite no elevated concentrations of contaminants, hydrocarbon odours and a metallic blue sand material were reported in the relevant exploratory holes, which could indicate the presence of gasworks waste. In addition, oily sheens were noted on perched groundwater in this area that could pose a risk via direct contact. The potential significance of these visual and olfactory indicators is discussed further in **Section 6.2.3**. The existing ground investigation data suggests that contamination associated with the former gasworks feature is not widespread but is indicative of localised contamination that may require remediation.

Widespread exceedances of the GACs for beryllium and lead were noted across the entire area covered by the ground investigation. For beryllium, exceedances are generally only marginally in excess of the GAC.

Elevated concentrations of arsenic were generally only observed on the Red Bank Plateau area. Arsenic can be associated with former railway sites as a result of the deposition of boiler ash and clinker, which can also contain PAH compounds. The presence of these contaminants indicates that they could pose a risk to future site users as a result of exposure to soils.

The elevated contaminants that have been identified across the wider site area are not volatile and therefore potential contaminant linkages which include a soil vapour pathway (**Table 30** and **Table 31**) can be discounted. Given the general absence of volatile contaminants, risks to future site users are not deemed to be present where soils are located beneath hardstanding.

In areas of soft landscaping and gardens a risk to future site users could arise from exposure to soils. However, these risks could be addressed by a suitably designed clean cover system (see **Section 8.2**).

The screening assessments indicate there is a potential risk to construction workers who may come into direct contact with contaminated soils, particularly during earthworks. In addition, there is a risk to construction workers and site neighbours associated with the potential release of asbestos fibres during construction. Appropriate mitigation measures will need to be applied to protect construction workers and site neighbours during construction works including good site practices such as dust suppression, designed and

implemented by a competent contractor. Measures will also be required to mitigate asbestos risk in the post-construction phase, such as clean cover system in soft landscaped areas.

On completion of the HIF IW, in the interim period prior to follow-on plot development, risks to site users and neighbours must be considered. There remains a potential risk from contaminants in the exposed made ground soils. The plausible pollution pathways associated with these risks include direct contact with contaminated soils by unauthorised users of the site and the risk to neighbours of the site associated with dust arising from the surface of the site (potentially including asbestos fibres) during periods of dry weather. Measures to address these risks, are considered in **Section 8.2**.

6.2.3 Controlled waters screening assessment

6.2.3.1 Controlled waters assessment criteria

The conceptual site model has identified the following controlled waters receptors:

- Groundwater within the bedrock aquifers: Principal Aquifers (Chester Pebble Beds and Collyhurst Sandstone)
- Manchester Marls Formation (secondary B aquifer)
- Groundwater within the superficial deposits: alluvium (Secondary (A) aquifer) and glacial till (Secondary (Undifferentiated) aquifer), and
- the River Irk, which forms the southern boundary of the planning application site.

Groundwater and soil leachate test results have been screened against criteria based on published freshwater Environmental Quality Standards (EQS) and UK drinking water standards (DWS) to identify potential contaminants of concern. Where no EQS values are available the results have been compared against EU or UK drinking water standards (DWS) or World Health Organisation standards (WHO). The water quality standards applicable to the above receptors are discussed, with the screening assessment, in **Appendix C**.

Where the screening criteria are hardness dependent, the hardness of the receiving watercourse (the River Irk) has been used, which was determined by testing during the 2021 ground investigation to be 160mg/l. The bioavailable concentrations of certain contaminants were estimated using the M-BAT tool, as noted in **Appendix C**.

6.2.3.2 Controlled waters screening results

Groundwater samples were obtained from four monitoring wells installed within the sandstone bedrock principal aquifers, two installed within the mudstone Secondary B aquifer and fifteen installed within the superficial deposits (made ground, glacial till and alluvium). Some standpipes were lost due to vandalism, but 11 standpipes were sampled and tested on two occasions and eight on one occasion. Two samples were taken from trial pits where oily groundwater was observed (TP202B and TP202C), considered to be perched groundwater within a remnant structure (carriage shed). No gross contamination was observed, such as NAPL. The results of the groundwater screening assessment are presented below, summarised on **Drawing 13** and provided in full (together with details of

the screening criteria that have been applied) in **Appendix C**. A total of 30 groundwater samples were screened.

Two samples of surface water were taken from the River Irk to provide an indication of receiving water quality, one at the upstream end of the site and one at the downstream end.

The contaminants which exceed the screening criteria are summarised in the following sections.

Bedrock groundwater quality

Bedrock groundwater quality was measured in six locations across the wider site area, in monitoring wells with response zones in both the mudstone Secondary B aquifer and the sandstone Principal aquifers. The results of the bedrock groundwater screening are summarised in **Table 34** below and locations shown on **Drawing 02**.

Groundwater level monitoring indicates that the general groundwater flow direction in sandstone units beneath the HIF IW site is towards the river (i.e. roughly north-south) and comparison with river levels (see **Section 4.7**) suggests that the sandstone groundwater is discharging into the River Irk. The monitoring wells along the northern site boundary (BH201, BH205, BH209) typically identify exceedances of the screening criteria for manganese and zinc. Manganese is present at concentrations above the EQS in all monitoring wells in the bedrock and may be due to naturally elevated background concentrations of manganese in groundwater. Zinc is present at concentrations in excess of the EQS in BH205 and BH209 and at the EQS in the third well BH201. Isolated exceedances of other screening criteria are noted for copper, nickel and ammonia. The former Queens Road Tip landfill may be affecting the quality of groundwater entering the site from the north.

A number of exceedances of the screening criteria were noted in BH203, which was located close to the area of the former gasworks in the St. Catherine's Wood area. The made ground is particularly thick in this location and made ground directly overlies bedrock. Contaminants observed in BH203 include copper, iron, complex cyanide, fluoranthene, naphthalene and anthracene, which are consistent with contaminants that are associated with former gasworks. No petroleum hydrocarbons (TPH) were noted in the groundwater sample tested from this location.

Exceedances of the screening criteria were also noted in BH212, which is located in the Red Bank Viaduct area, close to the River Irk. Exceedances of the screening criteria for antimony, zinc, cyanides and fluoranthene were noted in this location. However, exceedances are generally marginal and not indicative of gross contamination. The borehole log indicates that made ground directly overlies sandstone at this location, and the Red Bank Viaduct area has a history of contaminative land uses including dye works and a chemical works. Groundwater quality in the sandstone close to the Irk may also be affected by historical contamination from the nearby Rochdale Road gasworks site.

Table 34: Exceedances of groundwater screening criteria in bedrock

Contaminant	GAC (mg/l)	No. of samples	Exceedances				
			No.	Location	Conc (mg/l)	Formation	Area
Antimony	0.005	10	1	BH212	0.0059	Chester Pebble Beds	RB Viaduct
Copper	0.001	10	4	BH201	0.006	Manchester Marl	RB Plateau
				BH210	0.003, 0.002	Chester Pebble Beds	RB Plateau
				BH203	0.005	Collyhurst Sandstone	RB Viaduct
Manganese	0.012	10	9	BH201	0.39	Manchester Marl	RB Plateau
				BH205	0.28, 0.46	Manchester Marl	RB Plateau
				BH209	0.75, 1.6	Chester Pebble Beds	RB Plateau
				BH210	0.75, 0.85	Chester Pebble Beds	RB Plateau
				BH203	0.66	Collyhurst Sandstone	St. C Wood
				BH212	0.02	Chester Pebble Beds	RB Viaduct
Nickel	0.004	10	2	BH209	0.014, 0.012	Chester Pebble Beds	RB Plateau
Zinc	0.012	10	5	BH205	0.015, 0.024	Manchester Marl	RB Plateau
				BH209	0.1, 0.05	Chester Pebble Beds	RB Plateau
				BH212	0.022	Chester Pebble Beds	RB Viaduct
Iron (soluble)	0.2	6	3	BH210	1.1	Chester Pebble Beds	RB Plateau
				BH203	5.9	Collyhurst Sandstone	RB Plateau
				BH212	0.22	Chester Pebble Beds	RB Viaduct
Total Cyanide	0.001	10	1	BH212	0.29	Chester Pebble Beds	RB Viaduct
Complex Cyanide	0.001	2	2	BH203	0.001	Collyhurst Sandstone	RB Plateau
				BH212	0.36	Chester Pebble Beds	RB Viaduct
Ammoniacal Nitrogen as N	0.3	8	3	BH201	0.34	Manchester Marl	RB Plateau
				BH210	2.5, 7.4	Chester Pebble Beds	RB Plateau
Fluoranthene	0.000006	6	3	BH210	0.00002	Chester Pebble Beds	RB Plateau
				BH203	0.00006	Collyhurst Sandstone	RB Plateau
				BH212	0.00001	Chester Pebble Beds	RB Viaduct
Naphthalene	0.002	6	1	BH203	0.085	Collyhurst Sandstone	RB Plateau
Anthracene	0.0001	6	1	BH203	0.00012	Collyhurst Sandstone	RB Plateau

Made ground groundwater quality

Groundwater was sampled from the made ground in 11 discrete locations, some of which were sampled twice, providing a total of 15 samples of groundwater from made ground. The results of the screening are summarised in **Table 35** below.

As noted in the bedrock aquifers, concentrations of manganese were noted in excess of the screening value in all samples analysed.

The upper 95th percentile concentrations of copper, lead, nickel and zinc exceed the screening criteria, suggesting more widespread contamination of the groundwater in the made ground. Ammoniacal nitrogen is also noted to be present at elevated concentrations in several samples.

Oily groundwater was noted around the former carriage shed on Red Bank Plateau associated with the old carriage shed structure. Samples of groundwater taken from trial pits where free product was encountered (TP202B and TP202C) are noted to contain elevated concentrations of PAHs but not TPH, although it is acknowledged that sampling

from trial pits is not best practice. Monitoring well WS201B was installed close to the former carriage shed area and also identified elevated PAH in the made ground groundwater, but no TPH. It is thought that the remnant structure is hydraulically isolated and the groundwater contamination is localised.

An iridescent sheen on groundwater in the made ground was noted around the former gasworks in the St. Catherine's Wood area in TP204, TP205 and TP206A. Monitoring well BH204 installed in this part of the site detected PAH and TPH in the groundwater, but not at concentrations in excess of the screening criteria. Ammoniacal nitrogen was present in groundwater marginally in excess of the screening criteria at this location.

A hydrocarbon odour was noted in the base of the made ground at BH207. This borehole is believed to be located within a former mill race. Glacial till is absent in this location and the made ground directly overlies the Manchester Marl bedrock. A groundwater monitoring well with a response zone in the made ground did not identify any detectable concentrations of TPH, PAH, volatile or semi-volatile organics in groundwater at this location.

A number of contaminants were identified in excess of the screening criteria in BH211A, which targeted a former reservoir beneath Red Bank Plateau (shown as an infilled water body in **Drawing 03** and historical lagoon on **Drawing 06**). Material with a strong hydrocarbon odour was encountered at the base of the made ground in this borehole at a depth of over 10m below ground level². The made ground was found to rest directly on sandstone in this location, glacial till was absent. Groundwater was tested for a range of contaminants and identified elevated concentrations of ammonia, PAH, complex cyanide and metals including lead. It is possible that this contamination results from sediment that accumulated at the base of this reservoir during periods of industrial use, or materials that were used to infill the reservoir when it became disused.

A standpipe was installed in WS208, which is located within a former gasholder base in Travis Island. The perched groundwater within the gasholder base was found to be contaminated with chemicals consistent with former gasworks, including complex cyanide and PAH, although no hydrocarbon odours or gross contamination were noted during drilling. A dynamic sample was also drilled in the adjacent gasholder in Travis Island during the 2019 GI (WS106) which did encounter hydrocarbon odours in the made ground within the gasholder base. It should be noted that Travis Island is not within the current planning application site boundary.

² Historical mapping shows that the reservoir pre-dated the Red Bank Plateau. The materials used to create the plateau will have been tipped over the former reservoir.

Table 35: Exceedances of water screening criteria in made ground

Contaminant	GAC (mg/l)	No. of samples	Exceedances			
			No.	Location	Concentration (mg/l)	Area
Antimony	0.005	14	1	BH103	0.01	RB Plateau
Arsenic	0.01	14	1	BH211A	0.019	RB Plateau
Copper	0.001	14	8	BH103 BH208 BH211A WS201B WS207	0.003 0.003, 0.003 0.001 0.007, 0.008 0.008, 0.007	RB Plateau RB Plateau RB Plateau RB Plateau RB Plateau
Chromium	0.0047	14	1	BH103	0.008	RB Plateau
Lead	0.0012	14	2	BH103 BH211A	0.002 0.005	RB Plateau RB Plateau
Nickel	0.004	14	7	BH103 BH208 WS201B WS207 BH207	0.006 0.014, 0.04 0.005 0.004, 0.005 0.08	RB Plateau RB Plateau RB Plateau RB Plateau RB Plateau
Manganese	0.012	14	14	All	0.049 to 3.2	All
Zinc	0.012	14	7	BH103 BH208 WS201B WS207 BH207	0.013 0.014, 0.037 0.057 0.1, 0.09 0.077	RB Plateau RB Plateau RB Plateau RB Plateau RB Plateau
Iron (soluble)	0.2	4	2	BH211A WS208	0.82 4.1	RB Plateau Travis Island
Total Cyanide	0.001	10	1	BH212	0.29	RB Viaduct
Complex Cyanide	0.001	6	3	BH211A WS208	0.009, 0.003 0.19	RB Plateau Travis Island
Ammoniacal Nitrogen as N	0.3	13	9	BH103 BH204 BH208 BH211A WS201B WS207	3.8 0.36 1.3, 1 5.6, 2.7 22 16, 18	RB Plateau St. C Wood RB Plateau RB Plateau RB Plateau RB Plateau
Fluoranthene	0.000006	11	8	BH103 BH208 BH211A TP202B TP202C WS201B WS208 WS210	0.00006 0.00003 0.00001 0.019 0.007 0.00002 0.0008 0.0004	RB Plateau RB Plateau RB Plateau RB Plateau RB Plateau RB Plateau Travis Island RB Plateau

Contaminant	GAC (mg/l)	No. of samples	Exceedances			
			No.	Location	Concentration (mg/l)	Area
Naphthalene	0.002	11	1	WS208	0.016	Travis Island
Anthracene	0.0001	11	4	BH208 TP202B TP202C WS208	0.00005 0.05 0.006 0.00001	RB Plateau RB Plateau RB Plateau Travis Island

Glacial till groundwater quality

Groundwater quality was sampled in the glacial till in three locations, two of which were sampled twice, providing a total of 5 samples of groundwater. The results of the screening are summarised in **Table 36** below. Glacial till was generally only encountered beneath the Red Bank Plateau area and was absent close to the river.

As noted in the groundwater samples from the bedrock and made ground, manganese concentrations exceed the screening criteria in nearly all samples taken from the glacial till. As for made ground, concentrations of copper, lead and zinc in the glacial till groundwater exceed the screening criteria within the Red Bank Plateau.

Generally lower concentrations of contaminants are noted in the groundwater within the glacial till compared to the made ground, which indicates that the glacial till may be preventing significant vertical migration of perched groundwater contamination from the made ground, where the till is present.

A marginal exceedance of the screening criteria for chloride was noted in BH202. Elevated chloride has not been encountered in groundwater elsewhere within the site, including in perched groundwater in made ground and no historical sources of chloride were identified within the Red Bank Plateau area.

Table 36: Exceedances of water screening criteria in glacial till

Contaminant	GAC (mg/l)	No. of samples	Exceedances			
			No.	Location	Concentration (mg/l)	Area
Antimony	0.005	1	1	BH105	0.008	RB Plateau
Cadmium	0.00008	1	1	BH105	0.0001	RB Plateau
Copper	0.001	5	2	BH202 BH105	0.007 0.003	RB Plateau RB Plateau
Lead	0.0012	5	1	BH202	0.0014	RB Plateau
Manganese	0.012	5	2	BH202 BH206	1.25 0.85, 1.5	RB Plateau RB Plateau
Zinc	0.012	5	3	BH202 BH206 BH105	0.16 0.03, 0.03 0.02	RB Plateau RB Plateau RB Plateau
Chloride	250	3	1	BH202	320	RB Plateau
Ammoniacal nitrogen	0.3	2	1	BH105	1.3	RB Plateau

Alluvium groundwater quality

Groundwater quality was sampled in the alluvium in one location on Red Bank Viaduct (BH214A). The results of the screening are summarised in **Table 37** below.

Alluvium was generally absent in most of the boreholes. It is only present as a narrow zone associated with previous course of the River Irk. As a result, there were not many opportunities to sample groundwater within the alluvium. Marginally elevated concentrations of contaminants were identified in the alluvium, similar to those observed in the made ground.

Table 37: Exceedances of water screening criteria in alluvium

Contaminant	GAC (mg/l)	No. of samples	Exceedances			
			No.	Location	Conc (mg/l)	Area
Cadmium	0.00008	1	1	BH214A	0.0002	RB Viaduct
Copper	0.001	1	1	BH214A	0.005	RB Viaduct
Selenium	0.01	1	1	BH214A	0.05	RB Viaduct
Ammoniacal Nitrogen	0.3	1	1	BH214A	0.34	RB Viaduct

Surface water quality

Two samples of surface water were taken during the 2021 ground investigation from the River Irk. The upstream sample was taken from the pedestrian bridge crossing the Irk into St. Catherine's Wood and the downstream sample was taken from Union Bridge, which crosses the Irk between Dantzic Street and Hargreaves Street.

The river samples identified exceedances of the screening criteria for copper, nickel and zinc in both samples. Contamination is not observed to worsen significantly as the river passes through the site, indicating that groundwater quality in made ground, the alluvium and bedrock is not having a significant impact on surface water quality.

Some low concentrations of TPH and acenaphthene were noted in the downstream surface water sample. Although the concentrations were not in excess of the screening criteria, there is insufficient data to draw conclusions regarding the source of the concentrations observed.

Table 38: Exceedances of water screening criteria in river Irk

Contaminant	GAC (mg/l)	No. of samples	Exceedances		
			No.	Location	Conc (mg/l)
Copper	0.001	2	2	U/S D/S	0.004 0.004
Nickel	0.004	2	2	U/S D/S	0.0041 0.0041
Zinc	0.012	2	2	U/S D/S	0.026 0.029

6.2.3.3 Soil leachate quality screen

Soil leachate was prepared in line with BS EN12457 and the results of eluate at a 2:1 liquid to solid ratio has been screened against the same water quality standards that have been used to assess groundwater and surface waters in this section. A total of 22 samples of soil leachate from made ground were analysed.

The screening identifies exceedances of the criteria for antimony, cadmium, copper, lead, zinc and sulphate. Exceedances for copper are mostly noted in the made ground in the St. Catherine's Wood area, with a smaller number of exceedances in the Red Bank Plateau and Viaduct areas. The results indicate that some of the contaminants within the made ground are potentially mobile, but this is not consistent across the site, and exceedances are typically marginal. The screening is summarised in **Table 39** below.

Table 39: Exceedances of water screening criteria in soil leachate

Contaminant	GAC (mg/l)	No. of samples	Exceedances			
			No.	Location	Conc (mg/l)	Area
Antimony	0.005	22	1	WS209	0.005	Travis Island
Cadmium	0.00008	22	3	WS209	0.00016	Travis Island
				TP215	0.00028	RB Plateau
				BH212	0.00018	RB Viaduct
Copper	0.001	22	12	BH203	0.0034	RB Plateau
				BH210	0.0018	RB Plateau
				WS209	0.0013	Travis Island
				WS203	0.0012	St. C Wood
				WS208	0.0025	Travis Island
				WS204	0.0024	St. C Wood
				WS206	0.0014	St. C Wood
				BH212	0.0017	RB Viaduct
				BH214	0.0089	St. C Wood
				WS202	0.0032	St. C Wood
				WS210	0.0013	RB Plateau
				WS212	0.0033	St. C Wood
Lead	0.0012	22	3	WS204	0.0013	St. C Wood
				WS202	0.0013	St. C Wood
				WS212	0.0028	St. C Wood
Zinc	0.012	22	2	TP212	0.058	St. C Wood
				BH212	0.19	RB Viaduct
Sulphate	250	22	1	BH212	360	RB Viaduct

6.2.3.4 Summary of controlled water screening assessment

No gross groundwater contamination was observed during ground investigation, except an iridescent sheen in the former gasworks area (northern part of St Catherine's Wood), localised oily water within the carriage shed former structure (northern part of Red Bank Plateau), and in deep made ground likely to be within an infilled reservoir (western Red Bank Plateau).

Elevated concentrations of copper, nickel, zinc and lead are present in all groundwater bodies sampled within the planning application site. This does not appear to be having a significant impact on the quality of the River Irk through the site, which contains similar concentrations of these metals upstream and downstream of the site.

Currently, the Red Bank Plateau area of the site is not entirely covered with hardstanding. The final development of this area comprises mostly hardstanding and buildings, which will reduce the potential for infiltration through the made ground in the longer term.

In accordance with Environment Agency guidance, given the findings of the Tier 1 controlled waters screening assessment presented above, further detailed quantitative controlled waters risk assessment is required to determine the extent of remediation required. This is discussed further in **Section 10**.

6.2.4 Ground gas risk

6.2.4.1 Methodology

The risk posed to buildings by hazardous ground gases has been assessed in accordance with CIRIA C665 [15] and British Standard guidance [19] and follows the source-pathway-receptor model.

6.2.4.2 Gas monitoring results

Six rounds of gas monitoring were undertaken in standpipes installed within the site in 2021. No gas monitoring has been undertaken in the standpipes installed in 2019. Access issues prevented a full set of complete monitoring rounds for several standpipes installed as part of the 2021 investigation. Each round of gas monitoring included readings of air temperature, groundwater level, borehole gas flow rates, atmospheric pressure, methane, carbon dioxide, oxygen, hydrogen sulphide and carbon monoxide concentrations. In addition, readings were taken from each installation with a photo-ionisation detector (PID). The results of gas monitoring are presented in the 2021 factual report [4].

The total number of complete monitoring rounds for each standpipe and the results of gas monitoring are indicated in **Table 40**. **Table 40** also includes summarises the assessment of Characteristic Situation (CS) for each monitoring installation. CS values have been established based on the calculation of Gas Screening Values (GSV) for methane and carbon dioxide, in accordance with CIRIA C665 [18].

Table 40: Gas monitoring results

Monitoring well	Response Zone stratum	No. of completed visits	Methane (range % v/v)	Carbon Dioxide (range % v/v)	Peak gas flow (l/hr)	Characteristic Situation
BH201	Bedrock	5 of 5	0.1 to 1.7	0.2 to 0.9	0	CS1
BH202	Glacial till	3 of 3	0.1 to 0.1	0.1 to 0.1	1.2	CS1
BH203	Bedrock	3 of 5	0.1 to 0.1	1.8 to 2.1	0.1	CS1

Monitoring well	Response Zone stratum	No. of completed visits	Methane (range % v/v)	Carbon Dioxide (range % v/v)	Peak gas flow (l/hr)	Characteristic Situation
BH204	Glacial till	6 of 6	0.1 to 0.1	4.0 to 9.7	1.5	CS1
BH205	Bedrock	3 of 3	0.1 to 0.1	0.5 to 11	1	CS2
BH206	Glacial till	5 of 5	0.1 to 0.3	0.7 to 6.6	0.1	CS1
BH207	Made ground	6 of 6	0.1 to 0.1	0.4 to 5.6	0.6	CS1
BH208	Made ground	5 of 5	0.1 to 0.1	0.4 to 3.1	0.1	CS1
BH209	Bedrock	3 of 3	0.1 to 0.1	0.1 to 0.3	0.3	CS1
BH210	Bedrock	5 of 5	0.1 to 0.2	0.1 to 3.1	1.2	CS1
BH211A	Made ground	6 of 6	0.1 to 0.2	0.1 to 3.0	1.5	CS1
BH212	Bedrock	1 of 2	0.1	0.1	0.1	CS1
BH213	Made ground	6 of 6	0.1 to 0.4	0.1 to 2.1	1.1	CS1
BH214A	Glacial till	4 of 5	0.1 to 0.1	0.1 to 1.0	0	CS1
WS201B	Made ground	6 of 6	0.1 to 0.2	0.1 to 2.3	0.1	CS1
WS207	Made ground	6 of 6	0.1 to 0.1	0.4 to 1.8	1	CS1
WS208	Made ground	2 of 3	0.1 to 0.1	0.1 to 0.2	0.1	CS1
WS209	Made ground	1 of 3	0.2	0.4	0.1	CS1
WS210	Made ground	6 of 6	0.1 to 0.4	0.1 to 3.9	1.2	CS1
WS212	Made ground	6 of 6	0.1 to 0.1	0.1 to 0.9	1.2	CS1

All readings of hydrogen sulphide and carbon monoxide obtained during the monitoring were less than the relevant long-term occupational exposure limit, the lowest screening concentration cited in Table 2.2 of CIRIA C665. The highest PID reading obtained from the monitoring installations was 6ppm, which indicates that there are no significant volatile sources of contamination in the relevant areas of the site.

Atmospheric pressures during the monitoring were 1000 and 1018 mb. Although the data collected to date, together with a consideration of the conceptual site model, is considered

sufficient to assess the potential risks posed by ground gases to the works proposed in the planning application site, it is noted that none of the available monitoring was collected under low atmospheric conditions (i.e. below 1000 mb). It is therefore, recommended that further gas monitoring is undertaken as part of further proposed GI works (**Section 10**).

6.2.4.3 Assessment of gas monitoring data

The data presented in **Table 40** indicates CS1 conditions (equivalent to NHBC Green conditions [20]). According to CIRIA C665, Table 8.5 [18], CS1 conditions represent a “very low risk classification” for which no special measures will need to be adopted during development.

Given the extent of gas monitoring that has been undertaken to date, it is considered that this CS1 classification is robust despite the presence of two former landfill sites adjacent to the north of the site. With regard to the Queens Road landfill to the north west (**Drawing 02**) the location of monitoring installations (particularly BH201, BH205 and WS201B) are considered appropriate to identify any ground gases that may migrate from that site.

With respect to the Sand Street landfill adjacent to the north east of the planning application site and the Fitzgeorge Street landfill further to the east, although the nearest gas monitoring installations are some distance from the site boundary, it is considered that the River Irk and the associated saturated ground conditions will inhibit gas migration from the former landfill sites to the east.

As the details of future development on the planning application site are currently unknown and will be subject to separate planning applications, it is recommended that future developers conduct their own assessment of ground gas risk and, if appropriate, undertake additional gas monitoring.

6.3 Buried pipelines

A variety of contaminants have the potential to permeate water supply pipes, potentially degrading the integrity of the pipes or tainting water supplies. Aggressive conditions could also potentially impact on the integrity of metal pipes.

A potential pollutant linkage exists between potable water supply pipes (and the water within) and contaminants in the made ground. Consequently, PE and PVC water pipe materials are unlikely to be suitable for use within the wider site area (**Section 10**).

Any new water supply connections should be designed in consultation with United Utilities (UU), to ensure the pipe materials used are appropriate for the ground conditions. UU generally request that data on ground conditions is collected specifically from the areas of the site in which key potable supply mains are proposed and therefore, further ground investigation is proposed along principal potable supply corridors within the planning application site (**Section 10**).

6.4 Waste assessment

6.4.1 Approach

Reuse of suitable material onsite, where needed to achieve the site levels, will be implemented in preference to offsite disposal for sustainability reasons. The CL:AIRE Definition of Waste Code of Practice (DoWCoP) [24] and other appropriate waste management mechanisms will be applied. However a proportion of excavated soils produced by the HIF IW will be unsuitable for reuse or surplus to requirements and will require off-site disposal. A preliminary assessment of possible waste classifications and disposal options is presented below.

Under the current UK waste regulations, if excavated soils (including made ground) require offsite disposal as waste, they are to be classified as non-hazardous or hazardous for disposal depending on their chemical properties. Hazardous waste would need to be disposed of at a hazardous waste facility. Non-hazardous waste may be suitable for disposal at a landfill licensed to accept inert waste however, this is subject to the material meeting stringent waste acceptance criteria (WAC) defined in the The Waste and Environmental Permitting etc. (Legislative Functions and Amendment etc.) (EU Exit) Regulations 2020" (SI 2020 No. 1540). To assess this a number of samples have undergone WAC testing to provide an indication of the possible waste disposal options.

To support the WAC testing that has been undertaken, an indicative screen of a selection of made ground and glacial till samples has been undertaken to determine waste classification. This screen was undertaken using the online waste classification service HazWasteOnline [21] which classifies material in line with current waste guidance, WM3, Waste Classification – Guidance on the classification and assessment of waste [22].

Note however, that the results of the indicative waste assessment reported below reflect global conditions at the site and may not represent the actual soil materials that are subsequently identified for disposal. Once soils for disposal have been identified, further WAC testing will be required to assist in the determination of the requirements for off-site disposal.

6.4.2 Waste acceptance testing

For a landfill to accept a waste the material must be tested and meet the WAC for the type of landfill. The WAC testing assesses the leachability of certain contaminants for acceptance at landfills which accept inert or hazardous waste.

Waste acceptance criteria (WAC) testing has been undertaken on thirty four samples of made ground and are summarised in **Table 41** and on **Drawing 15**. The WAC test results are presented in full in the AEG Factual Reports [3][4]. None of the samples tested were classified as hazardous for disposal. 28% of the samples were determined as inert and 72% as non-hazardous.

Table 41: Summary of WAC testing results

Exploratory hole ID	Sample top depth (mbgl)	Elevation (mAOD)	Stratum	Landfill type for the sample passes criteria for
BH103	1	41.57	Made ground	Non-Hazardous
BH106	0.3	40.37	Made ground	Non-Hazardous
BH203	1.2	40.69	Made ground	Non-Hazardous
BH207	2.2	39.44	Made ground	Non-Hazardous
BH210	2.2	38.25	Made ground	Non-Hazardous
BH211A	2.2	38.24	Made ground	Non-Hazardous
BH211A	5.2	35.24	Made ground	Non-Hazardous
BH212	1.2	29.18	Made ground	Non-Hazardous
BH214	0.3	30.07	Made ground	Non-Hazardous
TP102	0.3	42.32	Made ground	Non-Hazardous
TP105	1	40.11	Made ground	Inert
TP106	2.8	39.85	Made ground	Inert
TP109	1.3	40.66	Made ground	Non-Hazardous
TP112	2.3	38.53	Made ground	Non-Hazardous
TP115	1.3	39.21	Made ground	Non-Hazardous
TP207	1	42.34	Made ground	Inert
TP210	1	42.08	Made ground	Inert
TP211	1	40.64	Made ground	Inert
TP212	0.3	41.72	Made ground	Non-Hazardous
TP215	2	39.28	Made ground	Non-Hazardous
WS102	1	31.20	Made ground	Inert
WS202	0.3	41.27	Made ground	Non-Hazardous
WS203	1	31.64	Made ground	Inert
WS204	1	31.84	Made ground	Inert
WS205	3	39.12	Made ground	Non-Hazardous
WS205	0.2	41.92	Made ground	Non-Hazardous
WS206	2	30.61	Made ground	Inert
WS207	1	40.91	Made ground	Non-Hazardous
WS208	2	28.17	Made ground	Inert
WS209	0.3	29.65	Made ground	Non-Hazardous
WS210	0.3	40.58	Made ground	Non-Hazardous
WS211	0.3	39.61	Made ground	Non-Hazardous
WS212	0.6	39.29	Made ground	Non-Hazardous

A number of the samples that were identified as inert by the WAC testing were found to contain asbestos fibre concentrations below the hazardous waste threshold. It may be possible to dispose of this material at inert waste sites however, it will be necessary to discuss this with the proposed receiving sites to understand their specific permitting requirements.

6.4.3 Hazardous waste classification

An additional waste classification exercise has been undertaken to provide preliminary information to assist in the assessment of the management of waste soils at the site.

As part of the 2019 and 2021 ground investigations, 170 samples of made ground and glacial till were tested for a range of inorganic and organic contaminants of potential concern. The HazWasteOnline screening tool has been used to estimate the hazardous properties of these materials. The results of the screening are presented in **Appendix D** and summarised on **Drawing 14**. As a result of this assessment, 8 of the 170 samples were

classified as hazardous (approximately 5%) and the remainder as non-hazardous. A summary of the sample results is presented in **Table 42** below.

Table 42: Summary of hazardous waste screening

Stratum	No. of samples	Non hazardous	Hazardous	Principal contaminant type
Made ground	151	144	7	Total petroleum hydrocarbons Lead
Glacial till	19	18	1	Copper

Further detail on the waste classification is summarised in **Appendix D**.

The hazardous and potentially hazardous wastes have been assigned due to the following hazardous properties:

- HP7 – Carcinogenic
- HP10 – Toxic for reproduction
- HP11 – Mutagenic
- HP14 – Ecotoxic

As stated in WM3 guidance document, if the waste contains asbestos fibres that are free and dispersed then the waste will be classified as hazardous if the waste as a whole contains 0.1% or more asbestos. Where the waste contains identifiable pieces of asbestos containing material (ACM) (i.e. any particle of a size that can be identified as potentially being asbestos by a competent person if examined by the naked eye), then these pieces must be assessed separately. The waste is hazardous if the concentration of asbestos in the piece of asbestos containing material is 0.1% or more. The waste is regarded as a mixed waste and classified accordingly. The following codes should be assigned to the asbestos waste as appropriate:

- 17 06 05* Construction material containing asbestos
- 17 06 01* Insulation material containing asbestos

17 06 05* would normally be used in preference to 17 06 01* for the asbestos in asbestos contaminated soil and stones.

ACM has been detected in 17 samples (out of 121 tested across the wider site area - approximately 13% - **Table 33**). None of the samples that underwent quantification contained asbestos fibres at concentrations above the hazardous waste threshold of 0.1%.

6.4.4 Summary of waste assessment

There is potential for surplus soil to be generated either as a result of earthworks balance or presence of materials which are geotechnically or geochemically unsuitable for re-use within the development platform. These materials may require offsite disposal. WAC analysis and hazardous waste assessment has been undertaken on samples of made ground collected from the wider site area. The analysis indicates that most of the material will be classified as non-hazardous waste. As shown on **Drawing 14**, hazardous material was identified in localised areas across the site, however there was an area of Red Bank Plateau

in which samples from three adjacent exploratory holes (BH103, WS205 and TP109) were classified as hazardous for disposal. This area lies outside any proposed areas of excavation and as shown on **Drawing 13**. In each case, the hazardous identification was made on the basis of elevated concentrations of different determinands. It is therefore considered that the samples that have been shown to be Hazardous (**Drawing 14**) represent a series of discrete areas of soil contamination rather than indicating more widespread contaminant 'hotspots'.

Areas of material that are classified as hazardous waste for disposal will need to be delineated and any surplus/unsuitable arisings from these areas from these areas will need to be segregated from non-hazardous waste and handled and disposed of accordingly.

7 Engineering considerations

7.1 Introduction

A review of the ground conditions has been undertaken in relation to what is currently understood about potential development within the proposed HIF Infrastructure planning boundary shown in red on **Figure 1**.

An overview of the proposed development of the planning application site is presented in **Section 2.2**. The purpose of the HIF Infrastructure Works is to prepare the site for such development and will include:

- Earthworks and remediation to create suitable development platforms;
- The construction of new internal access roads;
- New utility and services connections;
- Provision of green infrastructure including green links and a new City River Park and
- New bridge crossings over the River Irk.

During the Stage 3 design stage an assessment of the ground conditions has been undertaken in order to identify risks and constraints to the proposed HIF Infrastructure works. Some issues identified have been incorporated into the Stage 3 design, some risks have been identified for further assessment or investigation, the results of which can be incorporated into subsequent design stages. The following is a summary of the engineering considerations relevant to the HIF Infrastructure works.

7.2 Ground condition considerations

7.2.1 Variability

The ground conditions across the wider site area are complex and highly variable both in plan across short distances and with depth. As a result, ground conditions across differing parts of the site will vary significantly between different plots and elements of the HIF Infrastructure works. The data assessment undertaken for this report has divided the site into a series of zones and has summarised a large amount of data for each zone. There is still significant scatter in each zone. It is recommended that for future stages of scheme design location specific ground conditions are reviewed for each individual scheme element.

7.2.2 Made ground

Made ground is present extensively within the planning application site. The nature and thickness of made ground is significantly variable. The rail sidings were formed by cutting into the valley side and filling towards the river. The works were not carried out to modern engineering standards and the fill cannot be relied upon to have a consistent engineering performance. Highly variable material will be encountered throughout the works and given

the limited nature of ground investigation, it is not possible to accurately classify the nature, extent and behaviour of this material. Risk allowances will need to be made to account for material not fitting in with the assumed classification based on available data.

7.2.3 Soft ground

The ground investigation has confirmed the presence of soft deposits at depth within several features. The site has former reservoirs in the south west of Red Bank Plateau, a former course of River Irk and a mill race, all of which have been infilled and have a risk of soft deposits being present at depth (**Drawing 03**). The full extent of soft deposits has not been confirmed but the GI data is consistent with the historical maps and desk study ground model.

Localised shallow soft spots may also be present in some areas of the site (e.g. St. Catherine's Wood), associated with alluvium or other natural superficial deposits.

The made ground in general across the site may also contain soft spots where historical compaction has not been to a controlled specification. These materials are unlikely to provide sufficient support for shallow building foundations and are potentially unsuitable for external works without some form of treatment/improvement.

7.2.4 Rockhead

The level of rock head beneath the wider site area is highly variable as result of different rock types (weathering/erosion potential) and also past erosional events from both glaciation and river. The rock head level typically drops towards the valley bottom.

At three exploratory hole locations across the proposed planning application site, the bedrock of the Chester Pebble Beds formation was found to be shallow (between 1.8 to 3.3m bgl). Of these, two instances of shallow rock head were in Red Bank Viaduct and one in St. Catherine's Wood. Bedrock was encountered at greater depths (up to 18m and 15.7mbgl beneath Red Bank Plateau and St. Catherine's Wood respectively), in the area of the historic infilled watercourse (**Drawing 03** - BH203 and BH207).

Rock head is typically below the zone of influence for the HIF Infrastructure works. With the exception of proposed bridge foundation adjacent to the river.

Future plot developers will need to assess site specific bedrock nature and profile for foundation assessment.

7.2.5 Groundwater

As discussed in **Section 5.6**, during the 2019 and 2021 GI, groundwater strikes were recorded in made ground, alluvium and glacial till. As summarised in **Table 12**, groundwater monitoring from borehole installations encountered groundwater in response zones installed in made ground, alluvium, glacial till and solid strata (predominantly sandstone).

Given that a number of the response zones in made ground were dry throughout the monitoring and typically a relatively thin saturated zone is present at the base of the made ground, it is likely that groundwater in made ground is discontinuous. Locally made

ground groundwater may be contained within obstructions in the made ground or perched on underlying natural cohesive deposits.

Groundwater encountered in glacial till appears to be associated with granular lenses within these generally cohesive deposits. Groundwater in alluvial deposits is likely to be in continuity with the river, as is groundwater in the underlying solid strata, particularly sandstones. Excavations in made ground and glacial till are likely to encounter perched groundwater which may require dewatering or other forms of groundwater management. Given that groundwater in alluvium may be in continuity with surface water and/or groundwater in the underlying solid strata, simple dewatering may not be practicable and other forms of groundwater management may be required if significant excavations are to be undertaken in these deposits.

7.2.6 Buried features

There is potential for buried features including old foundations, slabs, walls, voids, and both live and abandoned services to be present. These are discussed in more detail in section 7.8.

7.3 Earthworks

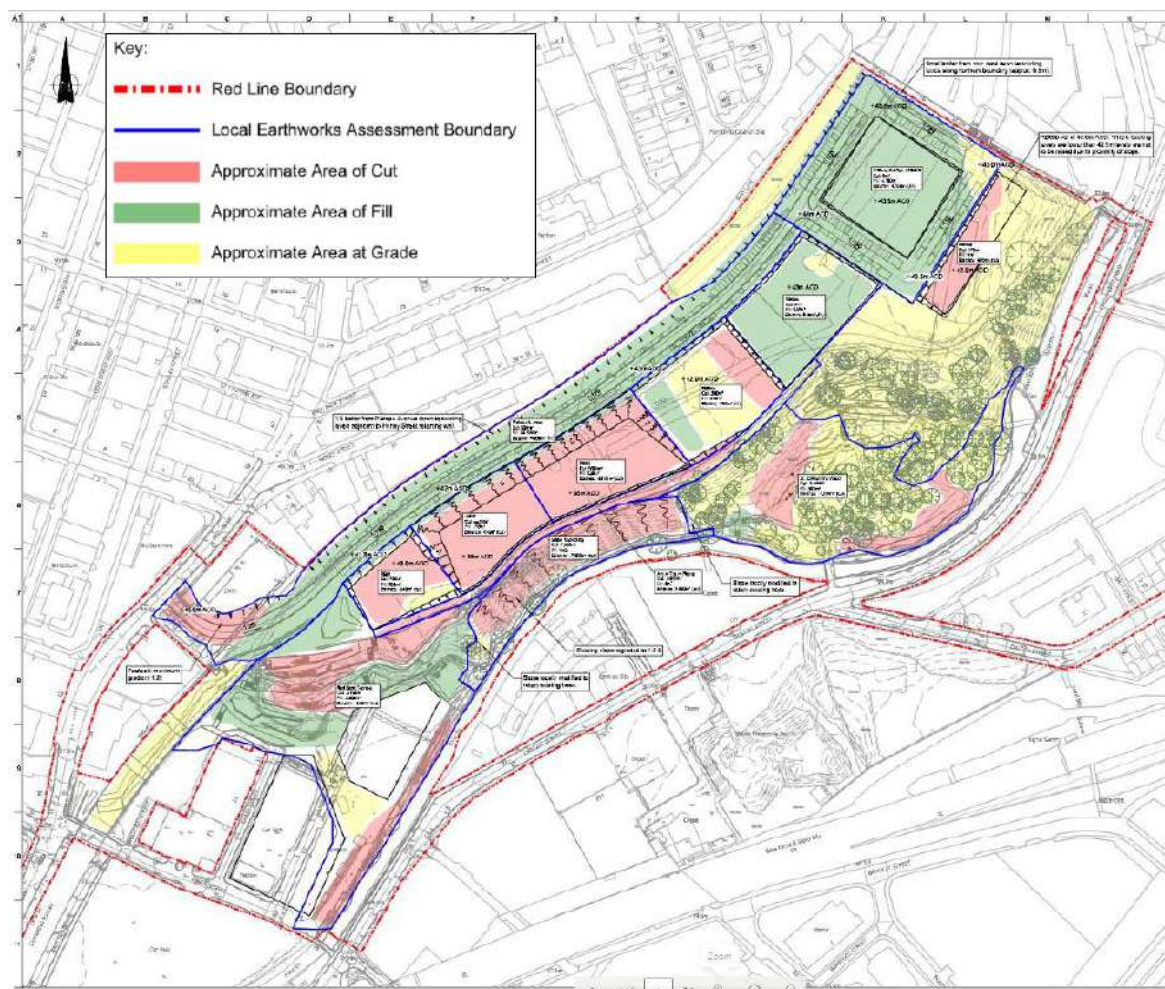
7.3.1 Cut-fill balance

Earthworks will be required to create level development plots; to construct the road embankment entering the site; and for a range of landscaping reprofiling around the planning application site.

The proposed plot levels for the planning application site are currently under discussion and therefore, a set of target finished levels has been established for the HIF Infrastructure Works. During design development there was an aspiration to match closely to existing levels where possible. However, there is variability in the existing topography and therefore some cut and fill will be required.

The outline remediation strategy, discussed further in **Section 8.2**, will generate a large volume of cut material and will impact the earthworks strategy for the planning application site. A significant amount of cut is proposed for Plots RB02 and RB03 and the adjacent slopes down to the river to mitigate slope stability risk (**Section 7.5**). Some regrading is also required for landscaping in the south west extent of the scheme (the area in which Red Bank Plateau transitions to Red Bank Viaduct) and also by the river in St Catherine's Wood.

As shown in **Figure 11** (taken from the work stage 3 design report - VNIF-ARP-ZZ-YYY-RP-MC-0001), in addition the excavation described above, filling will take place for the plateau road embankment, within a number of plots within Red Bank Plateau and within a variety of landscaping features around the site. However, to avoid excessive filling at the crest of slopes, which could adversely impact stability, platform levels close to the edge of Red Bank Plateau cannot be built up above existing to improve the cut/fill balance.

Figure 11: Indicative cut and fill proposals

Within the total fill requirement for the scheme, some selected engineering material (in accordance with Specification for Highway Works, SHW) will be required. Some of this material may be generated by processing suitable arisings from excavation (e.g. crushing and screening concrete and masonry and recovering suitable general fill from the made ground that is excavated), however it is likely that some of the fill material will need to be imported. Depending on the outcome of further design and the resulting cut/fill analyses, there may be a surplus of site won material that will need to be exported.

Even if site won material can be processed for re-use, it is likely that off-site disposal of surplus or unsuitable soils will be required. Further design development and material assessment is required to quantify volumes. It is recommended that the Contractor's material team are engaged to help identify opportunities for material re-use.

7.3.2 Re-use of site won material

It is considered that most of the material excavated from the planning application site as part of a general cut and fill exercise will be made ground soils. As discussed in **Section 4.6** and **Section 5**, the made ground materials across the site have been found to be highly variable, with the composition likely to vary both laterally and vertically. It is anticipated that between 45% and 63% of all the made ground on site could be classified as predominantly granular.

As noted in **Section 7.3.1** above, material from some buried structures may be suitable for crushing/processing on site to produce selected granular fill. Consideration should be given to excavation of these materials and replacement with general fill.

Focusing on the excavation in the vicinity of Plots RB02 and RB03, 86% of samples had less than 15% passing the 63 micron sieve, suggesting that for general filling, the majority of this material could be classified as Class 1 General Granular Fill in accordance with the SHW. Given that SHW classifications and acceptability are controlled by a range of properties, not just particle size distribution, additional testing and assessment will be required during the construction phase to confirm the SHW class and acceptability for general fills and to identify whether some of the material could be used as selected granular fill. It should be anticipated that some sorting will be required to eliminate unacceptable materials.

As discussed in **Section 5.6**, laboratory compaction testing has been undertaken and as expected for a made ground, there is a large variability in the performance and moisture content of the material. The testing results indicate that much of the material is close to or at the likely upper limit for compaction, and that a proportion of the material is likely to require conditioning to reduce its moisture content.

Refer to **Section 8** for geoenvironmental factors impacting the potential for re-use of site won materials.

7.3.3 Earthworks phasing

To maximise the potential for material re use, including sorting and processing of materials, it would be advantageous to undertake remediation, excavation and processing of material in advance of filling in some areas of the site. However, this may lead to double handling of some materials.

If the development is progressed in phases, this may reduce the potential to recover some materials, and lead to inefficiencies and costs associated with undertaking earthworks in small areas. This may include:

- Reduced flexibility for reusing potentially suitable fills resulting in additional offsite disposal or import of suitable fill materials.
- The need for additional temporary earthworks batters or retaining structures at the edges of plots.

7.4 Settlement

Settlement on sites where significant thicknesses of made ground have been deposited can be significant and have a pronounced effect on engineering solutions. Given the current ground model that has been developed for the planning application site, existing materials are likely to undergo a number of modes of settlement as discussed below.

- The natural superficial soils underlying the made ground materials can be expected to have undergone settlement due to the placing of up to 15m of fill. Given that the made ground was placed at least 130 years ago, it is likely that much of this settlement will now be complete and that negligible settlement is ongoing within the underlying natural materials.

- The magnitude of self-weight settlement of the existing made ground materials will depend on the compressibility and stiffness of the fill. It can be assumed that the fill materials placed across the Red Bank Plateau were placed without controlled compaction. Again, given that the majority of the made ground was placed at least 130 years ago, this self-weight settlement can be expected to be largely complete however, it will be important to understand the likely magnitude of residual settlement and the timescales over which this residual settlement is likely to occur.
- Assuming proposed filling operations are undertaken in accordance with an appropriate specification, settlement within the newly placed fill will be controlled. The resulting changes in earthworks loading however, may lead to additional settlement in the made ground and superficial deposits that are present beneath the newly placed fill.

In addition to the above, changes in site conditions may affect settlement at the planning application site.

- Changes in groundwater level can affect fill in two ways; (i) it will have a direct effect on the effective stress within the fill deposit (causing settlement or heave); and (ii) moisture content changes can cause shrink/swell behaviour in clays and can also result in 'collapse compression' which can result in significant settlement. In the current situation, there is no reason to believe that groundwater levels are rising or falling over the long term and therefore the degree of saturation of the existing fill materials is not likely to change significantly. However, future changes could occur due to future earthworks and installation of drainage infrastructure. For example, the use of infiltration drainage could result in local saturation and settlement due to local collapse compression.
- Volume changes can be caused by chemical reactions of components within the fill. Reactions are known to be associated with the presence of a number of materials in fill (for example sulphates, steel slag and pyritic shales). None of these materials, however, have been noted in any significant proportion in the ground investigation.

Given the above considerations, the design of remedial works, future earthworks (e.g. the embankment required to support the proposed access road as it leaves the former Creamline Dairies site) and future buildings will need to consider both the potential magnitude of settlement and the likely duration of on-going settlement. It will also be necessary to understand other issues such as the likely construction programme, to determine whether settlement is allowed to complete prior to construction of foundations, etc.

Once development proposals are agreed, it is recommended that assessments of the likely magnitude and timescales are undertaken for each of the relevant modes of settlement. If these assessments suggest settlement is a potential development constraint, it may be necessary to undertake mitigation works and settlement monitoring during and after Infrastructure Works, to measure actual settlement magnitude and timescales against predicted behaviour.

It is possible that settlement could influence building foundation design due to down-drag effects.

7.5 Slope stability

As discussed in **Section 2.4**, an approximate 175m length of the north western boundary of the Red Bank Plateau area is formed from a c. 7m high cutting with a gradient of approximately 1v to 3h. This slope is extensively vegetated and to date, a thorough inspection has not been possible. The area extending back from the crest of the slope is currently in third party ownership and is being used for storage by others, therefore access to these adjacent areas has not been possible. On the basis of the existing ground model, it is considered that this slope is a cutting in glacial till however, this and the estimated gradients will need to be confirmed once vegetation clearance in this area has been completed.

As discussed in **Section 2.3**, steep slopes between 9m and 13m high are present in the St. Catherine's Wood area, with slopes some 9m high separating the Red Bank Plateau and Red Bank Viaduct areas. Generally, except for an area adjacent to Plots RB02 and RB03 (**Figure 1**), these steep slopes are densely vegetated. At the steepest point, these slopes have gradients in the order of 1v to 1.6h. Slope gradients in the order of 1v to 2h to 1v to 2.5h are more common. These slopes are interpreted to have been formed by filling to create a level platform for the railway sidings area.

A preliminary slope stability analysis has been undertaken for a section of slope central to RB02 and RB03 (**Figure 1**). Refer to Preliminary Geotechnical Design Report [26]. This analysis confirmed that the slope has a global factor of safety close to unity for deep seated slips beneath the river wall and extending beyond the crest of the slope into the plateau. This is considered unacceptable in the context of future development. Development in this vicinity is likely to induce some changes to the slope and a small reduction in the factor of safety could result in slope failure. As discussed in **Section 10**, further ground investigation is to be undertaken to obtain additional data on ground conditions and to allow the conclusions of the preliminary slope stability assessment to be validated. The preliminary GDR recommended that to mitigate risk of future slope failures the existing slope should be regraded to a global gradient of 1(v) to 2.5(h), with ground levels at the top of the slope reduced to c. 38.5m AOD.

Assessments of slopes adjacent to Plot RB05b were also undertaken and are reported in the Preliminary Geotechnical Design Report. These assessments concluded that while the existing slopes are steep and do not meet current design standards, there are no immediately obvious signs of instability. Where low factors of safety were identified in the GDR, these tended to be associated with potential small scale movements for which the consequence of failure may be small. Therefore, a managed risk approach is proposed in which a risk zone has been defined, refer to figure 22 of the preliminary GDR. It is recommended that any proposed development including recreational areas and utilities are located outside this risk zone.

An additional area of sloping ground has been identified extending beyond the northern site boundary and into areas currently under third party ownership. As discussed in Section 5.6 of the preliminary GDR, it is considered that there exists a marginal risk of slope failure in this area. It is therefore important that the loading conditions of the external slope are not altered without first assessing the potential impact on the development and appropriate mitigation put in place by others.

7.6 Retaining structures

7.6.1 Existing retaining walls

As discussed in **Section 2.3**, the following retaining walls have been identified within or forming the boundaries of the planning application site:

- A c. 5m high Victorian-era brick retaining wall along the north western boundary between the Creamline Dairies site and Red Bank Plateau (Retaining Wall 1, **Figure 4**).
- Sections of a masonry retaining wall (possibly constructed in the early 1900s) at the foot of the slopes between the Red Bank Plateau and the Red Bank Viaduct areas (Retaining Wall 1, **Figure 4**).
- Masonry retaining walls (date of construction not determined) that line the banks of the River Irk (**Figure 4**).

The geometry and founding levels of these structures is unknown.

Once development proposals have been confirmed and the implications for the future performance requirements of these retaining features have been determined, it will be necessary to assess the stability of any sections of the existing retaining walls that are required to provide on-going support.

Care will need to be taken during excavation and other construction activity in the vicinity of existing retaining wall, so as not to have an adverse impact on their integrity or performance.

7.6.2 Proposed retaining structures

Current development proposals require a new access road which will enter the site from the existing public highway from Red Bank, cross the Creamline Dairies site (Plot RB12b) and enter the Red Bank Plateau area. As this access road enters the Red Bank plateau area it will be supported on earthworks. However, space restrictions and other development aspirations mean that a retaining structure up to 4m high is likely to be required.

Consideration will need to be given to the sequence of development in this area, particularly the phasing of enabling works and the wider scope of remediation works. It is possible that the retaining wall could be formed using reinforced earth with a structural facing however, as discussed in **Section 7.4**, the potential impact of settlement would need to be considered. If the magnitude of future settlement without mitigation is found to be unacceptable, there is an opportunity to explore surcharging if time allows, otherwise a localised area of ground improvement may be appropriate. If a structural retaining wall is considered, then this may need to be supported on piled foundations if the ground is not improved first. Once development proposals are finalised and the most appropriate form of retaining structure has been determined, further design studies will be required during the future phases of development.

7.7 Foundations

Given the historical uses of the wider site area and the likely magnitude of loads from the proposed development it is unlikely that shallow foundations will be suitable for anything other than lightweight ancillary structures which are insensitive to ground movements.

The use of piles is anticipated to be required to both carry load and limit settlement. The type of piling will be dependent upon the structural form and loads, however variable ground conditions and risk of buried obstructions may influence the choice.

Without ground improvement or earthworks to an appropriate performance specification, ground floor slabs are likely to be required to be designed as suspended rather than ground bearing to avoid settlement issues and adverse loading on the slopes.

Ground improvement to improve the performance of individual plot development areas has not been considered as part of this scope, however it should be noted that ground improvement is typically only suitable for low rise buildings.

The design of the proposed buildings must be undertaken in such a way to avoid adversely impacting the stability of slopes or surrounding infrastructure. This includes consideration of settlement on surrounding assets. Further investigation will be required to inform the foundation design at each plot location.

7.8 Constraints to development

7.8.1 Buried obstructions

There is a high potential for encountering buried obstructions from past site use. Obstructions may include former basements, foundations, walls, utilities and made ground containing large concrete obstructions.

These types of obstructions may affect activities such as piling, excavations and earthworks as well as the design and construction of new retaining structures.

Further details of the encountered obstructions can be found in **Section 3.6**. The outline remediation strategy is also discussed in **Section 8.2**.

7.8.2 UXO

As reported in the 2019 desk study [1], a number of studies have been undertaken by specialists to determine the risk from UXO across the wider site area. Records indicate a number of recorded bomb strikes across the Red Bank Plateau and Travis Island areas, as shown in **Drawing 09**. There is the potential for further unrecorded strikes having taken place; the most recent UXO assessment by Zetica [23] concluded that the risk from UXO within the area of interest was low.

During the 2019 and 2021 ground investigations, UXO risk was managed in accordance with the recommendations made in the Zetica risk assessment i.e. through the use of UXO awareness briefings given by a specialist ordnance engineer to site operatives. These briefings enabled site operatives to recognise UXO if it was encountered in the ground.

It is recommended that the mitigation measures in the Zetica report are reviewed by BAM and further specialist advice obtained, in advance of proposed further works (including any further ground investigation).

7.8.3 Voids

The desk study identified several potential sources of voids within the ground ranging from smaller scale voids resulting from uncontrolled backfill of historical features (such as basements, an infilled former section of the River Irk, and reservoirs) and larger voids due to incomplete backfill such as below former bridge structures (refer to **Drawing 3**).

Without some form of treatment (such as excavation/replacement or other treatment such as grouting or ground improvement), any voids present may pose a hazard to shallow foundations and potentially external works.

The ground investigations targeted areas with potential risk of voids, although the number of exploratory holes was limited, and no significant voids were recorded during the two phases of ground investigations. However, in BH106 (**Drawing 01**) the driller recorded poor recovery from 0.2 to 5.8m bgl. which may represent a poorly infilled void. Further investigation is recommended in this area (**Section 10**).

It is recommended that developers of individual plots undertake plot specific ground investigation to further quantify the risk and mitigate if needed.

7.8.4 Buried structures

The 2019 desk study [1] indicated the potential presence of tunnels across the wider site area. Those identified included a culverted section of the River Irk and a subway, both of which were shown on historical maps close to the south-western tip of the Red Bank Viaduct area, outside the current planning application site (**Figure 1**). The 2019 and 2021 GIs included only a single exploratory hole in this area of the site (**Drawing 01**).

Further intrusive investigation may be needed by third parties to confirm the existing geometry of these features and inform discussions regarding any constraints they may present for remediation and development. These features do not however, affect the HIF Infrastructure development.

7.8.5 Utilities

Existing utilities may present a constraint to the development in some areas. There is also a risk of unrecorded services being present. Diversion and protection works may be needed, in advance of site clearance, earthworks and remediation.

Available records for site utilities and drainage have been reviewed by Arup as part of the current HIF study. This has identified a combined sewer crossing Red Bank Plateau and descending the steep slopes before crossing beneath the River Irk adjacent to Travis Island. The proposed earthworks and development will impact the sewer. Few details are available for the condition and depth of the full sewer route and a detailed survey is required. It is likely a new diversion route will be required for the existing sewer. In addition, a drain has been identified which crosses the Red Bank Plateau (**Figure 12**). Further assessment and possibly intrusive investigations will be required to confirm the existence of this drain.

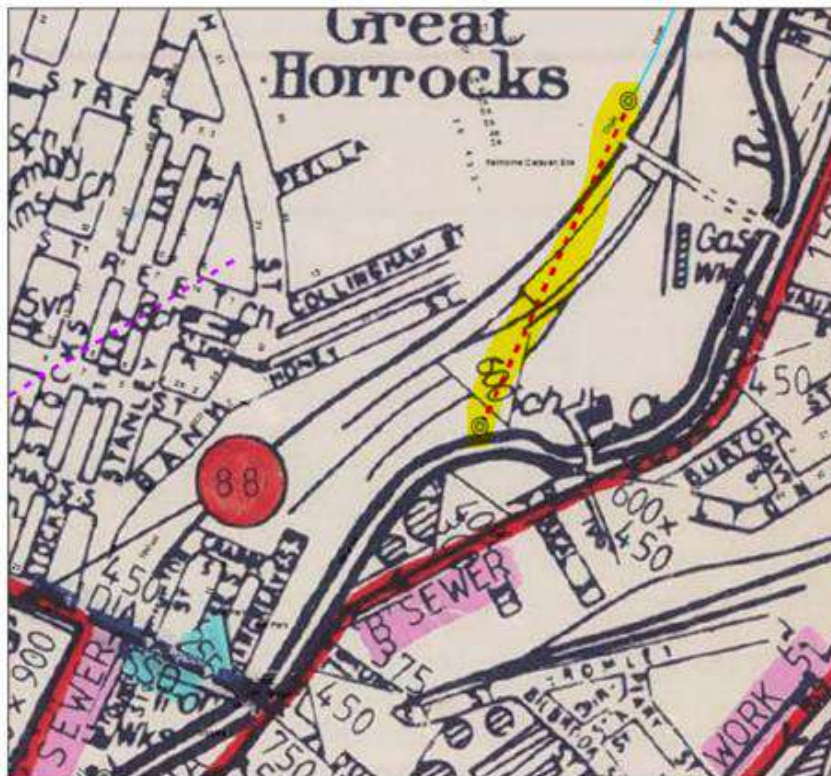


Figure 12: Potential alignment of a drain thought to cross the site (highlighted yellow).

A sustainable urban drainage strategy is being developed for the planning application site and subject to obtaining regulatory approval, it is proposed to incorporate some elements of infiltration into this scheme. The presence of contaminants in the made ground across the site is likely to prevent the use of soakaways in most areas of the site however, depending on groundwater conditions, soakaways and other infiltration systems may be possible in areas close to the River Irk where sandstone strata is at relatively shallow depths. Further detailed studies will be required to investigate the viability of soakaways and other infiltration systems at the site (**Section 10**).

7.8.6 Existing structures

Network Rail should be consulted in relation to works conducted close to their assets (including the viaducts) as vibration limitations are likely to be stipulated and will require monitoring.

8 Geoenvironmental considerations

8.1 Introduction

Based on the assessments presented in **Section 6**, the conceptual site models in **Table 30** and **Table 31** have been reassessed in order to consider the proposed redevelopment of the Red Bank Plateau, Red Bank Viaduct and St. Catherine's Wood. Given that Travis Island and The New Town Plots do not form part of the proposed HIF planning application, these areas are not considered further.

The results of this reassessment are presented as **Table 43** and **Table 44**.

Table 43: Revised conceptual site model for the HIF IW construction phase

Source		Pathway		Receptor	Linkage?
Made Ground (containing solid contaminants, asbestos fibres and possible hydrocarbons)	→	Dermal contact	→	Construction worker	No
		Ingestion of soil/ soil dust	→	Assuming appropriate health and safety procedures are adopted (including the use of appropriate PPE)	No
		Inhalation of soil vapour	→	Assuming appropriate health and safety procedures are adopted (including the use of appropriate PPE)	No
		Inhalation of soil and soil dust	→	Construction worker Assuming appropriate health and safety procedures are adopted (including the use of appropriate PPE)	No
Temporary stockpiles of excavated arisings Accidental leaks and spills during construction	→	Leaching and runoff	→	Site users and neighbours Assuming appropriate health and safety measures are adopted i.e. dust suppression	No
			→	Surface water drainage Assuming appropriate site management procedures are adopted	No
		Leaching and infiltration	→	River Irk Assuming appropriate health and safety procedures are adopted	No
			→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock	No

Source		Pathway		Receptor	Linkage?
				River Irk Assuming appropriate site management procedures are adopted	
Impacted shallow groundwater, including groundwater entering the site from landfill to the north	→	Dermal contact	→	Construction worker Assuming appropriate health and safety procedures are adopted	No
		Ingestion	→	Construction worker Assuming appropriate health and safety procedures are adopted	No
		Lateral migration	→	River Irk	Yes
Ground gases/landfill gases	→	Ingress and accumulation of toxic, asphyxiating or explosive concentrations within excavations	→	Construction worker in deep trenches and chambers	No

Table 44: Revised conceptual site model post-completion of HIF IW

Source		Pathway		Receptor	Linkage?
Made Ground (containing solid contaminants and possible hydrocarbons from historical spills)	→	Dermal contact	→	Future site user in soft landscaping areas only	Yes
		Ingestion of soil/ soil dust	→		Yes
		Inhalation of soil vapour	→		No
		Inhalation of soil and soil dust	→	Interim users of plots where no hardstanding exists prior to follow-on development Pathways broken where hard surfacing and buildings present but exposure possible in landscaped areas/gardens	Yes
		Leaching and infiltration	→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock River Irk	Yes
		Direct contact	→	Buried structural concrete	No – assuming the recommendations of Section 5.7 are observed.
			→	Potable water supply pipes	No – assuming the recommendations

Source		Pathway		Receptor	Linkage?
					of Section 6.3 and subsequent assessments are observed.
			→	New planting in public open space areas	Yes
Impacted shallow groundwater (including groundwater if entering site from landfill to north)	→	Dermal contact	→	Future site resident	No
		Ingestion	→	Future site resident	No
		Lateral migration	→	Secondary A aquifers in superficial deposits Principal aquifers in bedrock River Irk	Yes
Ground gases/landfill gases	→	Ingress and accumulation to toxic, asphyxiating or explosive concentrations within buildings	→	Future site user Building structures	No - Initial data indicates CS1, plot-specific assessment required

The potential contaminant linkages (PCL) identified for the HIF IW construction phase can be addressed by the adoption of appropriate mitigation measures typical of brownfield development (**Section 8.2**), except for the PCL relating to possible impact on the River Irk due to legacy groundwater contamination. This PCL is continuous into the post-construction phase and to avoid duplication, is considered with post-HIF IW PCLs below. The risks to construction workers during the HIF IW can be addressed with mitigation measures standard for brownfield site construction works, with negligible residual risk.

The scope of remediation that will be carried out as part of the HIF IW will be limited to ensuring that the land is suitable for the current masterplan uses, and that any unacceptable risks to groundwater or the River Irk are addressed. Potential contaminant linkages will remain post-HIF IW construction, identified in red in **Table 44**. These relate to human health, where there is no barrier to prevent direct contact with existing site soils (e.g. in landscaped areas or gardens) and controlled waters, where existing contamination in groundwater is able to migrate into the bedrock aquifers and/or river Irk. These PCLs will require further risk assessment and possibly remediation to mitigate them. This is discussed further in **Section 8.2**.

It is understood that the development of each individual plot within the planning application site will be subject to a separate assessment by others and as such is not included in the scope of this report.

8.2 Outline remediation strategy

8.2.1 Scope

Remediation in its broadest sense implies a form of intervention to reduce and control risks where linkages exist between contaminant sources and sensitive receptors. This can include source removal or reduction through treatment; pathway interruption (for example

by barriers and cover layers or gas membranes); enhanced health and safety and site control measures (protecting construction workers and neighbours); and long-term monitoring. Remediation objectives relate to the requirement to address contaminant linkages by one or more means. In some cases, more detailed investigation and further risk assessment may indicate that no further intervention is required.

The key objectives for the remediation works specific to the planning application site are:

- to address the contaminant linkages identified in the conceptual model that can be addressed prior to final development;
- to mitigate significant environmental risks or liabilities;
- to achieve regulatory approval, and
- to provide a sustainable solution, within budget and programme constraints, avoiding unacceptable nuisance and H&S impacts.

The outline remediation strategy relates to the HIF IW only, i.e. the ‘master developer’ works to create development platforms for follow-on development and associated Infrastructure Works. At plot development stage (under separate planning application) ‘plot developer remediation’ activities will be necessary that can only be completed at that stage, such as:

- in-building gas protection measures;
- clean cover in soft landscaping and residential development private gardens within the development plots;
- installation of services;
- foundations works risk assessment for plot developments.

8.2.2 Data gaps and uncertainties

This is an outline remediation strategy that does not present the complete information that would be required, for example to discharge a land contamination planning condition. This will be produced when the HIF IW design development allows and once the identified data gaps have been addressed.

As discussed in **Section 6.2.2.5**, despite no exceedances of the selected GACs having been identified in the area of a former gas works (Plot RB05b), hydrocarbon odours and a metallic blue sand material were reported in the relevant exploratory holes, which could indicate the presence of gasworks waste. With respect to human health risk therefore, further investigation is recommended to validate the findings of the 2019 and 2021 GIs in the area of the former gas works and to confirm the extent of any of relic infrastructure associated with former activities that may require breaking out during the HIF Infrastructure Works (**Section 10.1**).

As discussed in **Section 6.2.3.4**, although no gross groundwater contamination was observed during ground investigation, an iridescent sheen was noted in the former gasworks area, localised oily water was noted within the relic carriage shed sub-structure in the northern part of Red Bank Plateau and in deep made ground likely to be associated

with an infilled former reservoir (western Red Bank Plateau). In order to determine whether the groundwater contamination identified generally across the site or the instances of hydrocarbon impacted groundwater described above present a risk to controlled waters, further detailed quantitative risk assessment is required.

In addition, this further risk assessment together with the results of further ground investigation in the areas of regrading and reduced-level excavation will inform validation and material reuse criteria for use during the HIF Infrastructure Works.

Given that the outcome of these further assessments is required before the HIF Infrastructure Works are undertaken, it is recommended that the detailed controlled waters risk assessment begin as soon as possible (using assumed values for certain input parameters if required). Once further GI is completed (**Section 10**) and the resulting data has been assessed, the findings of the detailed controlled waters risk assessment can be validated against the newly obtained data. Provision should also be made in the programme for the design of additional mitigation measures that may need to be implemented.

8.2.3 Remediation strategy tasks

On the basis of current assessments, the following key tasks have been identified as forming part of the site preparation and remediation works:

Site clearance and demolition

Red Bank Plateau area is heavily overgrown and will require vegetation clearance prior to earthworks and remediation. Any invasive species such as Japanese knotweed and Himalayan balsam will require removal and/or treatment. Vegetation clearance and the management of invasive species is outside the scope of this strategy.

It should be noted that the St. Catherine's Wood area is heavily wooded and there is a need to retain as many trees as possible in this area to meet the sustainability goals of the Victoria North project. The presence of trees and vegetation effectively sterilises this area of the site for the purposes of intrusive remediation.

The existing buildings on the Creamline Dairies site (Plot RB12b) are to be demolished as part of the HIF IW contract and part of the retaining wall that separates the Creamline plot from Red Bank Plateau is to be removed. It is assumed that any asbestos will be stripped from the buildings and disposed of prior to demolition and that all suitable demolition materials will be retained on site for re-use.

Parts of the planning application site are currently unsecured and have been fly-tipped in the past. Any fly-tipped material will require removal from site prior to the works, once the site perimeter is secured so further fly-tipping is prevented. In addition, the channel of the River Irk may need to be cleared of accumulated material (to improve river flow). It is recommended that samples of fly-tipped material and accumulated material in the river are recovered and tested during future ground investigation (**Section 0**); the results from the testing will require assessment to determine appropriate disposal routes for the material.

Removal of hardstanding and surface turnover

Areas of surface hardstanding across the planning application site will be removed.

The remains of former rail infrastructure (**Drawing 03**) will be removed including:

- The remains of two former rail turntables present at the surface of the site.
- The below-ground remains of a former carriage shed that have been encountered in a number of trial pits, with brick sub-structure extending to depths of at least 1.4m bgl. In preparation for this breaking out work, dewatering of the sub-structure will be required, with careful management and treatment/disposal of the abstracted oil/water. Depending on the distribution of this perched water within the substructure, this groundwater management may need to be extended throughout the breaking out works. Once the remains of the carriage shed have been removed, this area will require validation against appropriate criteria (**Section 8.2.2**) before being reinstated using suitable engineered fill, placed and compacted to an appropriate specification.

The upper surface of the Red Bank Plateau and Red Bank Viaduct areas are to be turned over to an average depth of 500mm to identify and remove relic structures and other potential obstructions to development (**Section 7.8.1**). In cases where obstructions are encountered at the resulting sub-formation (i.e. at the base of the 500mm turnover), these obstructions will be removed to a depth of 1m below sub-formation level.

Utilities and drainage diversion and protection works may be needed, in advance of earthworks and remediation (**Section 7.8.5**).

Slope regrading

Areas of steep slopes have been identified (**Section 7.2**). Assessments of global stability have concluded that these slopes have unacceptably low factors of safety and a two-part strategy has been set out by Arup to address future stability issues. This strategy involves:

- a). Regrading the slope adjacent to plots RB02 and RB03 to target gradients of 1v to 2.5h.
- b). Lowering ground levels beneath plots RB02 and RB03 to a reduced level of 38.5m AOD.

Proof-rolling of sub-formation

Once slope regrading, excavation and site turnover operations are complete, the resulting sub-formation should be proof-rolled. Any soft spots identified during proof-rolling should be treated by removal and infilling with suitable granular fill, placed and compacted in accordance with the SHW. In accordance with **Section 5.5.4**, soft spots will be defined as areas of the sub-formation with $\text{CBR} < 2\%$ ($k_{762} < 22 \text{ MN/m}^3$).

Material processing and management

Following the regrading and reduced level excavations and other earthworks operations at the planning application site, excavated materials will need to be processed to recover soils for re-use on site as fill. Processing of site won soils is likely to lead to three categories of material:

- a). Material that is suitable for re-use as an engineering fill and meets the requirements of an appropriate earthworks specification (e.g. SHW Class 1 and

Class 2 fill). This category of material is to be used as general earthworks fill across the site (for example to infill the area of the former carriage shed or to raise plot or carriageway levels) or selected fill for more specific applications.

- b). Material that is unsuitable for use as a general engineering fill but may be suitable for use in areas of landscaping (e.g. SHW Class 4 fill).
- c). Material that is unsuitable for use as either general engineering fill or landscaping fill or is surplus to requirements.

In addition to determining material as suitable for re-use based on its engineering properties, it will be necessary to establish chemical acceptability criteria and a verification plan for all site-won materials that are intended for re-use on site (**Section 8.2.2**). The re-use of suitable materials using the CL:AIRE Definition of Waste Code of Practice (DoWCoP) [24] has been proposed in early discussions with the Environment Agency.

Further ground investigation is proposed for the areas of regrading and reduced-level excavation to better define likely classification of recovered soils.

Discovery strategy

A geoenvironmental watching brief should be implemented by the Contractor during excavations. The watching brief should include a defined discovery strategy that describes the response to visible contamination encountered during the works.

Clean cover system in HIF IW soft landscaped areas

Areas of completed soft landscaping within the planning application site must have a suitably designed clean cover system. For the purposes of this outline remediation strategy, it has been assumed that a nominal 600mm validated clean cover will be required in all areas of soft landscaping. It may be possible to reduce the thickness of cover required through a development-specific assessment of risk.

Interim condition on development plots

The HIF IW must be completed to a standard that addresses risks to users of the site and risks to neighbours (e.g. associated with dust arising from the surface of the site) in the interim condition between completion of the HIF IW and follow-on development. A validated cover layer across the site would address these risks, for example a nominal 200mm layer of cover material. It may be possible to win suitable cover within the site boundary, for example from demolition materials.

Site management and environmental monitoring during construction

Some of the contaminant linkages identified in the updated conceptual model are identified as to be addressed by appropriate health and safety procedures to be implemented during the construction (including demolition, earthworks and building works) to ensure that the works do not pose a risk to construction workers, adjacent site users and the wider environment. Similarly, environmental monitoring will be necessary during the works.

Verification plan

The detailed remediation strategy will need to include a verification plan identifying the data that must be collected during the HIF IW to demonstrate the requirements of the remediation strategy have been implemented.

9 Conclusions

9.1 Key engineering issues

An area of existing steep slopes adjacent to Plots RB02 and RB03 (**Figure 1**) has been shown by preliminary assessment to be marginally stable [26]. To mitigate risk of future slope failures, it is recommended that the existing slope should be regraded to a global gradient of 1(v) to 2.5(h), with ground levels at the top of the slope reduced to c. 38.5m AOD.

An assessment of existing slopes adjacent to Plot RB05b and extending into third party land to the north east of the Site have been presented in the GDR [26] and has concluded that there are no immediately obvious signs of instability. Where low factors of safety have been identified, the GDR concludes that the consequence of failure may be small. To manage these risks, the GDR defines a risk zone in which proposed development is not permitted (see Figure 22 in the GDR). For the third-party land to the north east, it is important that the loading conditions are not altered without first assessing the potential impact on the development.

Material that is excavated from within the site, should be considered for re-use as suitable fill as part of the HIF Infrastructure Works (**Figure 11**). Globally across the site, GI data suggests that between 45% and 63% of all the made ground on site could be classified as predominantly granular. In the context of the excavations proposed in the vicinity of Plots RB02 and RB03, the available data indicates that 86% of samples had less than 15% passing the 63 micron sieve, suggesting that for general filling, the majority of this material could be classified as class 1 general granular fill in accordance with the SHW.

Laboratory testing results indicate that the made ground material is typically close to or at the upper limit that is likely to be acceptable for compaction, and some material may require conditioning to reduce its moisture content in order to meet the requirements of the SHW. Additional testing and assessment will be required during the construction phase to confirm the SHW class and acceptability of materials proposed for re-use. In addition, material proposed for re-use will be required to comply with chemical re-use criteria (**Section 8.2.2**).

It should be anticipated that some sorting of excavated made ground will be required to eliminate unacceptable materials. Unacceptable or surplus materials are likely to require offsite disposal. WAC analysis and hazardous waste assessment indicates that most of the material will be classified as non-hazardous waste. Localised areas may be classified as hazardous waste.

It is recommended that a CBR design value of 2% ($k_{762} = 22 \text{ MN/m}^3$) should be assumed for made ground exposed at sub-formation level. In areas of engineered fill (using recovered, site-won general granular fill), a CBR design value of 5% ($k_{762} = 37 \text{ MN/m}^3$) should be assumed at formation level.

The existing made ground beneath the site will be unsuitable for supporting anything but lightly loaded structures. Therefore, the use of bored piles is recommended, either conventional bored or contiguous flight auger (CFA), socketed into the underlying bedrock. Although outside the scope of the existing commission, further investigation will be required by the development team to include rotary coring of the bedrock and detailed

logging will be required in order to inform the foundation design at each plot location. In addition to consideration of UXO risk, initial discussions should also be held with experienced piling contractors to assist in the development of an outline design for the site and construction advice for cost plan purposes.

Given the thickness and variability of the made ground deposits, the use of suspended floor slabs should be assumed. It may be possible to develop engineered fill platforms which would facilitate ground bearing slabs of low to moderate capacity as part of an earthworks/remediation phase in advance of plot development.

A number of existing retaining walls are present within or forming the boundaries of the planning application site. Once development proposals have been confirmed, it will be necessary to assess the stability of any sections of the existing retaining walls that are required to provide on-going support.

New earthworks and a new retaining structure are required to support a proposed access road serving the site. Once the details of the proposed development in this area have been established, further design studies will be required to determine the most appropriate retaining structure and to address any associated settlement risks.

The design of remedial works and future buildings will need to consider both the potential magnitude of settlement and the likely duration of on-going settlement at the site. Once development proposals are agreed, assessments of the likely settlement magnitude and timescales will be required. If these assessments suggest settlement is a potential development constraint, it may be necessary to undertake settlement monitoring to determine how closely actual settlement matches the predicted behaviour. It is possible that foundation pile design may need to allow for downdrag effects.

As discussed in **Section 7.8**, the following additional constraints have been identified:

- The potential for buried obstructions to be encountered within the made ground;
- Specialist advice is required to address risks from UXO;
- There exists a low risk of encountering voids within the site;
- There exists a risk of encountering buried structures, principally within the made ground;
- Existing utilities may present a constraint to the development in some areas and will need to be identified on site. Of particular note is a combined sewer crossing Red Bank Plateau and descending steep slopes before crossing beneath the River Irk adjacent to Travis Island. In addition a drain has been reported crossing the site (**Figure 11**);
- The potential for the proposed works to impact adjacent structures such as operation railway viaducts will need to be discussed with appropriate stakeholders.

9.2 Key geoenvironmental issues

The wider site area has had a long history of industrial use and areas of contaminated ground and groundwater have been identified during the ground investigations. The key issues identified are:

- presence of asbestos fibres and asbestos containing materials in made ground, which will require mitigation during construction and operation of the planning application site, including any interim undeveloped phase;
- contaminants including metals and PAH in made ground, which will require mitigation during construction and operation, including during any interim periods between the completion of remediation and the beginning of plot development;
- potentially contaminated made ground and groundwater around the former gasworks in St. Catherine's Wood, which may pose a risk to human health and controlled waters;
- potentially contamination in the vicinity of a former carriage shed on Red Bank Plateau which may pose a risk to human health and controlled waters;
- contamination at depth (>10m bgl) associated with a former reservoir which may pose a risk to controlled waters.

The identified risks to construction workers during the HIF Infrastructure Works can be addressed with mitigation measures standard for brownfield site construction works.

Potential contaminant linkages relating to a possible impact on the River Irk and bedrock aquifers due to legacy contamination require more detailed risk assessment and possibly remediation in order to mitigate them. Further ground investigation is required to provide a basis for the detailed risk assessment.

Potential contaminant linkages have been identified post-HIF IW construction relating to human health, where there is no barrier to prevent direct contact with existing site soils (e.g. in landscaped areas or gardens).

An outline remediation strategy has been presented, which sets out the actions required to be taken to mitigate the identified risks as part of the HIF IW (**Section 8.2**). It should be noted that the scope of remediation to be carried out as part of the HIF IW will be limited to ensuring that the land is broadly suitable for the current masterplan uses and that any unacceptable risks to groundwater or the River Irk are addressed. It will be the responsibility of future plot developers to mitigate the residual risks that remain post HIF IW e.g. the placement of clean cover in residential gardens or landscaping areas, the requirements for protected pipe materials and ground gas protection to buildings.

9.3 Data gaps

A number of data gaps have been identified during the Arup review of the 2019 and 2021 GIs. These include the requirement for further ground information to provide:

- Additional data to validate the findings of preliminary slope stability assessments for the steep slopes adjacent to Red Bank Plateau.
- Additional information on ground conditions in the former Creamline Dairies site.
- Additional information on ground and groundwater conditions in the area of a former gas works (Plot RB05b).
- Additional information on ground conditions adjacent to the River Irk.

- Additional information to address any data gaps arising from widely spaced boreholes.

The specific data gaps and further investigation recommended to address them are described in **Section 10.1**. In addition, further detailed quantitative controlled waters risk assessment is required to determine whether the site in general or specific features within the site (such as oily water identified in the substructure of a former carriage shed) present a demonstrable risk to controlled waters. Furthermore, this quantitative risk assessment will be used to determine validation and re-use criteria for use during the HIF Infrastructure Works.

10 Recommendations

Arup consider that the data presented and interpreted above is sufficient to secure conditional planning consent for the HIF Infrastructure Works. To address anticipated planning conditions related to ground conditions together with data gaps that has been identified, further ground investigation, monitoring and analysis is proposed as discussed in **Section 10.1** below. In addition to the proposed further investigation, additional assessments including quantitative controlled waters risk assessment will be required, as discussed in **Section 10.2**.

10.1 Further ground investigation

On the basis of the assessment presented above, it is recommended that a further phase of ground investigation is undertaken to address a number of data gaps that have been identified and to address a number of specific issues that have arisen as the masterplan for the planning application site has been developed. A rationale for the proposed further ground investigation is presented in **Appendix A**.

The current proposals for additional GI include the following:

1. A series of trial trench excavations in the area of the gas works to delineate the area of contamination identified during the 2021 GI, with monitoring of groundwater quality downgradient of the gasworks, to assess the quality of groundwater that is potentially reaching the River Irk.
2. A series of boreholes located along the crest and toe of existing slopes to validate existing slope stability assessments. Selected boreholes will be provided with inclinometer installations with monitoring to assess ground movements.
3. A series of boreholes located along the river to:
 - a) confirm conditions adjacent to existing retaining walls for use in structural assessments and
 - b) to provide further data on the distribution of alluvial deposits to assist with controlled waters risk assessment.
4. Boreholes at accessible proposed bridge abutment locations to inform the design of abutments and foundations.
5. A number of boreholes located to provide further data on the depth to engineering rockhead to validate current interpretation and to fill data gaps.
6. Additional GI to fill more general gaps in spatial coverage across the site (i.e. where exploratory holes from previous GIs are widely separated).
7. Borehole infiltration tests in selected installations in areas where made ground is thin and absent (primarily in the River Irk corridor) to investigate the feasibility of incorporating soakaways into the site drainage system.
8. Additional geotechnical sampling and testing in areas of proposed excavation to confirm suitability of arisings for re-use.

9. Additional geoenvironmental soil sampling and analysis across the site to validate conclusions reached in this GIR and in detailed quantitative controlled waters risk assessment that is recommended.
10. Selected boreholes will be provided with groundwater monitoring installations (to complement existing serviceable installations), with monitoring to confirm hydraulic gradient across site.
11. Selected boreholes will be provided with ground gas monitoring installations (to complement existing serviceable installations), with monitoring to confirm ground gas conditions particularly during periods of low atmospheric pressure.
12. Sampling of groundwater from installations for analysis plus additional leachability testing of soil samples.
13. Sampling of shallow made ground along main potable water corridors with relevant analysis, to allow requirements for potable supply pipe to be determined.
14. Surface water sampling and analysis from the river to assist with further controlled waters risk assessment.
15. Sampling and analysis from stockpiles of fly-tipped material within the site and from sediment and other accumulations in the river, to determine waste disposal options.

All selected analysis suites will reflect the previous relevant recorded uses of the site, making reference to relevant DoE Industry Profiles [25].

A GI specification has been prepared for the recommended further GI works [27].

10.2 Further design studies

As discussed in this GIR, a number of further design studies are required, as follows:

- Quantitative controlled waters risk assessments are required to determine the risks to controlled waters.
- Once the details of the proposed new highway access through Plot RB12b are confirmed, further design studies will be required to determine the most appropriate retaining structure to support this access.
- Further assessments will be required to determine the likely settlement magnitude and settlement timescales.

11 References

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GIR - Drawing list

Drawing 01 – Arup Ground Investigation Positions (2019 and 2021)

Drawing 02 – Monitoring Installations

Drawing 03 – Historic Features and Potential Development Constraints

Drawing 04 – Visual and Olfactory Evidence of Contamination

Drawing 05 – Interpretative Geological Long Section

Drawing 06 – Interpretative Geological Cross Section 1

Drawing 07 – Interpretative Geological Cross Section 2

Drawing 08 – Inferred Groundwater Elevation in Bedrock

Drawing 09 – Approximate UXO Strike Locations

Drawing 10 – Risk Assessment for Residential with Plant Uptake

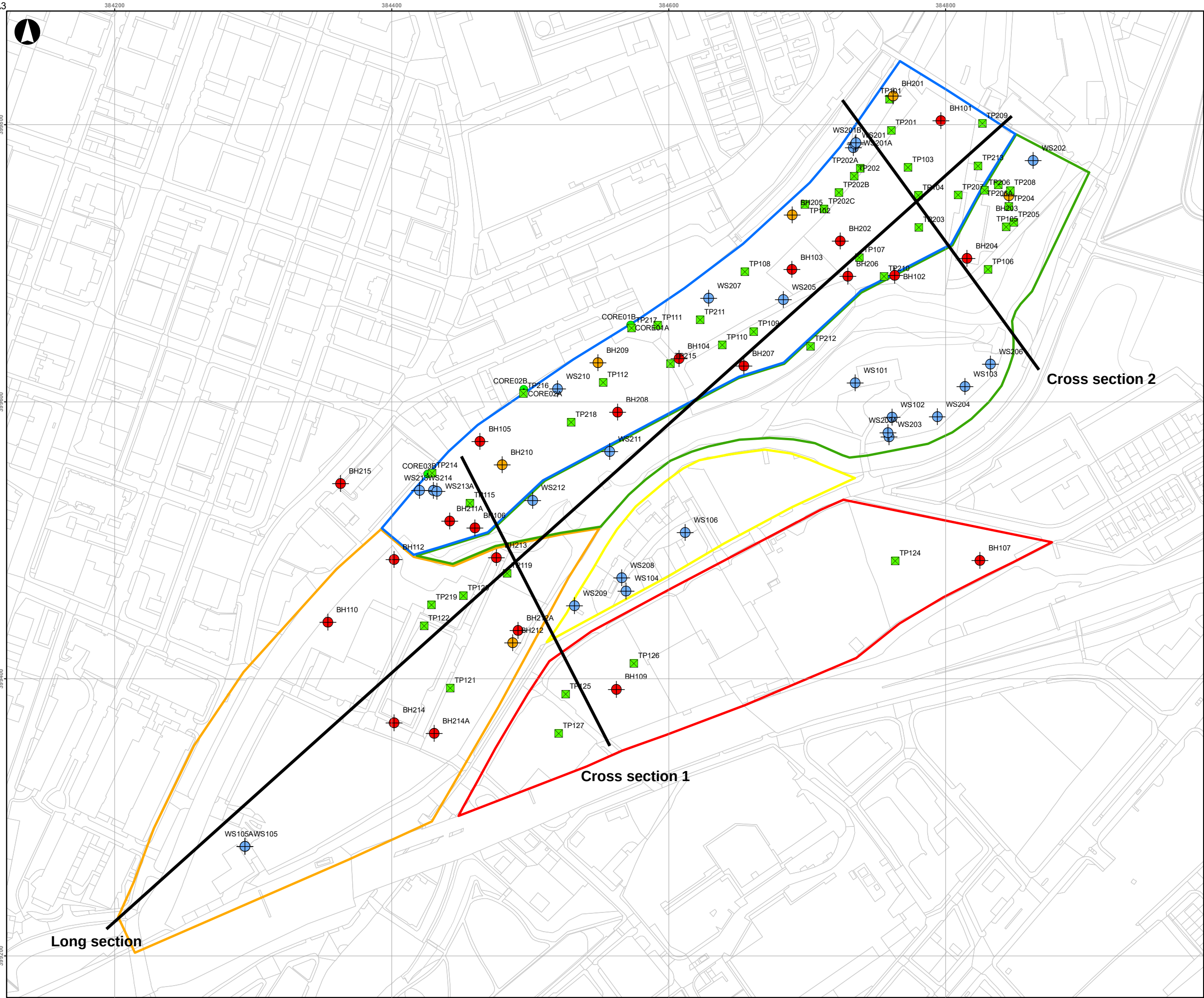
Drawing 11 – Risk Assessment for Public Open Space for St. Catherine's Wood

Drawing 12 – Identification of Asbestos in Soil Samples

Drawing 13 – Controlled Waters Risk Assessment

Drawing 14 – HazWasteOnline Assessment

Drawing 15 – Waste Acceptance Criteria Samples Summary

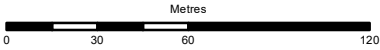


- Key**
- New Town Plots
 - Red Bank Plateau
 - Red Bank Viaduct
 - St Catherine's Wood
 - Travis Island

Exploratory Hole Locations

- Type**
- Concrete Core
 - Cable Percussive
 - Cable Percussive and Rotary
 - Trial Pit
 - Window Sample

P0	2021-11-19	TH	TH	TH
Issue	Date	By	Chkd	Appd



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Project Title
Victoria North

Drawing Title
**Arup Ground Investigation
Positions (2019 and 2021)**

Scale at A3
1:2,500

Arup Job No 282022 - 00	Suitability Preliminary
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Name Drawing - 01	Rev P0
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Key

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

Monitoring Installations

Type

- Gas and Groundwater
- Groundwater

P0	2021-11-19	TH	TH	TH
Issue	Date	By	Chkd	Appd

Metres
 0 30 60 120

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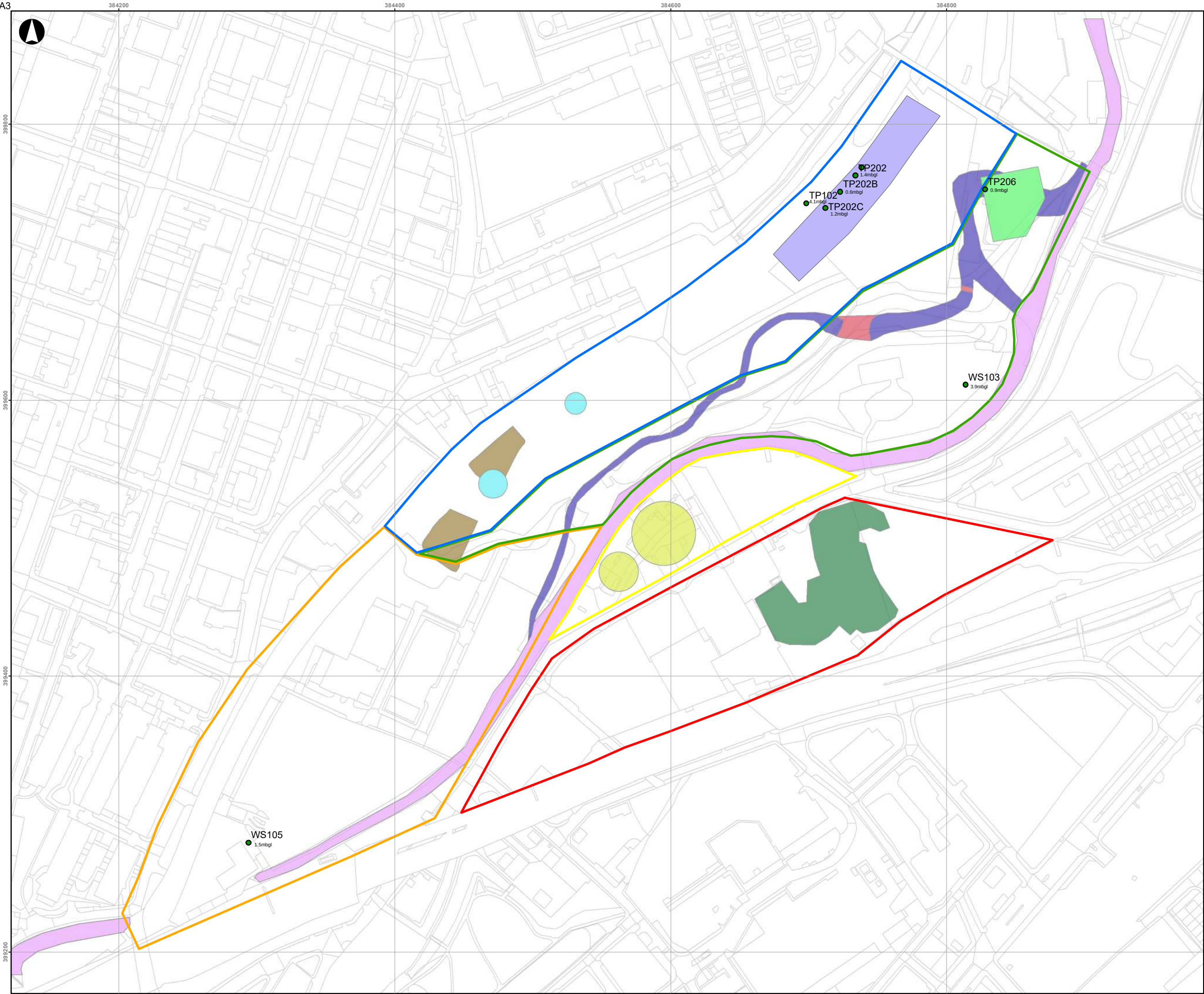
Project Title
Victoria North

Drawing Title
Monitoring Installations

Scale at A3
1:2,500

Arup Job No	Suitability
282022 - 00	Preliminary

Name	Rev
Drawing - 02	P0



Key

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

- Recorded obstructions

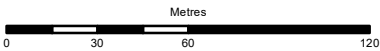
Geotechnical_constraints

Feature

- Bridge
- Carriage Shed
- Gas Works
- Infilled Channel
- Infilled Water Body
- Railway Turntable
- River Irk
- Soil stockpiles
- Tank

P0	2021-11-19	TH	TH	TH
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Issue	Date	By	Chkd	Appd
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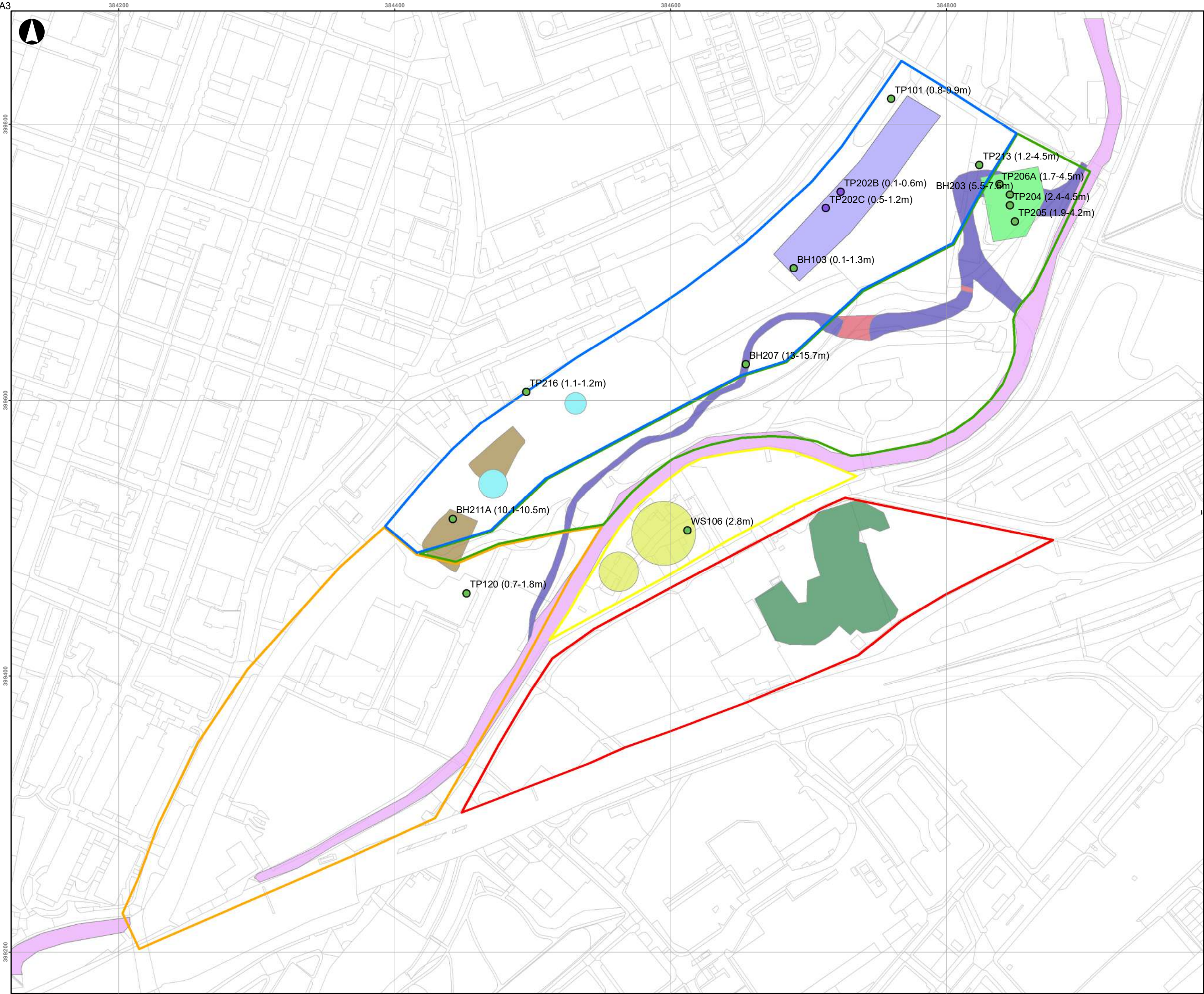
Drawing Title
Historic Features and Potential Development Constraints

Scale at A3

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Arup Job No 282022 - 00	Suitability Preliminary
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Name Drawing - 03	Rev P0
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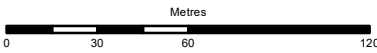
Key

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

Key contamination features

- Hydrocarbon odour
- Oily groundwater
- Bridge
- Carriage Shed
- Gas Works
- Infilled Channel
- Infilled Water Body
- Railway Turntable
- River Irk
- Soil stockpiles
- Tank

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Issue	Date	By	Chkd	Appd



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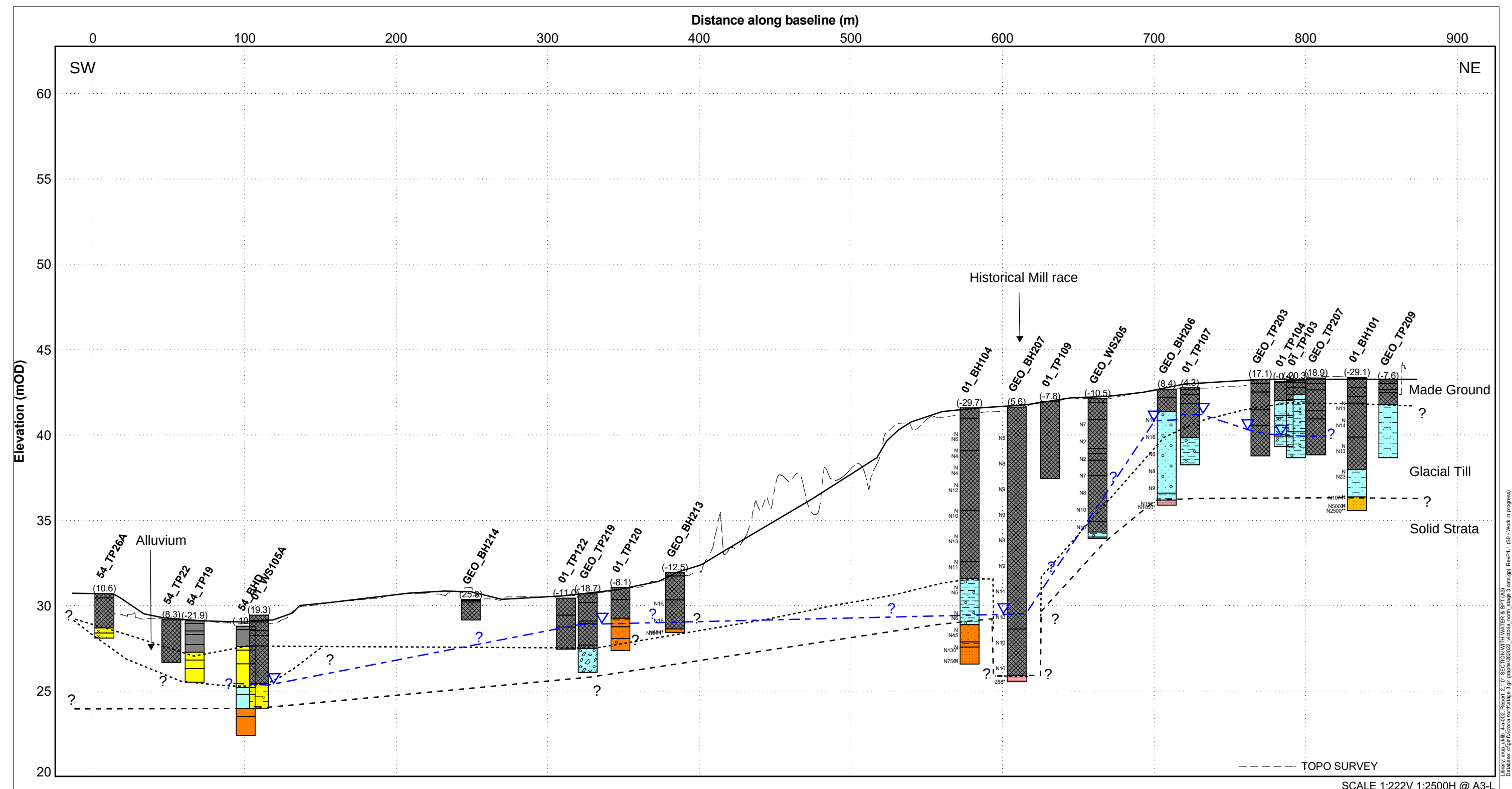
Client
BAM Nuttall Limited

Project Title
Victoria North

Drawing Title
**Visual and Olfactory
evidence of contamination**

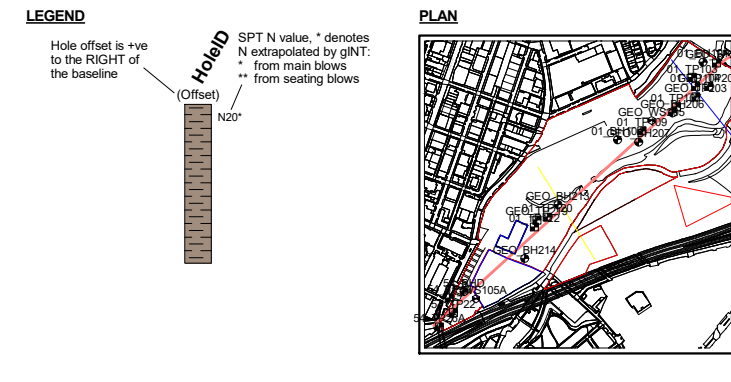
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Arup Job No 282022 - 00	Suitability Preliminary
Name Drawing - 04	Rev P0



SCALE 1:222V 1:2500H @ A3-L

ARUP gINT v10.00.01.07. Made by Jonny Tyrer on 1-Nov-21



MATERIALS	
	Fill (MADE GROUND)
	Clayey SAND
	SANDSTONE
	Sandy gravelly CLAY
	SAND
	CLAY
	Gravelly SAND
	Sandy CLAY
	MUDSTONE
	Clayey gravelly SAND
	Silty sandy gravelly CLAY
	Silty sandy CLAY
	Silty SAND
	SAND and GRAVEL

- Ground level from 2021 Topographical survey
- Interpreted ground level from exploratory hole records
- Soil boundary
- Rock boundary
- Interpreted Ground water level

ARUP

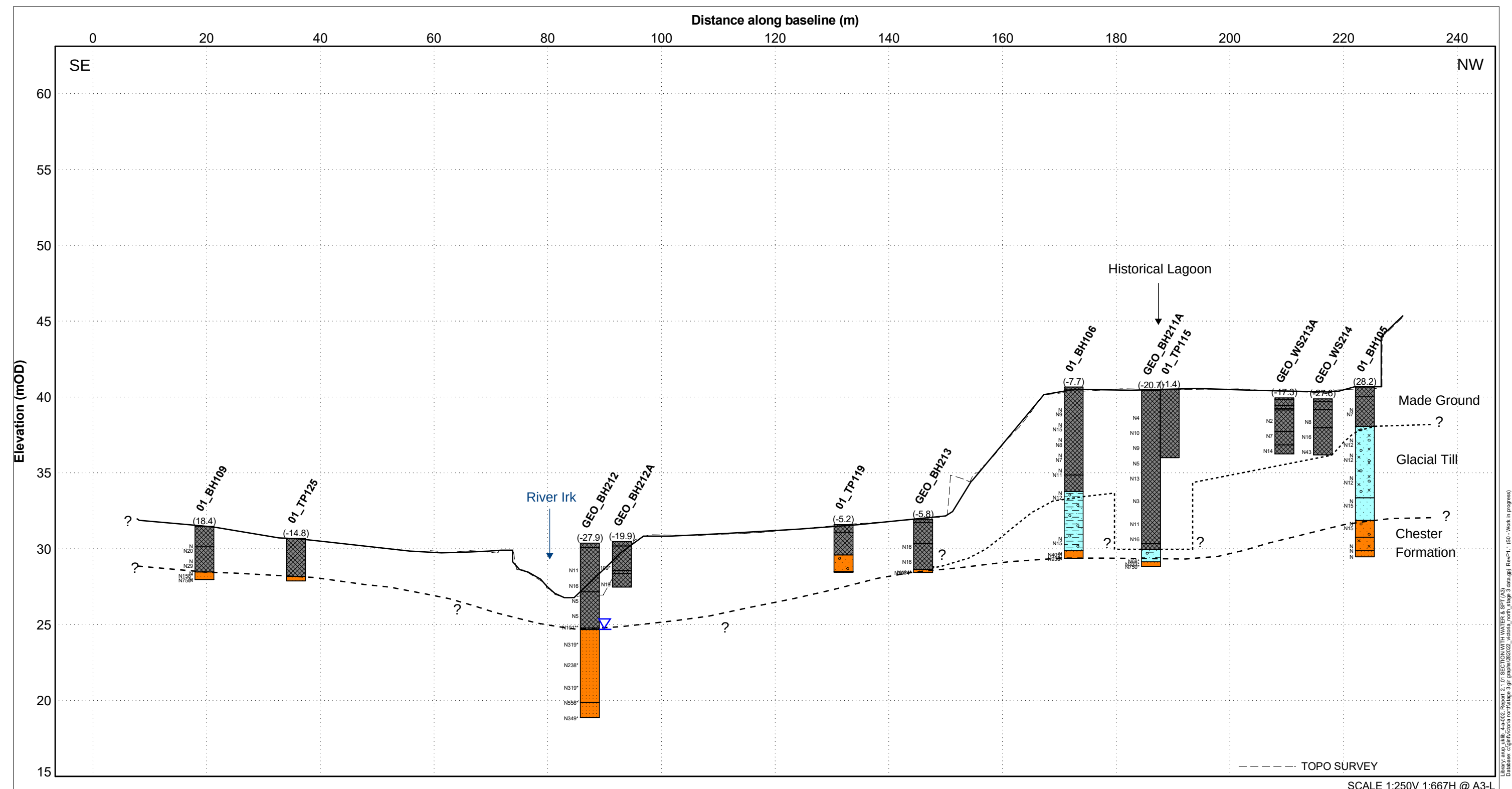
Job Title
Victoria North

Figure Title
Interpretative Geological Long section
Refer to Drawing - 01 GI plan

Job No
282022

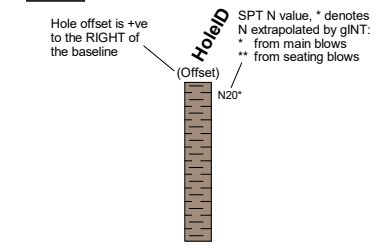
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Drawing - 05

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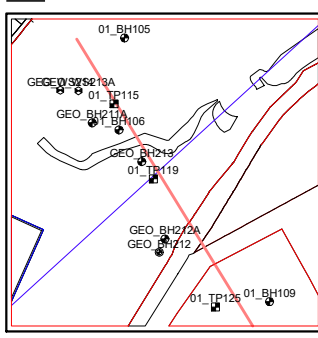


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LEGEND



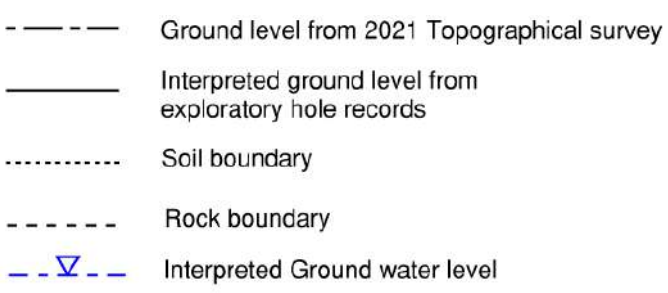
PLAN



COLOUR LEGEND



MATERIALS



ARUP

Job Title
Victoria North

Figure Title

Geological cross section 1
Refer to Drawing - 01 GI plan

Job No
282022

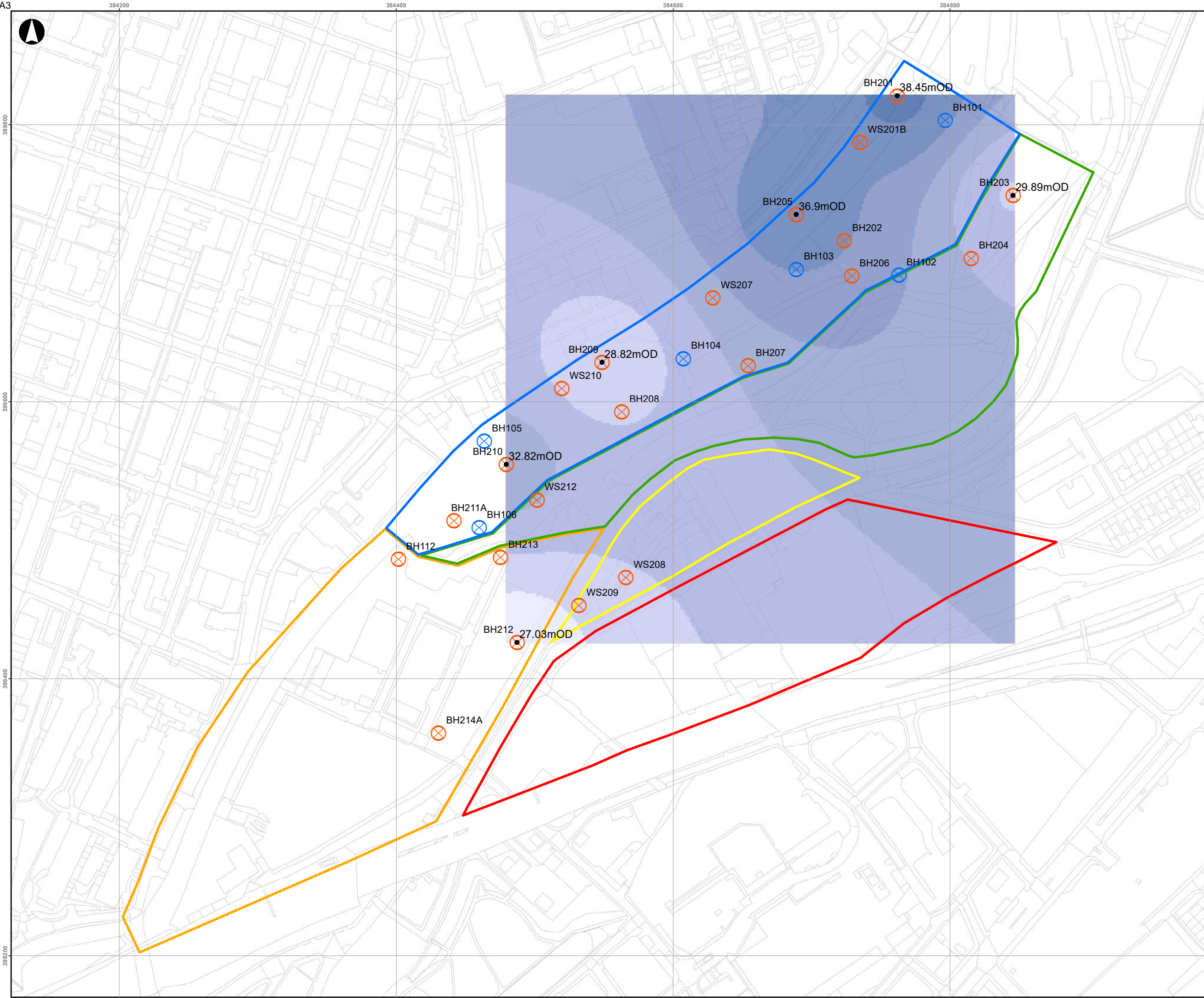
Figure No
Drawing - 06



ARUP, qINT v10.00.01.07. Made by Jonny Tyrer on 29-Oct-21

Figure No

Drawing - 07



Key

Site Areas

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

Monitoring Installations

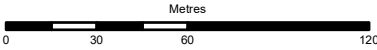
- Gas and Groundwater
- Groundwater
- Groundwater elevation in bedrock (mOD)

Inferred groundwater elevation (mOD)

- <28
- <30
- <32
- <34
- <36
- <38
- <40

P0	2021-12-15	TH	TH	TH
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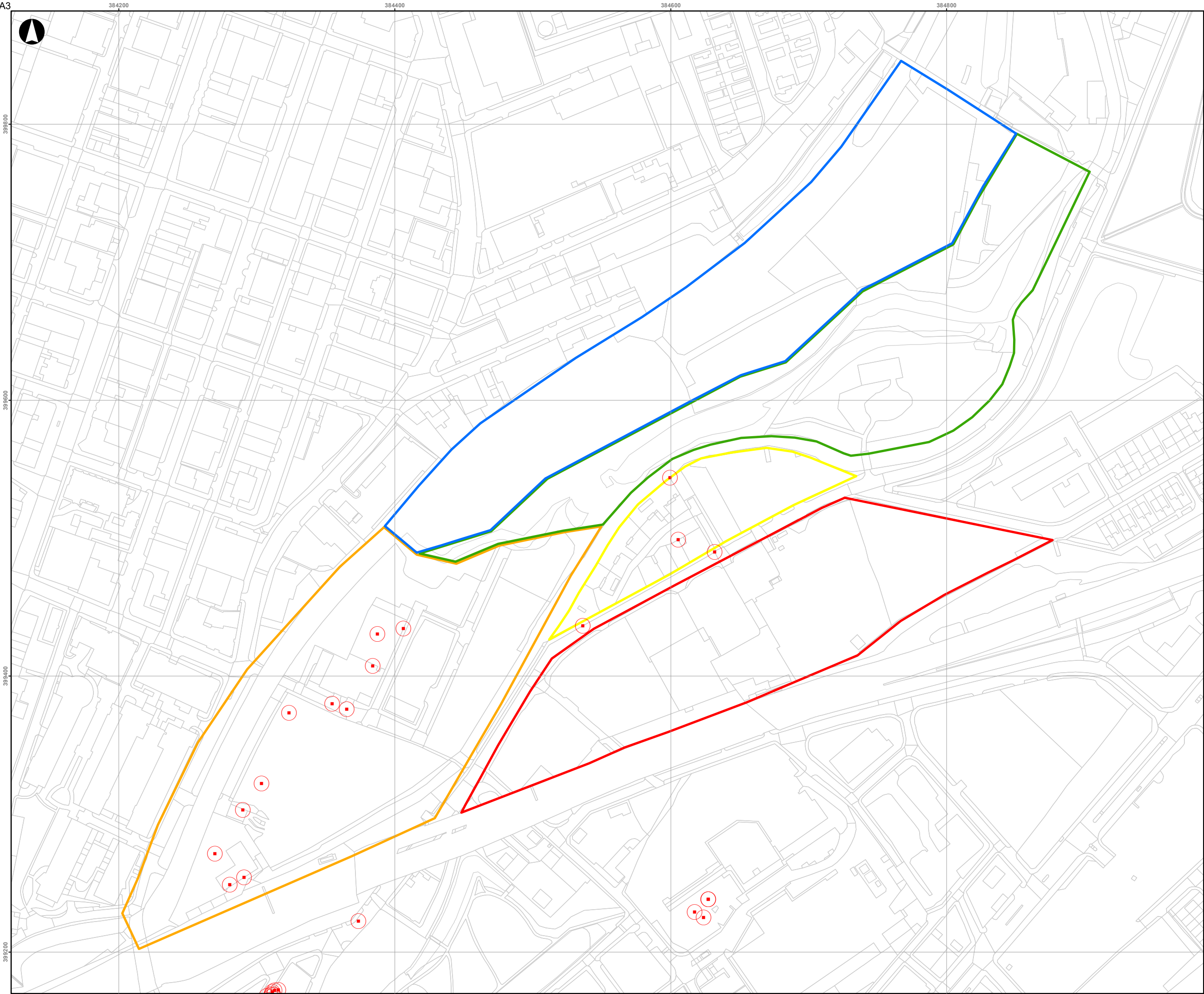
Project Title
Victoria North

Drawing Title
Inferred groundwater elevation in bedrock

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Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 8	Rev P0
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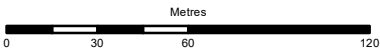


Key

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island
- UXO Strike Locations

P0	2021-11-19	TH	TH	TH
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Issue	Date	By	Chkd	Appd
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Project Title
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Drawing Title
**Approximate UXO
Strike Locations**

Scale at A3

1:2,500

Arup Job No 282022 - 00	Suitability Preliminary
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Name Drawing 9	Rev P0
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Key

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

Residential with Plant Uptake

GAC Exceedances

- >1 contaminant significantly exceeds GAC
- >1 contaminant exceeds GAC
- No contaminants tested exceed GAC

P0	2021-11-19	TH	TH	TH
Issue	Date	By	Chkd	Appd

Metres
0 30 60 120

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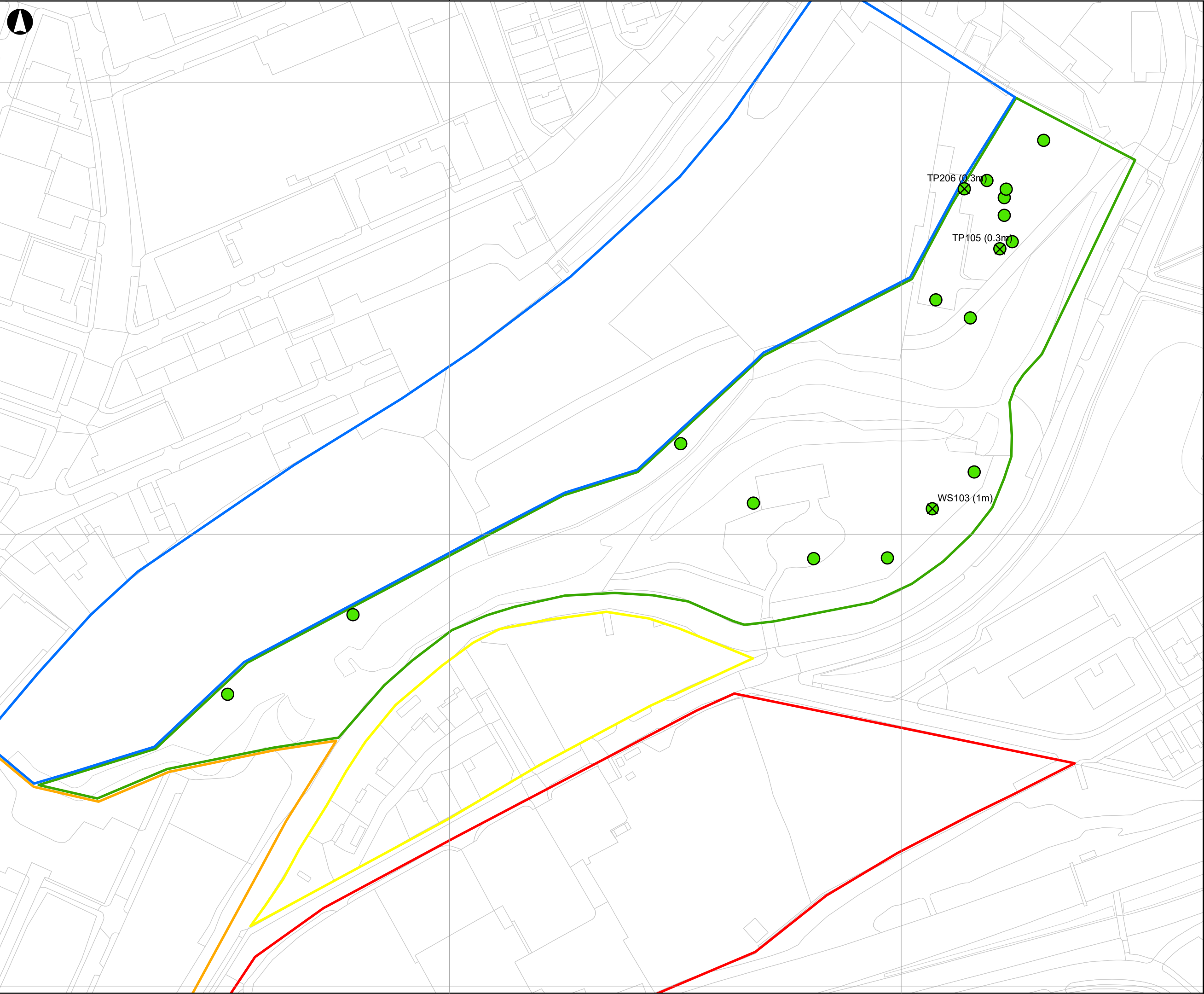
Client
BAM Nuttall Limited

Project Title
Victoria North

Drawing Title
**Risk assessment for residential
with plant uptake**

Scale at A3
1:2,500

Arup Job No 282022 - 00	Suitability Preliminary
Name Drawing 10	Rev P0



Key

Public Open Space (Parks)

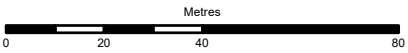
GAC Exceedances

- No contaminants tested exceed GAC
- ⊗ Asbestos detected
- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

Locations and depths of detected asbestos shown as labels.

The results of analysis are summarised here for all samples tested within St. Catherine's Wood and Plot RB05b

P0	2021-11-22	TH	TH	TH
Issue	Date	By	Chkd	Appd



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Victoria North

Drawing Title
Risk Assessment for Public Open Space for St. Catherine's Wood

Scale at A3
1:1,541

Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 11	Rev P0
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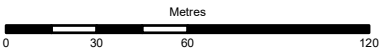
Key

Asbestos

- Asbestos detected
- No asbestos detected
- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

P0	2021-11-19	TH	TH	TH
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Issue	Date	By	Chkd	Appd
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Client
BAM Nuttall Limited

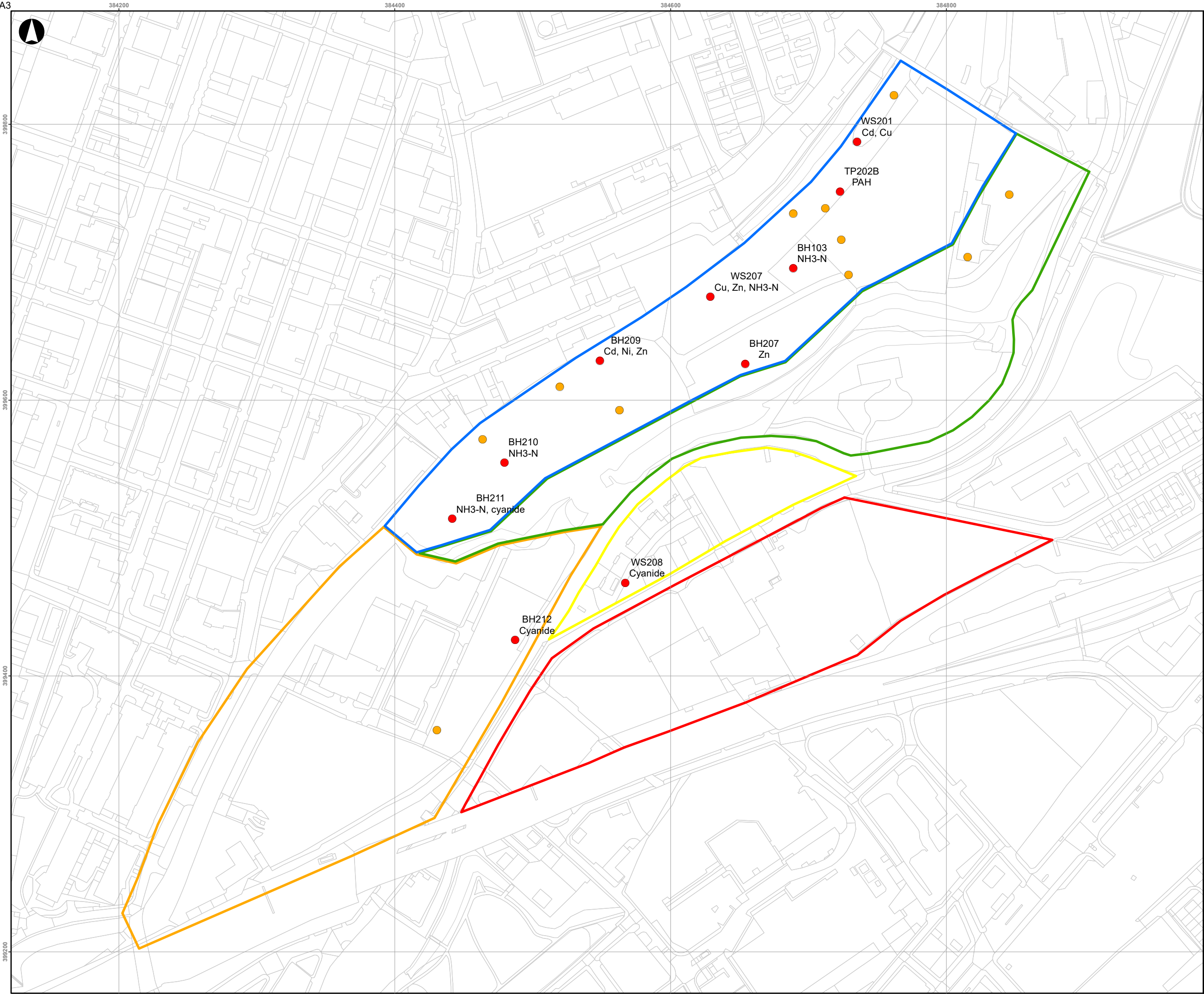
Project Title
Victoria North

Drawing Title
Identification of asbestos in soil samples

Scale at A3
1:2,500

Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 12	Rev P0
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Key

GAC Exceedances

>1 contaminant significantly exceeds GAC

>1 contaminant exceeds GAC

New Town Plots

Red Bank Plateau

Red Bank Viaduct

St Catherine's Wood

Travis Island

P0	2021-11-01	TH	TH	TH
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Issue	Date	By	Chkd	Appd

Metres

0

30

60

120

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Project Title
Victoria North

Drawing Title
Controlled Waters Risk Assessment

Scale at A3
1:2,498

Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 13	Rev P0
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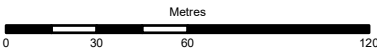


Key

HazWasteOnline classification

- Hazardous
- Non Hazardous
- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

P0	2021-11-19	TH	TH	TH
Issue	Date	By	Chkd	Appd



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Victoria North

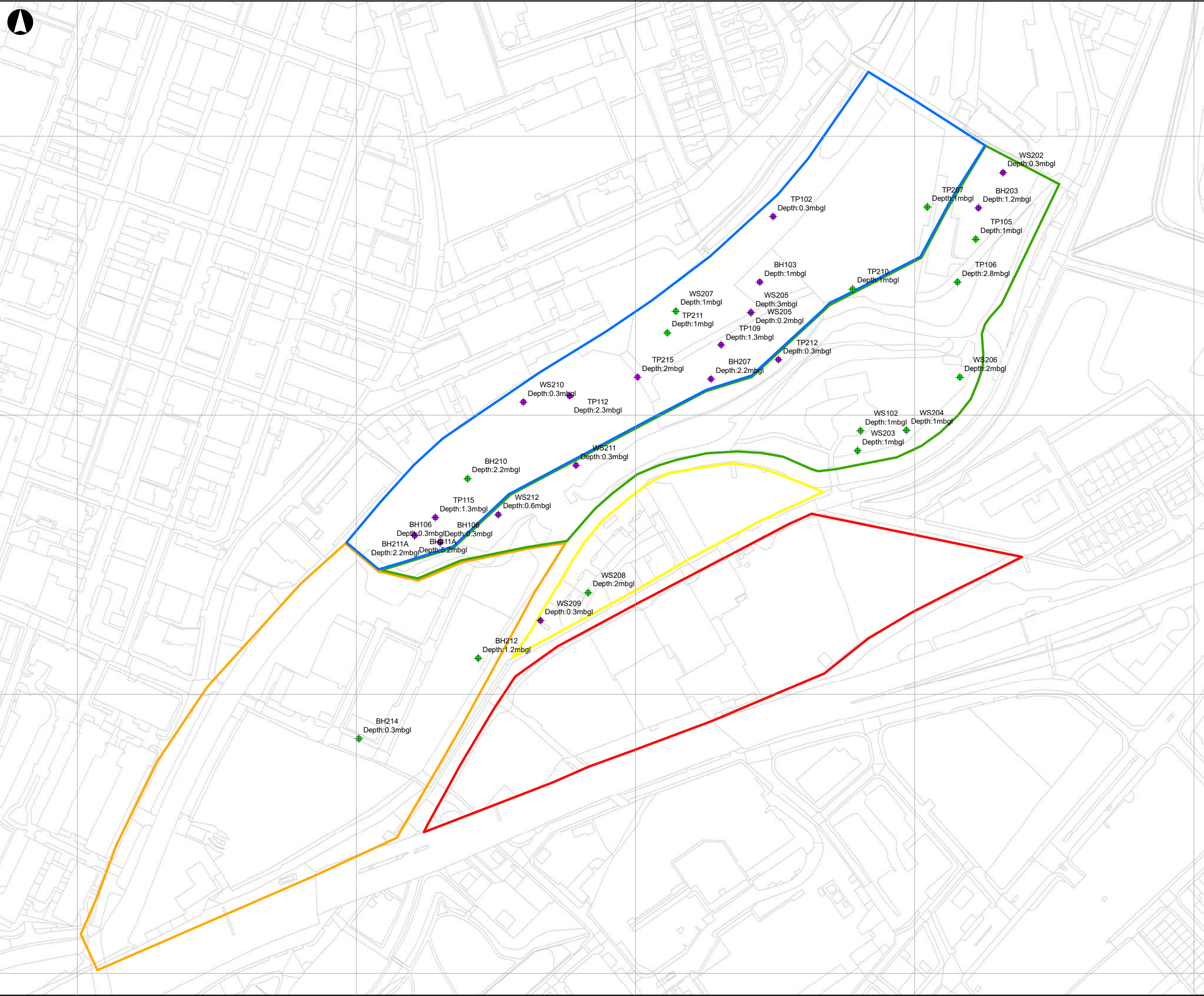
Drawing Title
HazWasteOnline Assessment

Scale at A3

1:2,500

Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 14	Rev P0
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Key

Site Areas

Site Areas

- New Town Plots
- Red Bank Plateau
- Red Bank Viaduct
- St Catherine's Wood
- Travis Island

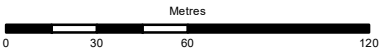
Waste Acceptance Criteria Samples

Type

- Inert
- Non-hazardous

D1	2021-11-22	TH	TH	TH
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Issue	Date	By	Chkd	Appd
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Client
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Project Title
Victoria North

Drawing Title
**Waste acceptance criteria
samples summary**

Scale at A3
1:2,500

Arup Job No 282022-00	Suitability Preliminary
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Name Drawing 15	Rev D1
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Appendix A - Ground Investigation Rationales

Planned scope of 2021 Ground Investigation

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
GEO_BH201	CP+RC	15	384766	399826	SPT every 1m for first 5m, then every 1.5m. GW, response zone in rock/deep MG	Rough ground	CP terminates at rockhead. RC 5m into rock. Flush cover.	Investigate rock quality. Installation to detect gas/leachate migration onto site from adjacent Queens Road landfill. Response zone detail provisional, pending review of groundwater flow.
GEO_BH202	CP	10	384724	399722	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate area beneath former carriage shed, potential contamination. Response zone detail provisional, pending review of groundwater flow.
GEO_BH203	CP	8	384856	399747	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate former river Irk channel beneath Red Bank. Response zone detail provisional, pending review of groundwater flow.
GEO_BH204	CP+RC	15	384816	399708	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	CP terminates at rockhead. RC 5m into rock. Flush cover.	Investigate former river channel beneath Red Bank. Response zone detail provisional, pending review of groundwater flow.
GEO_BH205	CP+RC	15	384686	399733	SPT every 1m for first 5m, then every 1.5m. GW, response zone in rock/deep MG	Rough ground	CP terminates at rockhead. RC 5m into rock. Flush cover.	Investigate rock quality. Installation to detect gas/leachate migration onto site from adjacent Queens Road landfill. Response zone detail provisional, pending review of groundwater flow.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
GEO_BH206	CP	8	384731	399693	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate potential contamination associated with former railway sidings. Response zone detail provisional, pending review of groundwater flow.
GEO_BH207	CP	10	384656	399622	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate former river/stream channel beneath Red Bank. Response zone detail provisional, pending review of groundwater flow.
GEO_BH208	CP	10	384565	399593	SPT every 1m for first 5m, then every 1.5m. GW, response zone in rock/deep MG	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate potential contamination associated with former railway sidings. Response zone detail provisional, pending review of groundwater flow.
GEO_BH209	CP+RC	15	384554	399632	SPT every 1m for first 5m, then every 1.5m. GW, response zone in rock/deep MG	Rough ground	CP terminates at rockhead. RC 5m into rock. Flush cover.	Investigate former river/stream channel beneath Red Bank. Response zone detail provisional, pending review of groundwater flow.
GEO_BH210	CP+RC	15	384478	399555	SPT every 1m for first 5m, then every 1.5m. GW, response zone in rock/deep MG	Rough ground	CP terminates at rockhead. RC 5m into rock. Flush cover.	Investigate old reservoir buried beneath red bank, potential for ground gas. Response zone detail provisional, pending review of groundwater flow.
GEO_BH211	CP	10	384448	399513	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate old reservoir buried beneath red bank, potential for ground gas. Response zone detail provisional, pending review of groundwater flow.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
GEO_BH212	CP+RC	15	384490	399427	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Tarmac/concrete car park.	CP terminates at rockhead. RC 5m into rock. Flush cover. Reinstatement of surfacing will be required.	Investigate contamination associated with former dye works. Response zone detail provisional, pending review of groundwater flow.
GEO_BH213	CP	10	384467	399489	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Rough ground	Terminate at rockhead/refusal. Flush cover	Investigate ground conditions at toe of slope, former scrapyards and dye works contamination potential. Response zone detail provisional, pending review of groundwater flow.
GEO_BH214	CP	8	384397	399371	SPT every 1m for first 5m, then every 1.5m. GW, response zone in MG/alluvium	Tarmac	Terminate at rockhead/refusal. Flush cover. Reinstatement of surfacing will be required.	Investigate potential contamination associated with former dye works, iron works, potential obstructions from terraced housing. Response zone detail provisional, pending review of groundwater flow.
GEO_BH215	CP	10	384371	399541	SPT every 1m for first 5m, then every 1.5m. No installation required.	Tarmac/concrete	Terminate at rockhead/refusal. Reinstatement of surfacing will be required.	Confirm ground conditions in area of proposed access route into red bank.
GEO_CORE_01	Core	N/A	384660	399720	None	Brick retaining wall	Horizontal core to recover samples from existing retaining wall. Reinstatement to be advised.	Investigate wall construction, condition.
GEO_CORE_02	Core	N/A	384568	399655	None	Brick retaining wall	Horizontal core to recover samples from existing retaining wall.	Investigate wall construction, condition.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
							Reinstatement to be advised.	
GEO_CORE_03	Core	N/A	384486	399603	None	Brick retaining wall	Horizontal core to recover samples from existing retaining wall. Reinstatement to be advised.	Investigate wall construction, condition.
GEO_TP201	TP	4.5	384772	399796	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Former carriage shed, potential contamination and obstructions
GEO_TP202	TP	4.5	384735	399751	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Former carriage shed, potential contamination and obstructions
GEO_TP203	TP	4.5	384784	399725	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		In footprint of former railway building, possible gasworks, potential for contamination and obstructions
GEO_TP204	TP	4.5	384850	399737	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground	Position exactly, TP to locate former gasholder base. Contamination likely.	Northern railway gasholder – position exactly
GEO_TP205	TP	4.5	384852	399728	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground	Position exactly, TP to locate former gasholder base. Contamination likely.	Southern railway gasholder – position exactly
GEO_TP206	TP	4.5	384835	399756	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Within footprint of former gasworks building, contamination potential and obstructions

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
GEO_TP207	TP	4.5	384807	399751	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Former chimney associated with gasworks, potential for contamination and obstructions
GEO_TP208	TP	4.5	384847	399746	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Within footprint of former buildings, contamination potential and obstructions
GEO_TP209	TP	4.5	384818	399804	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Railway sidings area, potential for contamination and obstructions
GEO_TP210	TP	4.5	384824	399776	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Former buildings, potential for contamination and obstructions
GEO_TP211	TP	4.5	384751	399691	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Former buildings, potential for contamination and obstructions
GEO_TP212	TP	4.5	384617	399654	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Railway sidings area, potential for contamination and obstructions
GEO_TP213	TP	4.5	384700	399654	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Railway sidings area, potential for contamination and obstructions
GEO_TP214	TP	3	384666	399726	3 x Mexe Cone and 1 x DCP at	Rough ground	In tandem with horizontal core through retaining wall.	To investigate footings of existing retaining wall. Logging of footings required.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
					depth less than 1.2m			
GEO_TP215	TP	4.5	384585	399619	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		Railway sidings area, potential for contamination and obstructions
GEO_TP216	TP	3	384576	399656	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground	In tandem with horizontal core through retaining wall.	To investigate footings of existing retaining wall. Logging of footings required.
GEO_TP217	TP	3	384492	399608	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground	In tandem with horizontal core through retaining wall.	To investigate footings of existing retaining wall. Logging of footings required.
GEO_TP218	TP	3	384525	399593	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Rough ground		To investigate old railway turntable, trial pit to be excavated down outside of structure to check construction.
GEO_TP219	TP	5	384427	399443	3 x Mexe Cone and 1 x DCP at depth less than 1.2m	Tarmac/concrete		Former area of terraced housing, potential for infilled cellars and contamination in cellar infill.
GEO_WS201	WS	5	384732	399777	GW, response zone in MG/alluvium	Rough ground	Flush cover.	Located on boundary with Queens Road landfill, to investigate gas/leachate migration from landfill site. Response zone detail provisional, pending review of groundwater flow.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
GEO_WS202	WS	5	384861	399781	GW, response zone in MG/alluvium	Rough ground	Flush cover	To investigate made ground in former railway sidings, may be deeper in this area than trial pitting can prove. Response zone detail provisional, pending review of groundwater flow.
GEO_WS203	WS	5	384750	399568	None	Rough ground		To obtain information for river edge reprofiling, include WAC testing.
GEO_WS204	WS	5	384790	399578	None	Rough ground		To obtain information for river edge reprofiling, include WAC testing.
GEO_WS205	WS	8	384679	399675	None	Rough ground		Railway sidings, made ground expected to be deeper than could be proven with a trial pit in this area. Prove depth of made ground and check contamination of ground.
GEO_WS206	WS	5	384841	399635	None	Rough ground		To obtain information for river edge reprofiling, include WAC testing.
GEO_WS207	WS	5	384628	399678	GW, response zone in MG/alluvium	Rough ground	Flush cover	Made ground expected to be deeper than could be proven in trial pit in this area. Prove depth of made ground and check contamination of ground. Response zone detail provisional, pending review of groundwater flow.
GEO_WS208	WS	8	384567	399467	None	Rough ground	In travellers site. Special access arrangements apply. To investigate	To locate and check condition of southern gasholder – position to locate this feature.

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
							former gasholder base. Contamination expected.	Nature of infill and contamination to be proven.
GEO_WS209	WS	5	384529	399443	GW, response zone in MG/alluvium	Concrete/tarmac	In travellers site. Special access arrangements apply. Flush cover on installation. Reinstatement of surfacing will be required.	To check groundwater quality at assumed downstream position of gasholders. Response zone detail provisional, pending review of groundwater flow.
GEO_WS210	WS	5	384522	399611	GW, response zone in MG/alluvium	Concrete/tarmac	Flush cover. Reinstatement of surfacing will be required.	In former stream channel. Response zone detail provisional, pending review of groundwater flow.
GEO_WS211	WS	5	384555	399571	None	Rough ground		Made ground expected to be deeper than could be proven in trial pit in this area. Prove depth of made ground and check contamination of ground. Response zone detail provisional, pending review of groundwater flow.
GEO_WS212	WS	5	384498	399534	None	Rough ground		Made ground expected to be deeper than could be proven in trial pit in this area. Prove depth of made ground and check contamination of ground. Response zone detail provisional, pending review of groundwater flow.
GEO_WS213	WS	5	384437	399534	None	Rough ground		Made ground expected to be deeper than could be proven in trial pit in this area. Prove depth of made ground and check

Hole	Type	Scheduled depth (m)	National Grid (provisional)		In-situ tests* and installations (response zones and depths)	Existing ground surface type	Remarks	Rationale
			Easting (m)	Northing (m)				
								contamination of ground. Response zone detail provisional, pending review of groundwater flow.
GEO_WS214	WS	5	384418	399540	None	Rough ground		To prove ground conditions along proposed access road.
GEO_WS215	WS	8	384247	399228	GW, response zone in MG/alluvium	Rough ground	Flush cover	To investigate historical subway located in this area. Position according to historical map location. Was formerly tannery, contamination possible in this location.

Planned scope of 2022 Ground Investigation

Bore ID	Type	Ground Level (mODD)	Anticipated Backhead Level (mODD)	Anticipated Depth to Backhead (m)	Rotary Bottom-on (m)	Scheduled Depth (m)	SPT (per 30cm)	Bulk Sample	Disturbed Sample	Casing	Nutting	Ground surface	Installation	Comments (see Key below for numbers in brackets)		Further Comments and design notes
BH101	Cable Percussion	41.00	25	16	N	20	14	20	20	38435	39951	Made ground	Inclinometer	Foot of slope (1) In former gas works area (8) Confirmation of rockhead (15) Inclinometer installation (17) - base level installed in rockhead		Possibly in area of refilled former meander head/cuttings - boundary of former channel
BH102	Cable Percussion	43.00	28	15	N	20	14	20	20	38427	39955	Paved - possible siltic floor slab	Inclinometer	Foot of slope (1) Adjacent former gas works area (8) Confirmation of rockhead (15) Inclinometer installation (17) - base level installed in rockhead		Close to electric cables
BH103	Cable Percussion	42.00	34	8	N	10	7	10	10	38420	39960	Made ground	Gas/GW	Foot of Slope (1) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		
BH104	Cable Percussion	41.00	28	13	N	15	10	15	15	38418	39952	Made ground	Gas/GW	Foot of slope (1) Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH105	Cable Percussion	39.80	28	12	N	15	10	15	15	38432	39953	Made ground	Gas/GW	Foot of slope (1) Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH106	Cable Percussion	31.50	27	5	N	8	6	8	8	38451	399493	Hardstanding	Gas/GW	Foot of Slope (2) Conditions adj to river and behind retaining walls (2) Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH107	Cable Percussion	31.00	25	6	N	10	7	10	10	38448	39944	Hardstanding	Gas/GW	Addressing gaps in previous GI coverage (12) GW Monitoring installation (4) Confirmation of rockhead (15)		Close to electric cables
BH108	Cable Percussion	30.00	25	5	N	8	6	8	8	38473	39939	Hardstanding	Gas/GW	Conditions adj to river and behind retaining walls (2) Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		
BH109	Cable Percussion/Rotary follow on	30.00	28	6	Yes	12	8	12	12	38463	39961	Hardstanding	Gas/GW	Conditions adj to river and behind retaining walls (2) GI at proposed bridge abutments (16) Confirmation of rockhead (15) Coring of solid strata to assist in pile design GW Monitoring installation (4)		Close to BT
BH110	Cable Percussion/Rotary follow on	31.40	30	6	Yes	12	8	12	12	38485	39962	Made ground	Gas/GW	Conditions adj to river and behind retaining walls (2) GI at proposed bridge abutments (16) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5) Coring of solid strata to assist in pile design		
BH111	Cable Percussion	45.50	31	15	N	18	18	18	18	38415	39957	Hardstanding	Gas/GW	Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		
BH112	Cable Percussion	45.00	29	16	N	20	20	20	20	38483	399518	Made ground/paving	Gas/GW	Addressing gaps in previous GI coverage (12) GW Monitoring (4) Confirmation of rockhead (15) Infiltration tests in BH/installation Required for design of entrance coffering/embankment and both retaining wall		
BH113	Cable Percussion	45.00	29	14	N	18	18	18	18	38497	399508	Made ground	Gas/GW	Baricolic adjacent to the top of the railway viaduct - to confirm soil materials Required for design of entrance coffering/embankment and both retaining wall		
BH114	Cable Percussion	43.00	29	14	N	16	16	16	16	38424	399504	Made ground	Gas/GW	Addressing gaps in previous GI coverage (12) GW Monitoring (4) Confirmation of rockhead (15) Baricolic adjacent to proposed area of regrading - to confirm soil materials Gas Monitoring installation (5)		
BH115	Cable Percussion	43.00	28	17	N	20	20	20	20	38455	399734	Made ground	Gas/GW	Foot of slope (1) In former gas works area (8) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		Inclinometers in adjacent BH101 and BH1 - need gas installation for this slope
BH120	Drilling method to be determined by contractor to suit site and anticipated ground conditions	34.00	26	8	-	10	10	10	10	38495	399757	Made ground	Gas/GW	Foot of slope (1) Along river bank (2) Conditions adj to river and behind retaining walls (2) Confirmation of rockhead (15) Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH121	Drilling method to be determined by contractor to suit site and anticipated ground conditions	35.00	32	3	-	6	6	6	6	38474	399640	Made ground	Gas/GW	Foot of slope (1) Additional geotechnical sampling in area of proposed excavations/regrading (1) GW Monitoring installation (4) Infiltration tests in BH/installation Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH122	Drilling method to be determined by contractor to suit site and anticipated ground conditions	32.50	31	2	-	6	6	6	6	38476	399588	Made ground	Gas/GW	Foot of slope (1) Along river bank (2) GW Monitoring installation (4) Gas Monitoring installation (5) Infiltration tests in BH/installation Conditions adj to river and behind retaining walls (2)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH123	Drilling method to be determined by contractor to suit site and anticipated ground conditions	31.50	28	4	-	8	8	8	8	38458	399579	Made ground	Gas/GW	Foot of slope (1) Along river bank (2) Conditions adj to river and behind retaining walls (2) Confirmation of rockhead (15) GW Monitoring installation (4) Gas Monitoring installation (5)		Access for plant/working space potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH124	Drilling method to be determined by contractor to suit site and anticipated ground conditions	29.50	28	2	-	8	8	8	8	38458	399597	Made ground	Gas/GW	Foot of slope (1) Along river bank (2) Conditions adj to river and behind retaining walls (2) GW Monitoring installation (4) Gas Monitoring installation (5) Infiltration tests in BH/installation		Access for plant/working space off possibly existing bank. Position potentially impeded by existing vegetation. Positions may need to be adjusted on site.
BH125	Drilling method to be determined by contractor to suit site and anticipated ground conditions	38.00	26	4	-	8	8	8	8	38445	399560	Hard Standing	Gas/GW	Conditions adj to river and behind retaining walls (2) Addressing gaps in previous GI coverage (12) Confirmation of rockhead (15) Infiltration tests in BH/installation		Close to electric cables
TT101	Total trench - 360 degree excavator	43.00	28	15	-	4.5	0	5	0	38436	399723	Paved - possible siltic floor slab		In former gas works area (8) Assume this low trench required		Close to electric cables
TT102	Total trench - 360 degree excavator	43.00	25	18	-	4.5	0	5	0	38440	399744	Paved - possible siltic floor slab		In former gas works area (8) Assume this low trench required		Close to electric cables
TT103	Total trench - 360 degree excavator	43.00	28	15	-	4.5	0	5	0	38462	399747	Paved - possible siltic floor slab		In former gas works area (8) Assume this low trench required		Close to electric cables
TT104	Total pit - 360 degree excavator	40.50	28	13	-	4.5	0	5	0	38424	399613	Made ground		Additional geotechnical sampling in area of proposed excavations/regrading (1) Infiltration tests in BH/installation Assume gas in direction of GI coverage (12)		
TT105	Total pit - 360 degree excavator	40.50	28	13	-	4.5	0	5	0	38480	399584	Made ground		Additional geotechnical sampling in area of proposed excavations/regrading (1)		
TT106	Total pit - 360 degree excavator	41.00	28	13	-	4.5	0	5	0	38450	399572	Made ground		Additional geotechnical sampling in area of proposed excavations/regrading (1)		
TT107	Total pit - 360 degree excavator	40.00	29	11	-	4.5	0	5	0	38465	399589	Made ground		To investigate pore recovery in BH106		
TT108	Total pit	41.00	30	11	-	3	0	3	0	38455	399640	Made ground		Potable water supply assessment (7)		
TT109	Total pit	43.00	37	6	-	3	0	3	0	38423	399768	Made ground		Potable water supply assessment (7)		
TT110	Total pit	43.00	34	9	-	3	0	3	0	38472	399711	Made ground		Potable water supply assessment (7)		
QP01	Observation pit	40.00	-	-	-	1.2	-	2	-	-	-	-	-	Investigate extent of buried former railway viaduct (18)		
QP02	Observation pit	40.00	-	-	-	1.2	-	2	-	-	-	-	-	Investigate extent of buried former railway viaduct (18)		
QP03	Observation pit	40.00	-	-	-	1.2	-	2	-	-	-	-	-	Investigate extent of buried former railway viaduct (18)		
QP04	Observation pit	40.00	-	-	-	1.2	-	2	-	-	-	-	-	Investigate extent of buried former railway viaduct (18)		
SWS Upstream	Surface water	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (9)		
SWS Midstream	Surface water	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (9)		
SWS Downstream	Surface water	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (9)		
Sediment sample Upstream	Sediment sample from river bed	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (10) Analysis to include WAC testing and hat waste on line assessment - diurnal/seasonal		
Sediment sample Mid stream	Sediment sample from river bed	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (10) Analysis to include WAC testing and hat waste on line assessment - diurnal/seasonal		
Sediment sample Downstream	Sediment sample from river bed	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (10) Analysis to include WAC testing and hat waste on line assessment - diurnal/seasonal		
Selected samples from flytipped assemblages	To be determined	-	-	-	-	-	-	-	-	-	-	-	-	Sample on three occasions (10) Analysis to include WAC testing and hat waste on line assessment - diurnal/seasonal		

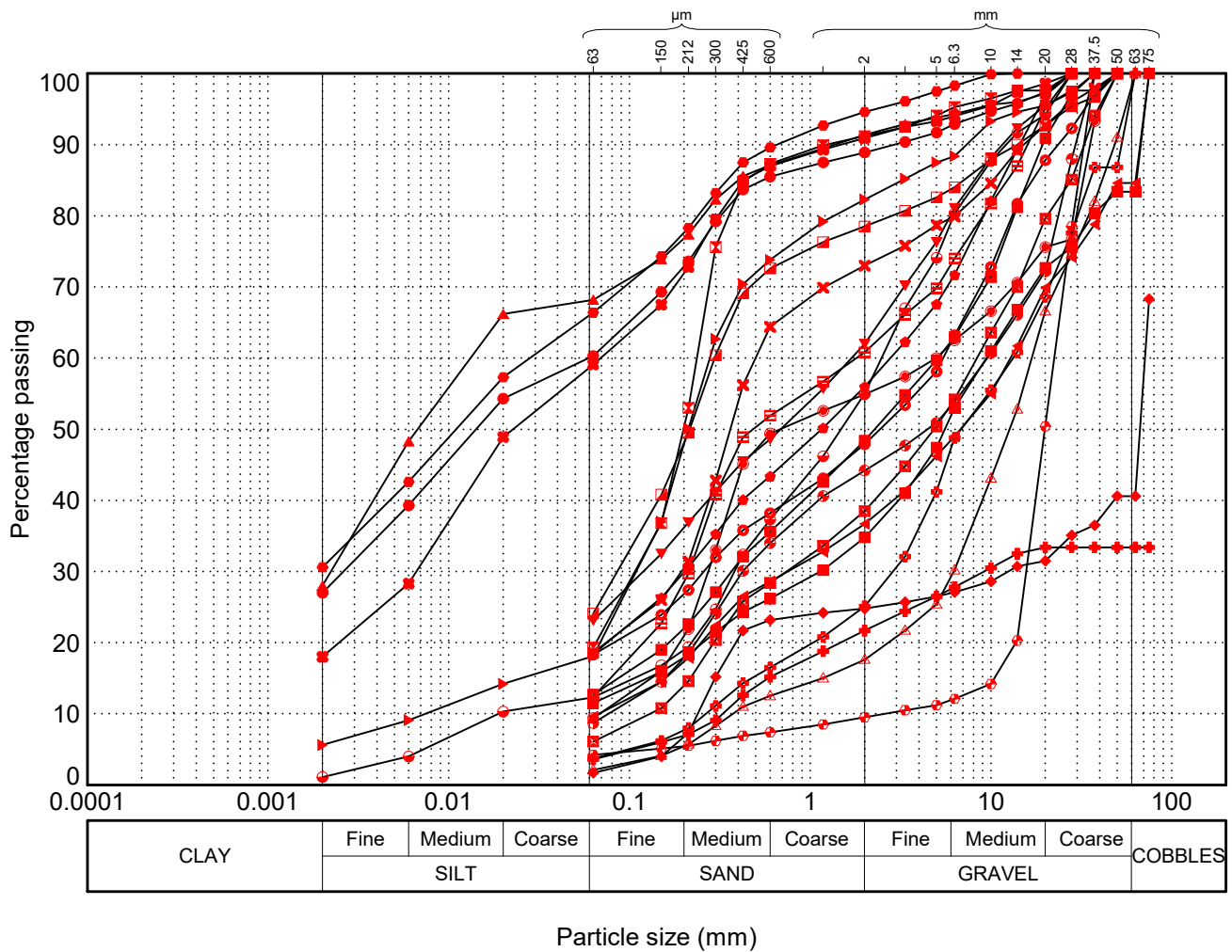
Other issues:

- 1 Needs leakability testing on selected and samples
- 2 GI contractor to inspect all Phase 1 and Phase 2 borehole installation for serviceability for on-going gas and groundwater monitoring and report to Arnp. Arnp will then confirm GW and gas monitoring and sampling requirements

Rationale:

- 1 BHs along crest and toe of slopes to validate slope stability assessments.
- 2 BHs in WS beds along river to confirm conditions adjacent to existing retaining walls and to provide further data on alluvial deposits.
also assist with risk assessment (river) and regarding river banks.
- 3 BHs to provide further data on depth to engineering rockhead to fill data gaps - not sure we can do anything - main gap is in St Cat's Wood - only hand held! WS across place - not building anything - except bridge abutments (see 15)
- 4 Selected BHs will be provided with gas monitoring installations (to complement existing serviceable installations)
a) with monitoring to confirm hydraulic gradient across site
b) use in controlled water risk assessment and validation of slope stability assessments.
- 5 Selected BHs provided with gas monitoring installations - particularly in SW and NE of the site adjacent to existing former landfill sites (to complement existing serviceable installations)
a) with monitoring to confirm ground gas conditions
- 6 Sampling of groundwater from installations for analysis plus leakability testing of soil samples
also use in controlled water risk assessment
- 7 Sampling of shallow made ground close main potable water corridor with relevant analysis (total gas)
also allow requirements for potable supply pipe to be determined.
- 8 Confirmatory GI in area of gas works (trial pits)
also satisfy likely EA requirements - following vegetation clearance in this area
- 9 Surface water sampling from river (to complement existing sampling under River Works contract)
also use in controlled water risk assessment.
- 10 Sediment sampling and analysis from river (to complement existing sampling under River Works contract)
also use to determine waste disposal options.
- 11 Additional geotechnical sampling and testing in areas of proposed excavation to confirm stability of cuttings for re-use (Precaster tests, moisture content, PSD, Atterberg, WAC and Hat Waste on Line)
- 12 Additional GI to fill spatial gaps in coverage (e.g. Cramelton Ditches - post demolition/Establishing Works)
- 13 Confirmation of rockhead in cut
- 16 BHs at proposed bridge abutment locations.
- 17 Assess current stability of slopes using inclinometers
- 18 Investigate extent of railway viaduct, that is part of the site may be buried

Appendix B- Geotechnical data charts



- Made Ground (MG)
- 01_BH101, 41.9mOD
- 01_BH102, 42.4mOD
- ▲ 01_BH102, 41.7mOD
- ✱ 01_BH103, 40.1mOD
- 01_BH104, 39.1mOD
- ▼ 01_BH104, 34.1mOD
- ✱ 01_BH106, 39.2mOD
- 01_BH107, 41.1mOD
- ▲ 01_BH109, 31.1mOD
- ▼ 01_BH110, 28.2mOD
- ✱ 01_BH112, 31.6mOD
- 01_WS102, 31.0mOD
- 01_WS104, 30.3mOD
- ◆ 01_WS105, 28.9mOD
- 01_WS105A, 27.2mOD
- ✱ 01_WS106, 30.3mOD
- 01_TP101, 42.7mOD
- ✱ 01_TP104, 42.3mOD
- 01_TP109, 40.4mOD
- 01_TP112, 40.0mOD
- 01_TP115, 39.7mOD
- ▲ 01_TP119, 31.2mOD
- ✱ 01_TP121, 29.5mOD
- ◆ 01_TP124, 38.7mOD

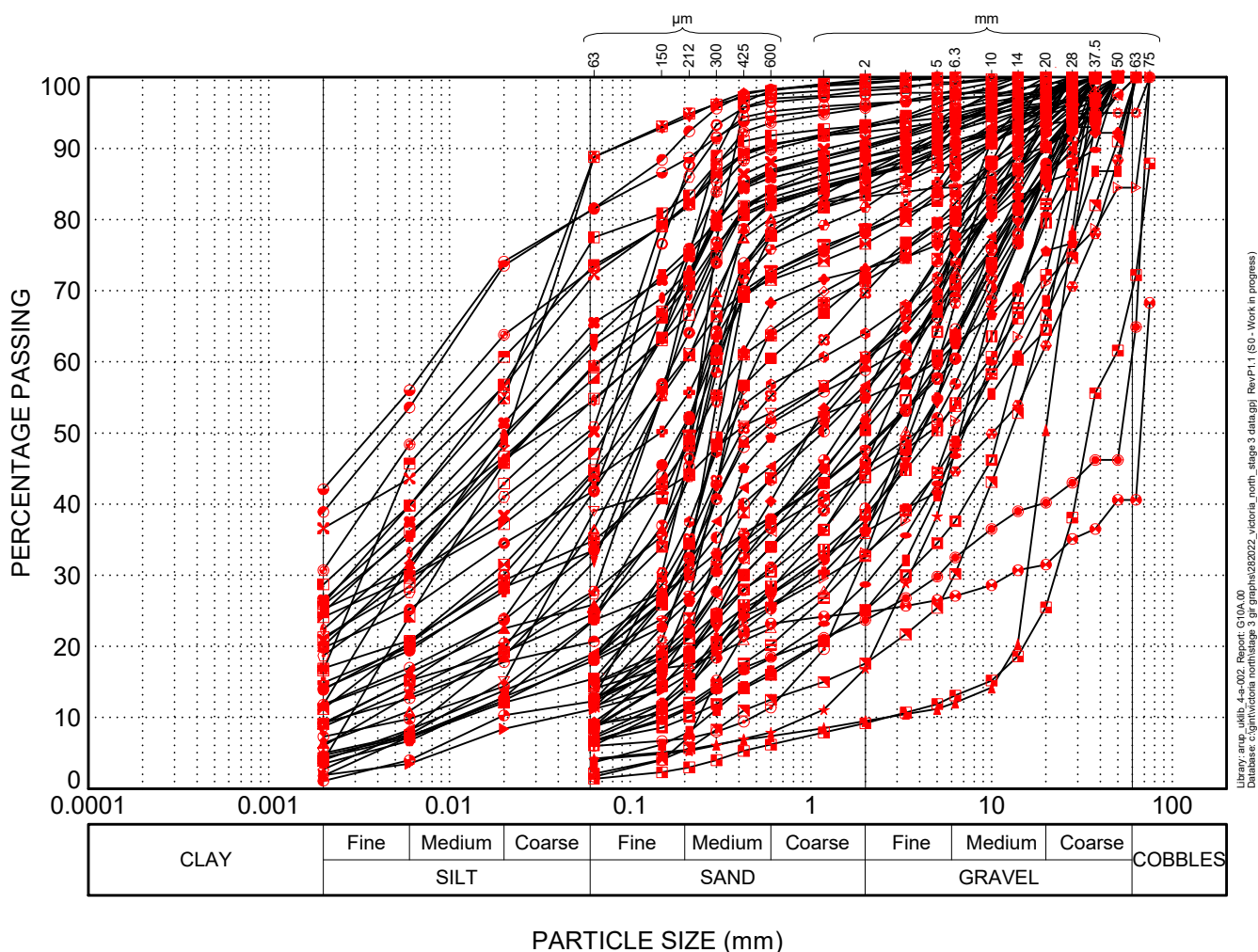
ARUP

Job Title
Victoria North

Figure Title
Particle size distribution
MADE GROUND
2019 GI Data

Job No
282022

Figure No
Chart 1A

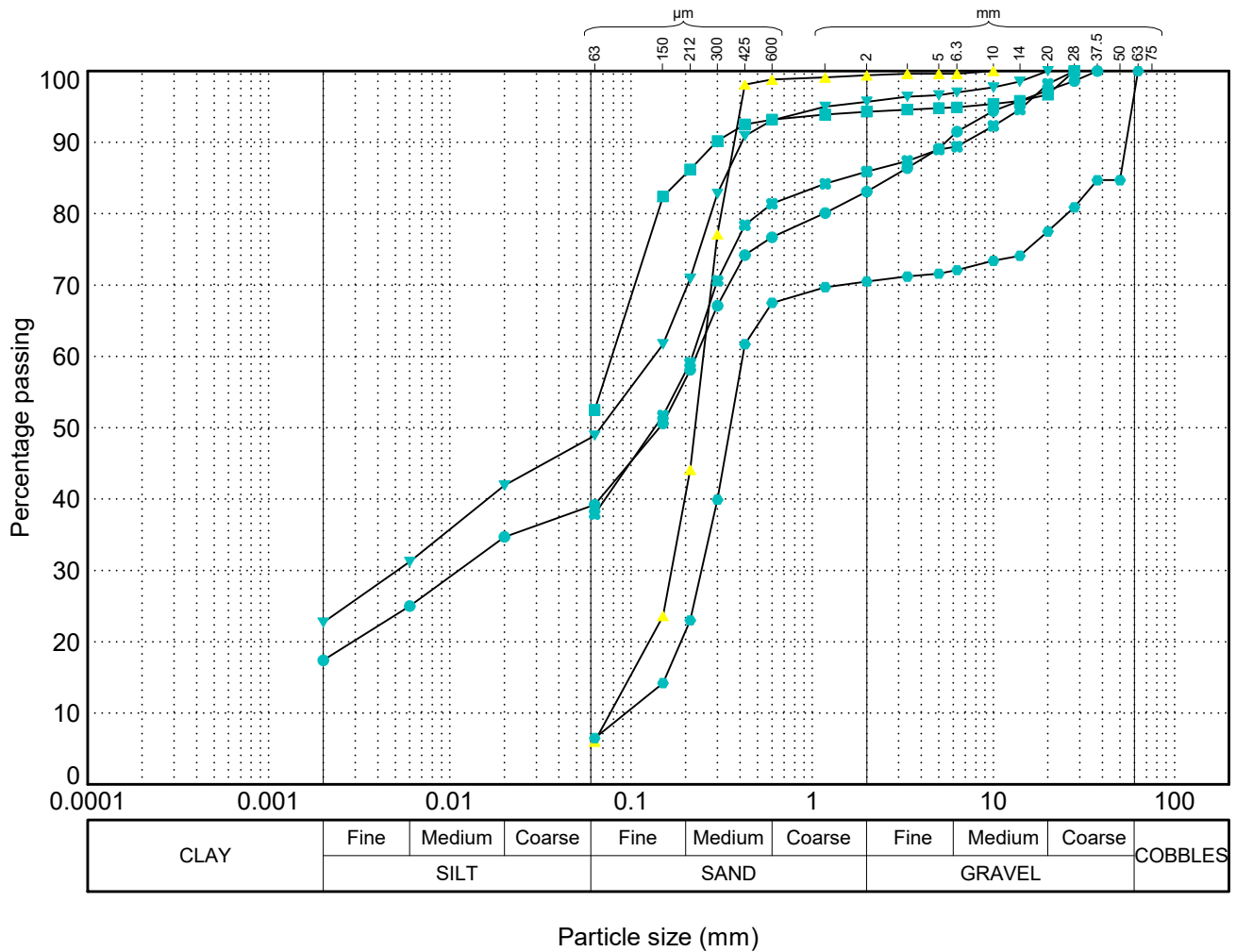


- Made Ground (MG)
 ● GEO_BH202, 42.0mOD
 ■ GEO_BH204, 42.6mOD
 ▲ GEO_BH204, 39.8mOD
 ✖ GEO_BH204, 33.1mOD
 ● GEO_BH207, 41.1mOD
 ▼ GEO_BH207, 35.6mOD
 + GEO_BH207, 28.1mOD
 ■ GEO_BH208, 39.2mOD
 ▲ GEO_BH208, 31.2mOD
 ▴ GEO_BH211A, 39.4mOD
 ▽ GEO_BH211A, 33.4mOD
 ● GEO_BH214A, 28.5mOD
 + GEO_BH214A, 27.5mOD
 ◆ GEO_BH215, 43.7mOD
 ■ GEO_BH201, 42.6mOD
 + GEO_BH203, 40.5mOD
 + GEO_BH203, 38.9mOD
 ✖ GEO_BH203, 37.9mOD
 ● GEO_BH205, 41.1mOD
 ■ GEO_BH209, 40.9mOD
 ● GEO_BH209, 39.2mOD
 ▲ GEO_BH210, 38.0mOD
 ✖ GEO_BH212, 25.9mOD
 ● 01_WS102, 31.0mOD
 ■ 01_WS104, 30.3mOD
 ● 01_WS105, 28.9mOD
 ● 01_WS105A, 27.2mOD
 ■ 01_WS106, 30.3mOD
 ● GEO_WS201, 42.6mOD
 ● GEO_WS202, 41.1mOD
 ■ GEO_WS203A, 31.7mOD
 ■ GEO_WS203A, 30.5mOD
 ● GEO_WS205, 41.3mOD
 ◆ GEO_WS206, 31.7mOD
 ✖ GEO_WS207, 41.1mOD
 + GEO_WS208, 27.0mOD
 ▴ GEO_WS209, 29.6mOD
 ■ GEO_WS210, 40.1mOD
 ★ GEO_WS211, 39.4mOD
 ● GEO_WS212, 39.4mOD
 ■ GEO_WS213, 39.3mOD
 ● GEO_WS214, 39.2mOD
 ▲ 01_TP101, 42.7mOD
 ■ 01_TP104, 42.3mOD
 ● 01_TP109, 40.4mOD
 ■ 01_TP112, 40.0mOD
 ● 01_TP115, 39.7mOD
 ▴ 01_TP119, 31.2mOD
 ● 01_TP121, 29.5mOD
 ● 01_TP124, 38.7mOD
 ■ GEO_TP201, 42.9mOD
 ● GEO_TP202, 42.4mOD
 ✖ GEO_TP203, 42.3mOD
 ▴ GEO_TP203, 40.3mOD
 ● GEO_TP204, 41.1mOD
 ■ GEO_TP204, 39.1mOD
 ◆ GEO_TP205, 40.0mOD
 ▼ GEO_TP206A, 41.0mOD
 ● GEO_TP206A, 38.0mOD
 ▲ GEO_TP207, 42.3mOD
 ■ GEO_TP207, 40.3mOD
 ● GEO_TP208, 38.0mOD
 ● GEO_TP209, 42.2mOD
 ▴ GEO_TP210, 41.5mOD
 ● GEO_TP211, 39.6mOD
 ● GEO_TP212, 41.0mOD
 ▴ GEO_TP212, 39.0mOD
 ● GEO_TP213, 42.3mOD
 ▼ GEO_TP213, 41.3mOD
 ■ GEO_TP214, 39.2mOD
 ● GEO_TP214, 37.2mOD
 ● GEO_TP215, 39.3mOD
 ✖ GEO_TP216, 39.8mOD
 ● GEO_TP216, 37.8mOD
 ● GEO_TP217, 39.3mOD
 ● GEO_TP217, 38.3mOD
 ▴ GEO_TP218, 39.5mOD
 ▴ GEO_TP218, 37.5mOD
 ✖ GEO_TP219, 29.7mOD
 ● GEO_TP219, 27.7mOD

MADE GROUND - particle size distribution 2021 GI Data

ARUP

 Job Title
 Victoria North
 Chart 1B



- Alluvium (ALV)
- Glacial Till Deposits (GTD)
- 01_BH104, 31.1mOD
- 01_BH105, 37.2mOD
- ▲ 01_WS105A, 25.2mOD
- ✱ 01_TP101, 41.7mOD
- 01_TP104, 41.3mOD
- ▼ 01_TP108, 40.7mOD

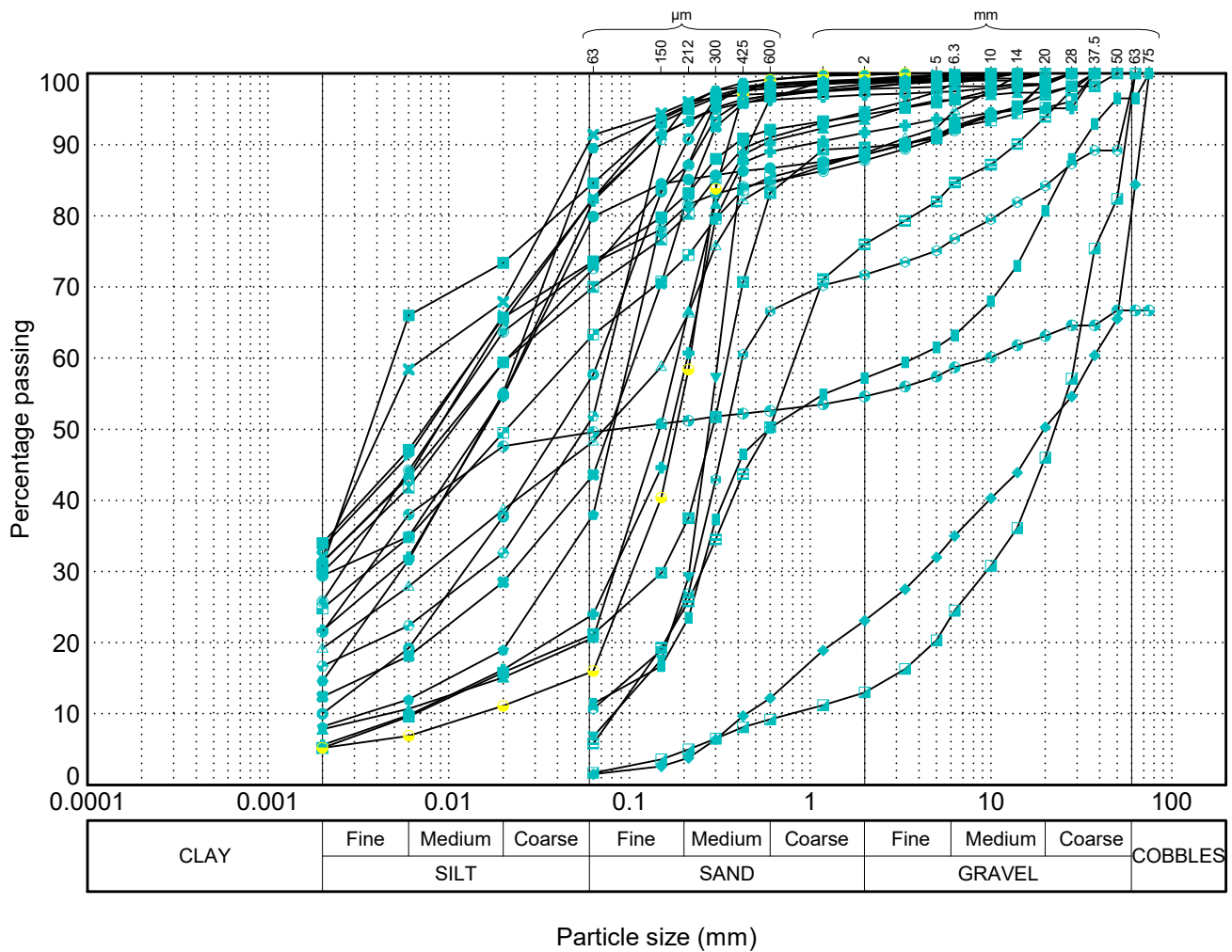
ARUP

Job Title
Victoria North

Figure Title
Particle size distribution
SUPERFICIAL DEPOSITS
2019 GI Data

Job No
282022

Figure No
Chart 1C



Library: arup_lib_4-a-002 Report: G10A.00 Database: C:\gnitvictoria\normalstage 3 gr graphs\282022_victoria_north_stage 3 data.gpi Rev:P1.1 (S0 - Work in progress)

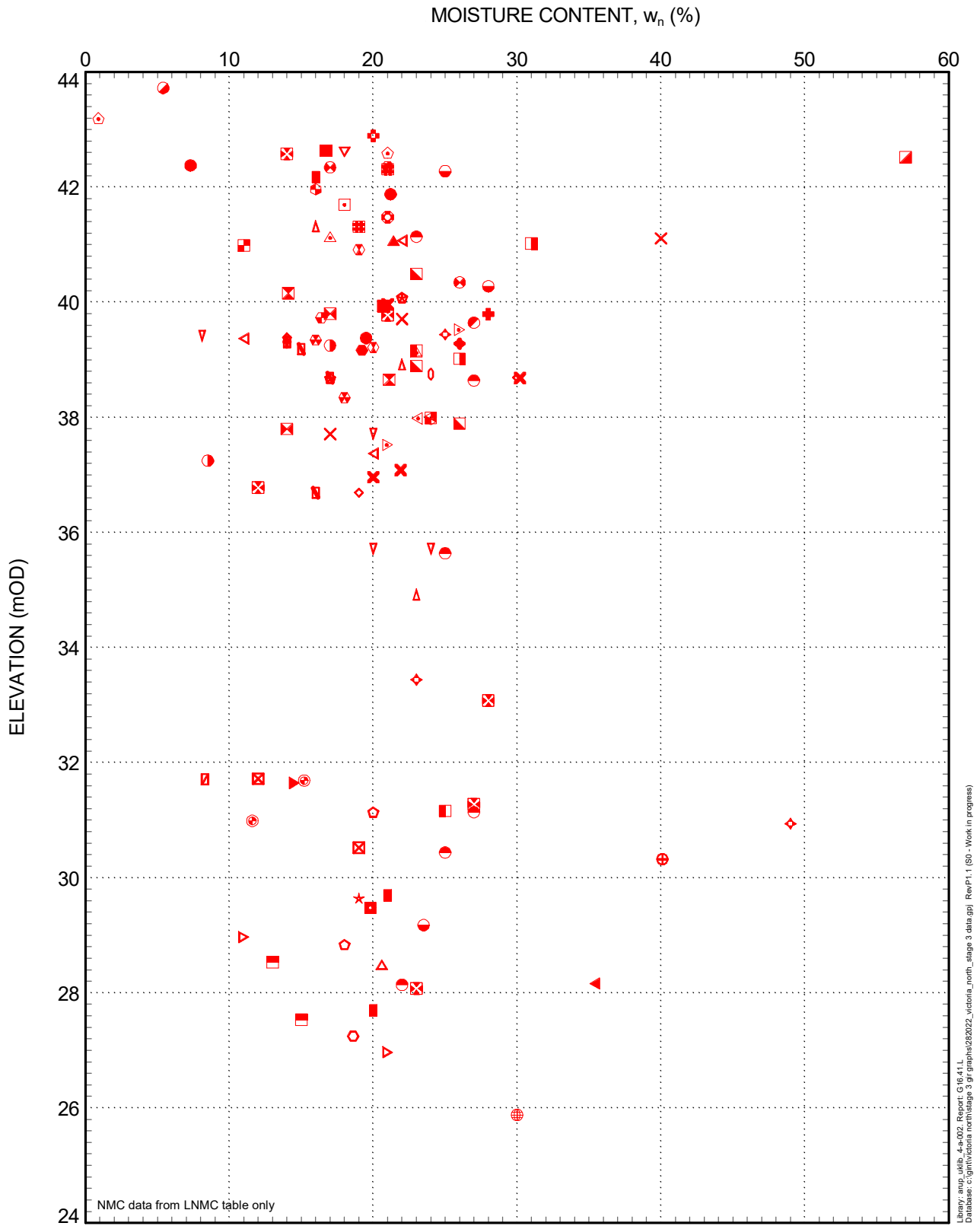
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Job Title
Victoria North

Figure Title
Particle size distribution
SUPERFICIAL DEPOSITS
2021 GI Data

Job No
282022

Figure No
Chart 1D



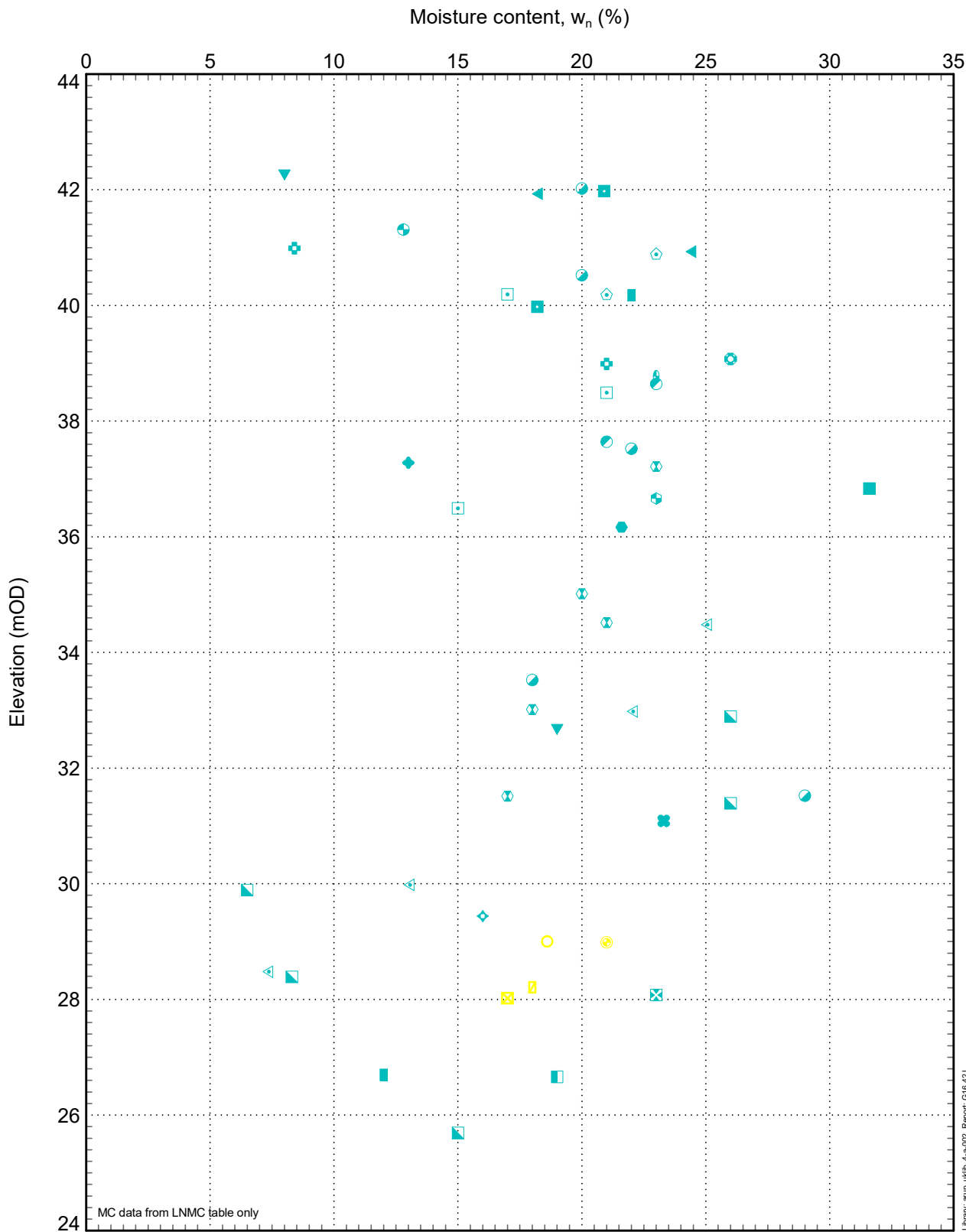
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| ■ Made Ground (MG) | □ GEO_BH206 | ⊙ 01_WS101 | ▷ GEO_WS208 | ✕ 01_TP124 | ⊗ GEO_TP210 |
| ● 01_BH101 | ⊙ GEO_BH207 | △ 01_WS104 | ★ GEO_WS209 | ⊕ GEO_TP201 | ⊙ GEO_TP211 |
| ■ 01_BH102 | ⊙ GEO_BH208 | ◇ 01_WS105A | ⊕ GEO_WS210 | ⊕ GEO_TP202 | ⊙ GEO_TP212 |
| ▲ 01_BH103 | ◇ GEO_BH211A | ⊕ 01_WS106 | ▽ GEO_WS211 | ⊕ GEO_TP203 | ⊙ GEO_TP213 |
| ● 01_BH105 | ⊙ GEO_BH214A | ▽ GEO_WS201 | ◇ GEO_WS212 | ⊙ GEO_TP204 | ⊙ GEO_TP214 |
| ⊕ 01_BH107 | ⊙ GEO_BH215 | ◁ GEO_WS202 | ■ GEO_WS213 | △ GEO_TP205 | ⊙ GEO_TP215 |
| ■ 01_BH109 | ⊙ GEO_BH201 | ⊕ GEO_WS203A | 0 GEO_WS213A | ✕ GEO_TP206A | ⊙ GEO_TP216 |
| ▲ 01_BH110 | ⊙ GEO_BH203 | ⊕ GEO_WS204 | ■ GEO_WS214 | ⊕ GEO_TP207 | ⊙ GEO_TP217 |
| ▼ 01_BH112 | ⊙ GEO_BH209 | △ GEO_WS205 | ⊕ 01_TP106 | ⊕ GEO_TP208 | ⊙ GEO_TP218 |
| ⊕ GEO_BH202 | ⊙ GEO_BH210 | ⊕ GEO_WS206 | ⊕ 01_TP112 | ⊕ GEO_TP209 | ⊙ GEO_TP219 |
| ✕ GEO_BH204 | ⊙ GEO_BH212 | ✕ GEO_WS207 | ⊙ 01_TP121 | | |

Made Ground - Natural moisture content

ARUP

Job Title
Victoria North

282022 - Chart 2A



- Alluvium (ALV)
- Glacial Till Deposits (GTD)
- 01_BH102
- ✱ 01_BH104
- 01_BH105
- ▼ 01_BH106
- ⊕ GEO_BH202
- ⊗ GEO_BH204
- GEO_BH206
- GEO_BH208
- ◆ GEO_BH211A
- GEO_BH215
- ◇ GEO_BH201
- GEO_BH203

- ⊕ GEO_BH205
- ⊗ GEO_BH209
- ◁ GEO_BH210
- ⊕ 01_WS101
- 01_WS102
- ⊗ GEO_WS203A
- ◻ GEO_WS206
- ▼ 01_TP101
- 01_TP103
- ◁ 01_TP104
- ⊕ 01_TP108
- ⊗ GEO_TP201
- GEO_TP209
- ⊕ GEO_TP210
- GEO_TP211

- ◆ GEO_TP215
- GEO_TP219

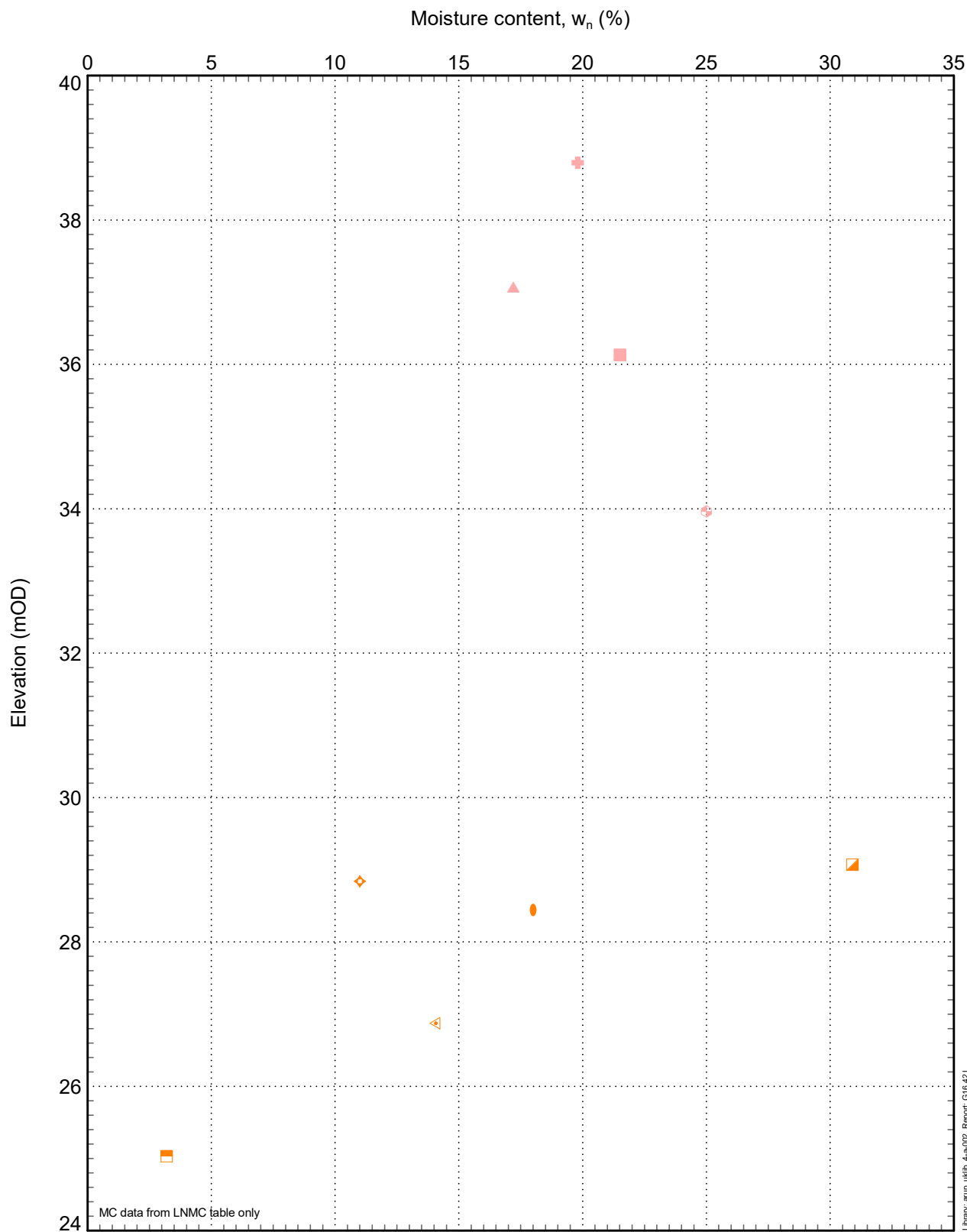
ARUP

Job Title
Victoria North

Figure Title
Natural moisture content
SUPERFICIAL DEPOSITS

Job No
282022

Figure No
Chart 2B



- Chester Formation (CHES)
- Manchester Marls Formation (MM)
- 01_BH102
- ▲ 01_BH103
- ✱ 01_BH107
- ◆ GEO_BH202
- ◆ GEO_BH211A
- GEO_BH213
- GEO_BH214A
- ▲ GEO_BH210
- 01_TP120

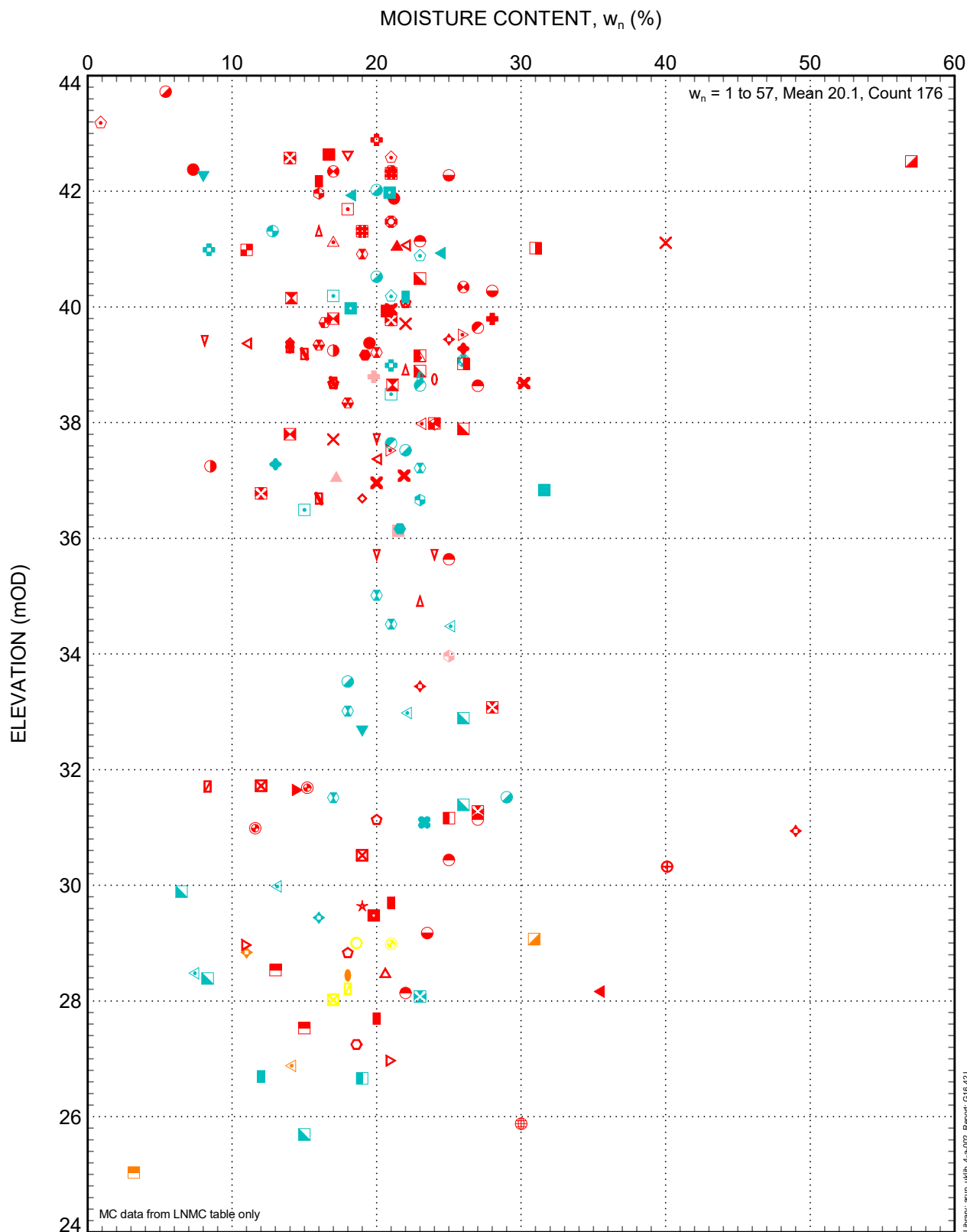
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Job Title
Victoria North

Figure Title
Natural moisture content
BEDROCK

Job No
282022

Figure No
Chart 2C



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 Range filter: None

■ Made Ground (MG)
 ■ Alluvium (ALV)
 ■ Glacial Till Deposits (GTD)
 ■ Chester Formation (CHES)
 ■ Manchester Marls Formation (MM)
 ■ Unknown
 ● 01_BH101
 ■ 01_BH102

▲ 01_BH103
 ■ 01_BH104
 ● 01_BH105
 ▼ 01_BH106
 + 01_BH107
 ■ 01_BH109
 ▲ 01_BH110
 ▼ 01_BH112
 ● GEO_BH202
 ■ GEO_BH204
 □ GEO_BH206

● GEO_BH207
 ■ GEO_BH208
 ◆ GEO_BH211A
 ● GEO_BH213
 ■ GEO_BH214A
 ● GEO_BH215
 ◆ GEO_BH201
 ■ GEO_BH203
 ● GEO_BH205
 ◆ GEO_BH209
 ▲ GEO_BH210

● GEO_BH212
 ● 01_WS101
 ○ 01_WS102
 △ 01_WS104
 ○ 01_WS105A
 ⊕ 01_WS106
 ▼ GEO_WS201
 ▲ GEO_WS202
 ■ GEO_WS203A
 ○ GEO_WS204
 ▲ GEO_WS205

■ GEO_WS206
 X GEO_WS207
 ► GEO_WS208
 ★ GEO_WS209
 ● GEO_WS210
 ▼ GEO_WS211
 ◆ GEO_WS212
 ■ GEO_WS213
 ○ GEO_WS213A
 ■ GEO_WS214
 ▼ 01_TP101

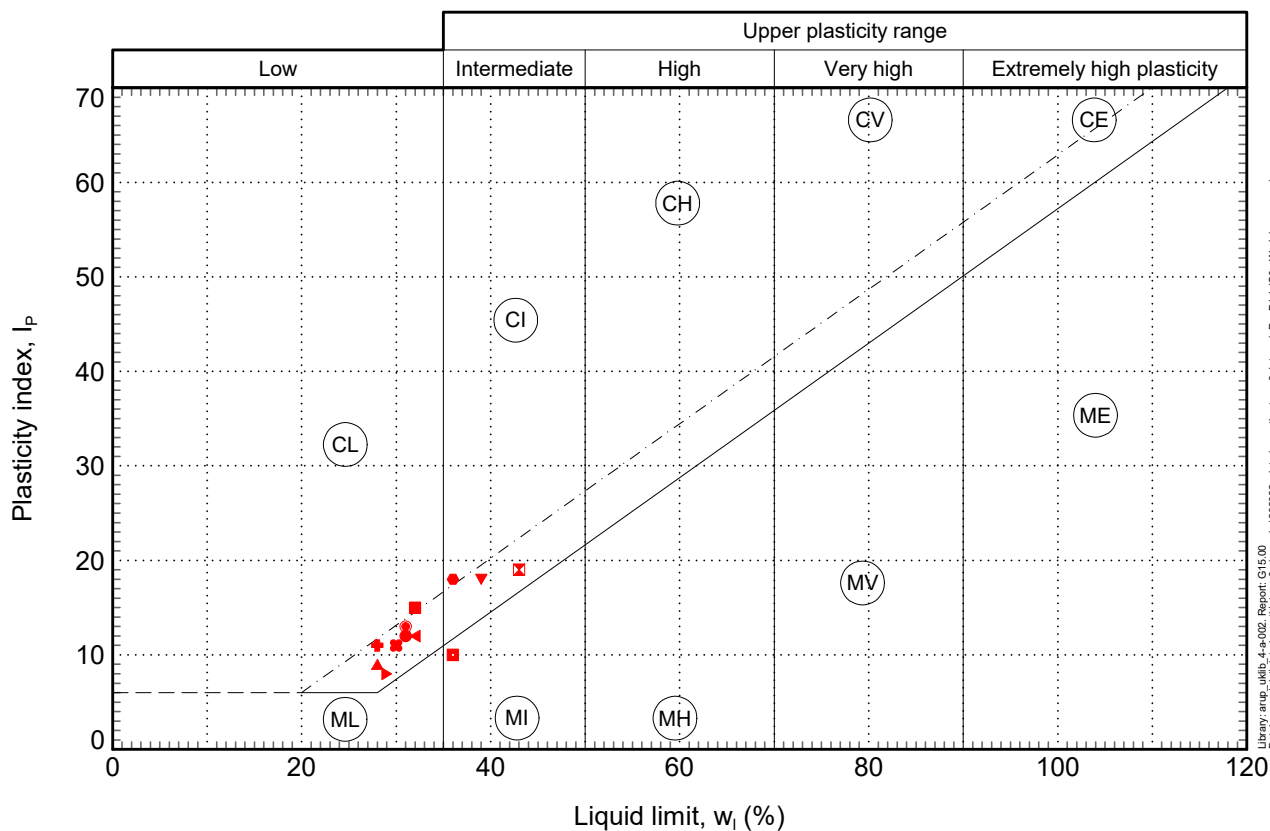
■ 01_TP103
 ▲ 01_TP104
 ■ 01_TP106
 ● 01_TP108
 ● 01_TP112
 ■ 01_TP120
 ● 01_TP121
 X 01_TP124
 ● GEO_TP201
 ● GEO_TP202
 ■ GEO_TP202C

All Formations - Natural moisture content

ARUP

Job Title
Victoria North

282022 - Chart 2D



Library: C:\gint\data\north\stage 3\data\api RevP1.1 (SO - Work in progress)
 User: J. Tyer, 4/10/2022, Report: C15.01
 Database: C:\gint\data\north\stage 3\data\api

- Made Ground (MG)
- 01_BH101, 41.9mOD
- 01_BH101, 39.4mOD
- ▲ 01_BH102, 42.6mOD
- ✱ 01_BH102, 39.9mOD
- 01_BH103, 41.1mOD
- ▼ 01_BH107, 39.8mOD
- ✱ 01_BH109, 29.5mOD
- 01_BH110, 28.2mOD
- ▲ 01_WS104, 28.5mOD
- ▼ 01_WS105A, 27.2mOD
- ✱ 01_WS106, 30.3mOD
- 01_TP124, 37.1mOD

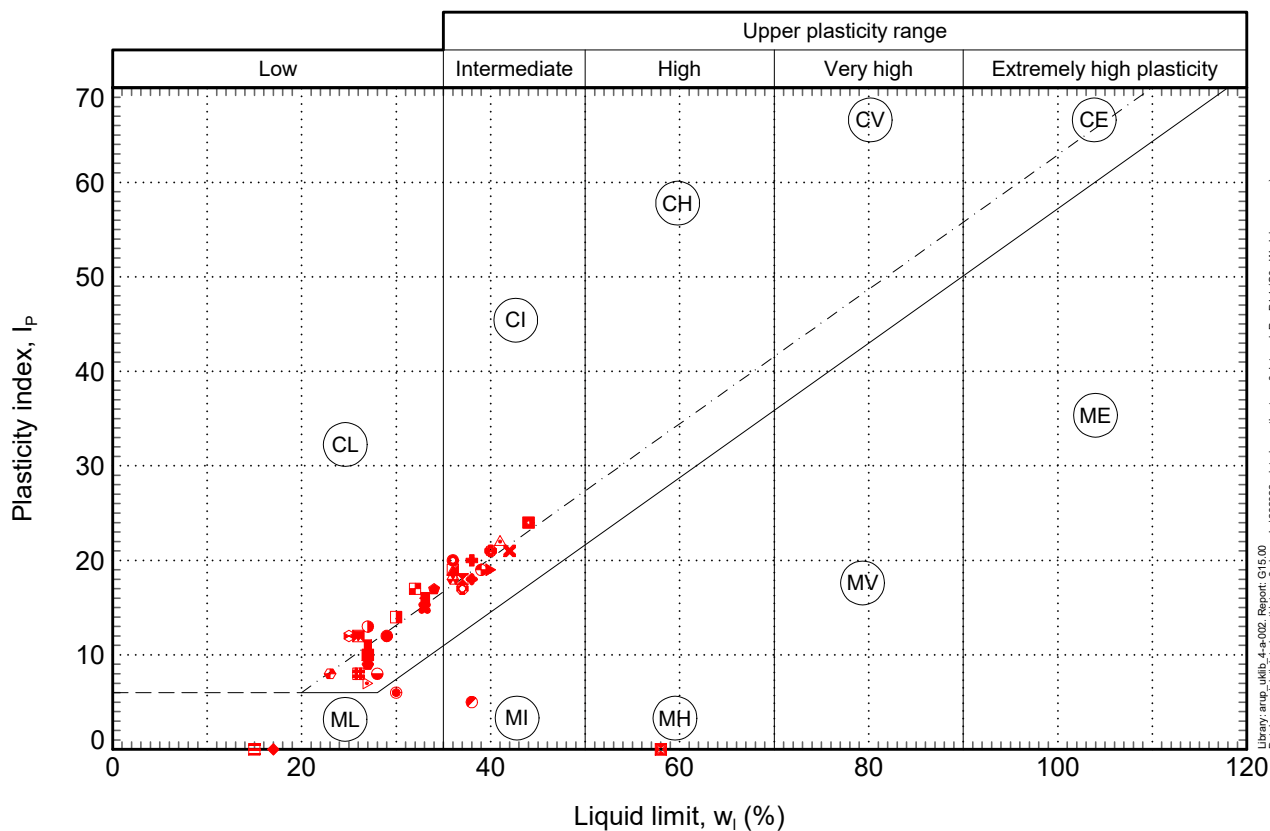
ARUP

Job Title
Victoria North

Figure Title
Plasticity chart
MADE GROUND
2019 GI data

Job No
282022

Figure No
Chart 3A



Library: arup, path: 4-a-003, Report: C15.01
Database: C:\gnivictoria\northstage-3-gr-graphics\282022_victoria_north_stage-3\data\api RevP1.1 (SO - Work in progress)

- | | | |
|-----------------------|-----------------------|----------------------|
| ■ Made Ground (MG) | ◆ GEO_WS208, 29.0mOD | ⊗ GEO_TP211, 39.6mOD |
| ● GEO_BH202, 42.0mOD | ≡ GEO_WS208, 27.0mOD | ⊙ GEO_TP212, 41.0mOD |
| ■ GEO_BH204, 39.8mOD | ⊕ GEO_WS210, 40.1mOD | ▣ GEO_TP213, 42.3mOD |
| ▲ GEO_BH204, 33.1mOD | ⊖ GEO_WS214, 39.2mOD | ▤ GEO_TP213, 41.3mOD |
| ✱ GEO_BH203, 40.5mOD | ⊗ GEO_TP202C, 42.5mOD | ⊙ GEO_TP214, 39.2mOD |
| ● GEO_BH203, 38.9mOD | ⊙ GEO_TP203, 42.3mOD | ◆ GEO_TP216, 39.8mOD |
| ▼ GEO_BH203, 37.9mOD | ▣ GEO_TP203, 40.3mOD | ◆ GEO_TP216, 37.8mOD |
| ⊕ GEO_BH209, 40.9mOD | ● GEO_TP204, 41.1mOD | ⊗ GEO_TP217, 39.3mOD |
| ▣ GEO_BH209, 39.2mOD | △ GEO_TP204, 39.1mOD | ▷ GEO_TP217, 38.3mOD |
| ▲ GEO_BH212, 25.9mOD | ✱ GEO_TP205, 40.0mOD | ■ GEO_TP218, 37.5mOD |
| ▶ GEO_WS202, 41.1mOD | ● GEO_TP206A, 38.0mOD | |
| ⊗ GEO_WS203A, 30.5mOD | ▣ GEO_TP207, 42.3mOD | |
| ● GEO_WS204, 31.1mOD | ⊙ GEO_TP207, 40.3mOD | |
| ⊙ GEO_WS207, 41.1mOD | ⊙ GEO_TP208, 38.0mOD | |
| | ■ GEO_TP210, 41.5mOD | |

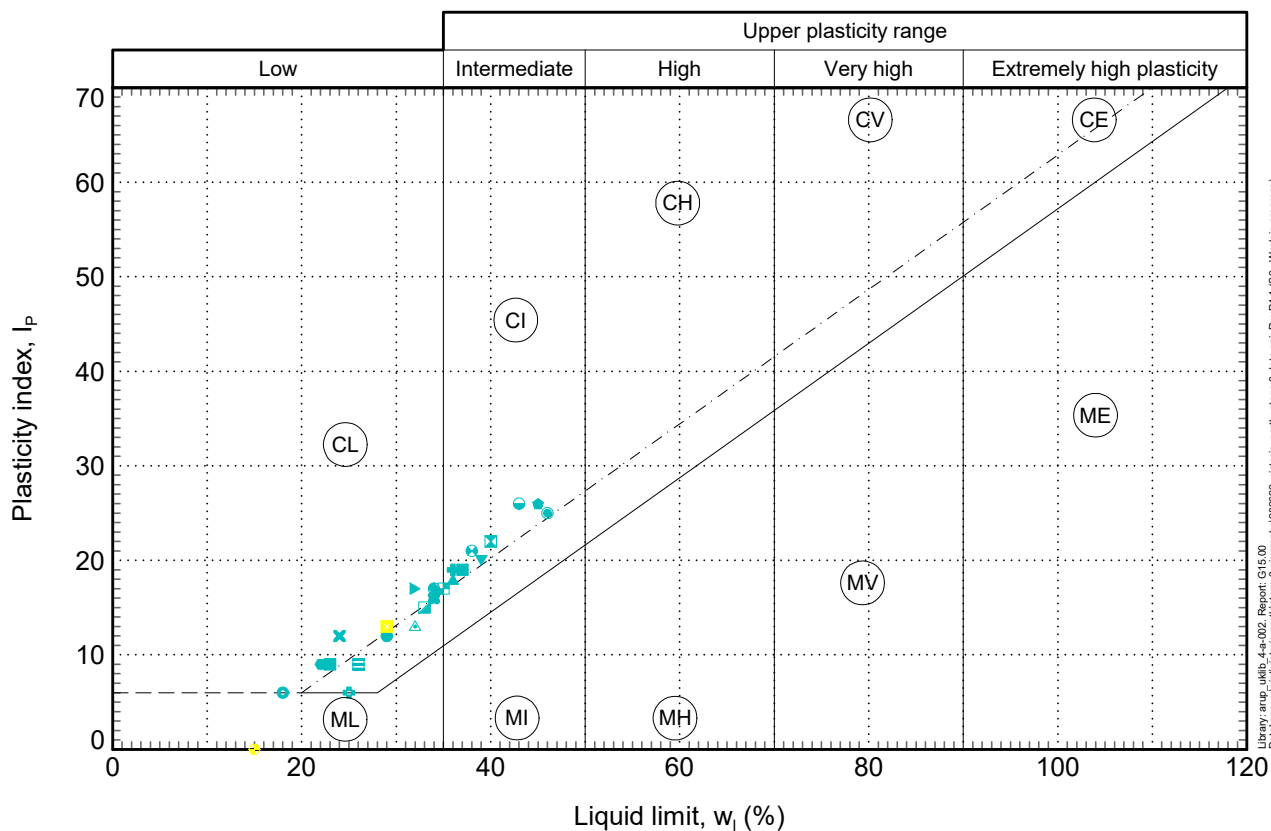
ARUP

Job Title
Victoria North

Figure Title
Plasticity chart
MADE GROUND
2021 GI data

Job No
282022

Figure No
Chart 3B



Library: arup, with 4.4.2022, Report: G15.00
Database: C:\gnt\vic\vicoria_north\stage 3\gr\graphs\282022_vicoria_north_stage 3\data/gpi RevP1.1 (S0 - Work in progress)

- Alluvium (ALV)
- Glacial Till Deposits (GTD)
- 01_BH104, 31.1mOD
- 01_BH106, 32.7mOD
- ▲ GEO_BH202, 36.7mOD
- ✱ GEO_BH204, 28.1mOD
- GEO_BH206, 38.5mOD
- ▼ GEO_BH206, 36.5mOD
- ✱ GEO_BH215, 42.0mOD
- GEO_BH215, 40.5mOD
- ▲ GEO_BH215, 37.5mOD
- ▼ GEO_BH215, 33.5mOD
- ✱ GEO_BH215, 31.5mOD
- GEO_BH201, 40.9mOD

- GEO_BH201, 40.2mOD
- ◆ GEO_BH205, 38.8mOD
- GEO_BH209, 34.5mOD
- ✱ GEO_BH210, 34.5mOD
- 01_WS102, 29.0mOD
- ✱ GEO_WS206, 28.2mOD
- 01_TP101, 42.3mOD
- 01_TP103, 42.0mOD
- 01_TP103, 40.0mOD
- ▲ 01_TP104, 40.9mOD
- ✱ GEO_TP201, 41.0mOD
- GEO_TP201, 39.0mOD
- GEO_TP210, 39.1mOD
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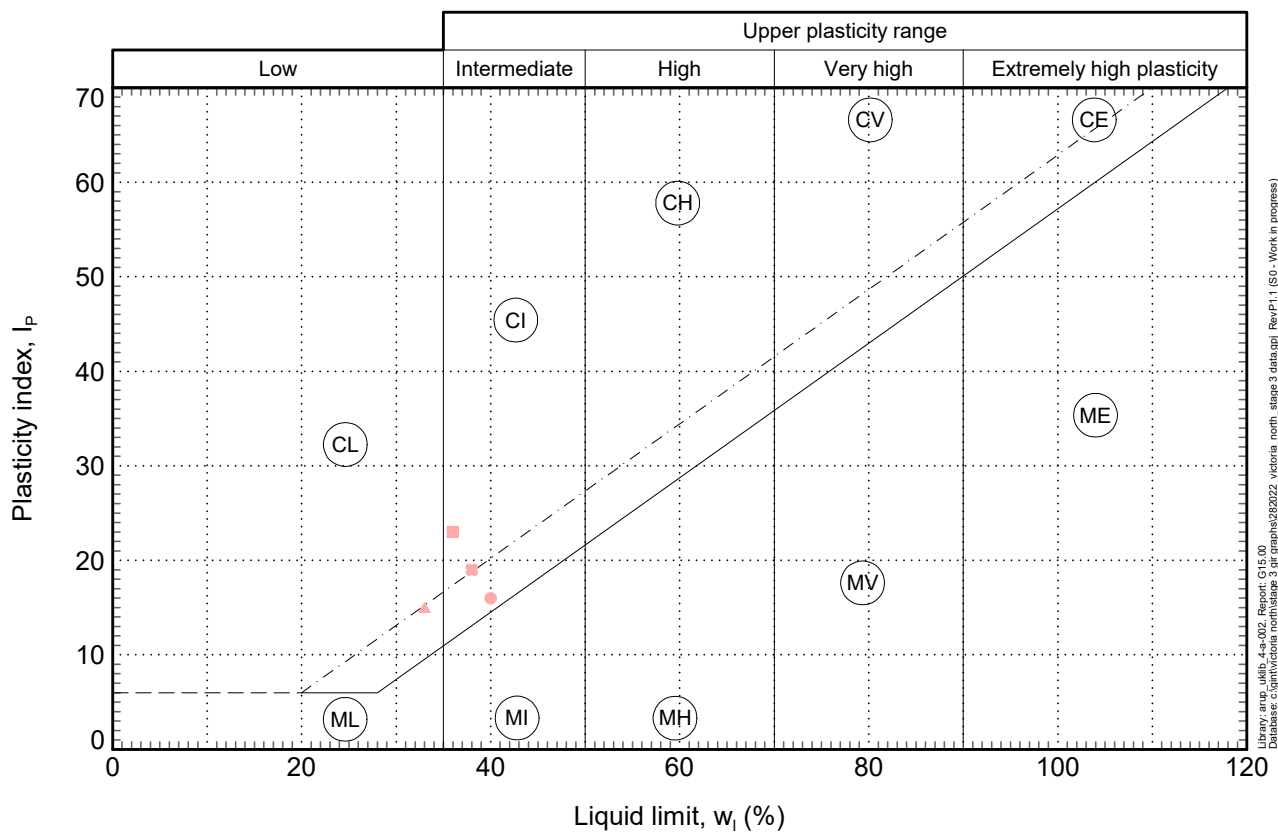
ARUP

Job Title
Victoria North

Figure Title
Plasticity chart
SUPERFICIAL DEPOSITS

Job No
282022

Figure No
Chart 3C



- Manchester Marls Formation (MM)
- 01_BH102, 36.1mOD
- 01_BH103, 37.1mOD
- ▲ 01_BH107, 38.8mOD
- ✱ GEO_BH202, 34.0mOD

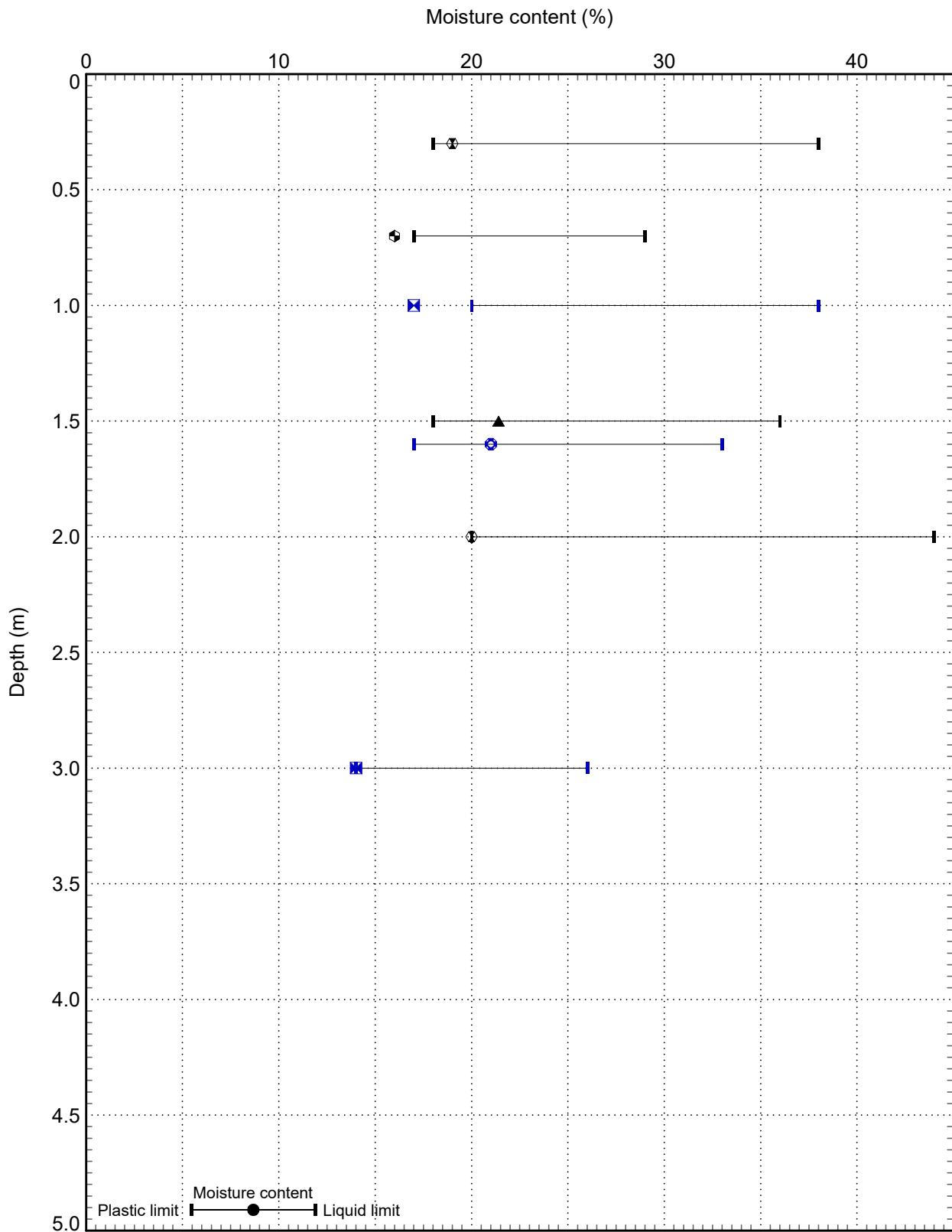
ARUP

Job Title
Victoria North

Figure Title
Plasticity chart
BEDROCK

Job No
282022

Figure No
Chart 3D



\\arup-arup-uk\fs_4-a-202_R\Borehole_G16.61.D
Database: c:\gint\vicoria north\stage 3\data\api RevP1.1 (SD - Work in progress)

- Cable percussion borehole
- Cable percussion + rotary core follow on
- Trial pit
- ▲ 01_BH103
- GEO_BH202
- GEO_BH209
- GEO_TP210
- GEO_TP216

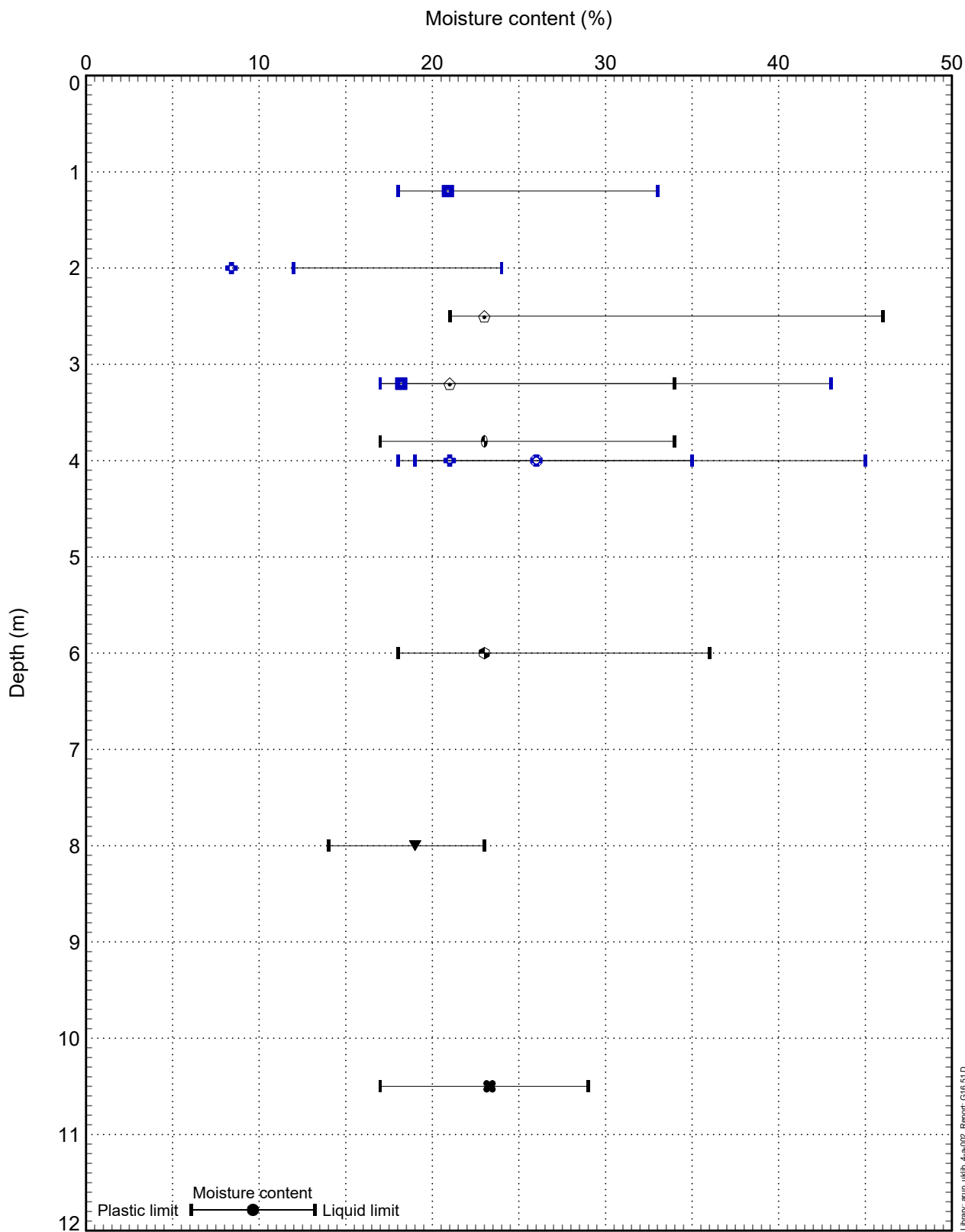
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
MADE GROUND
Redbank Plateau

Job No
282022

Figure No
Chart 3E



\\arup-arup\ukb_4-2022_R\Report_G1651.D
Database: c:\gint\vicoria north\stage 3\gr graph\282022_vicoria_north_stage 3\data.gpi RevP1.1 (SD - Work in progress)

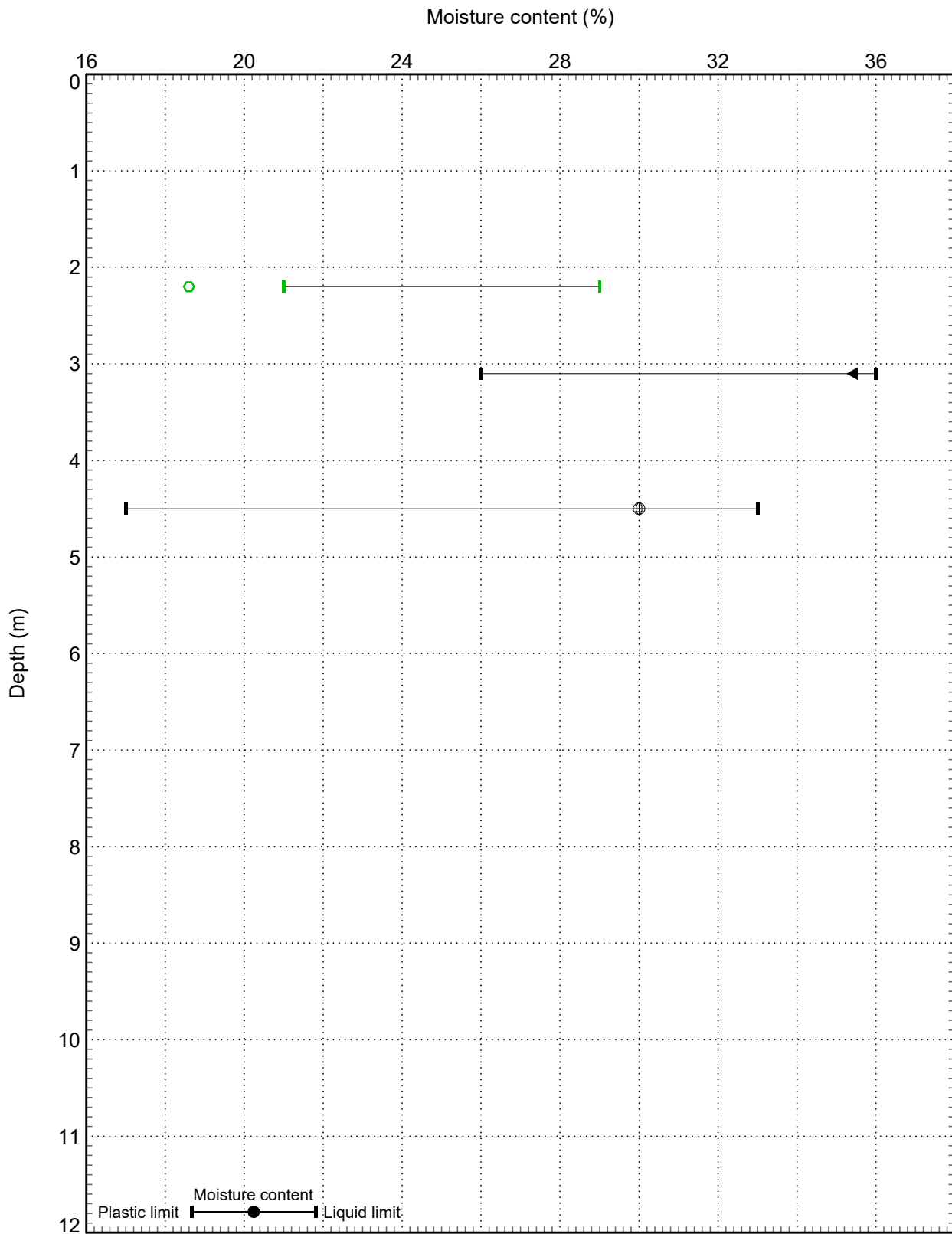
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
GLACIAL TILL DEPOSITS
Redbank Plateau

Job No
282022

Figure No
Chart 3F



Library: arup_v010_4-4-2022_Renard_C16.61.D
Database: c:\gnr\vicoria north\stage 3 data\api RevP1.1 (SD - Work in progress)

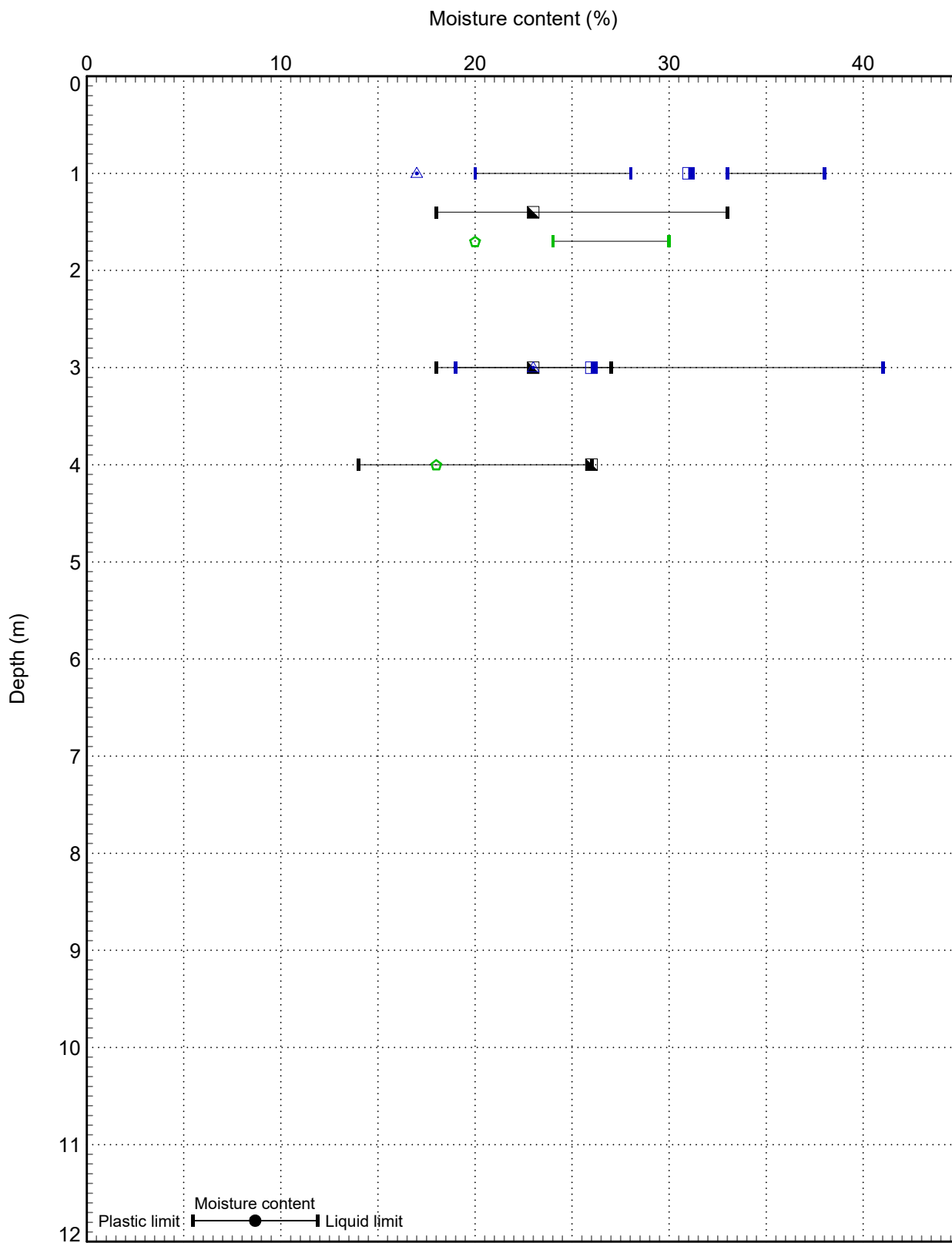
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
MADE GROUND
Redbank Viaduct

Job No
282022

Figure No
Chart 3G



\\arup-arup-uk\file_4-4-2022_R\Report_C16161D
Database: c:\grn\vicoria north\stage 3\data\api RevP1.1 (SD - Work in progress)

- Cable percussion + rotary core follow on
- Dynamic (windowless) sampler
- Trial pit
- GEO_BH203
- GEO_WS204
- GEO_TP204
- GEO_TP212

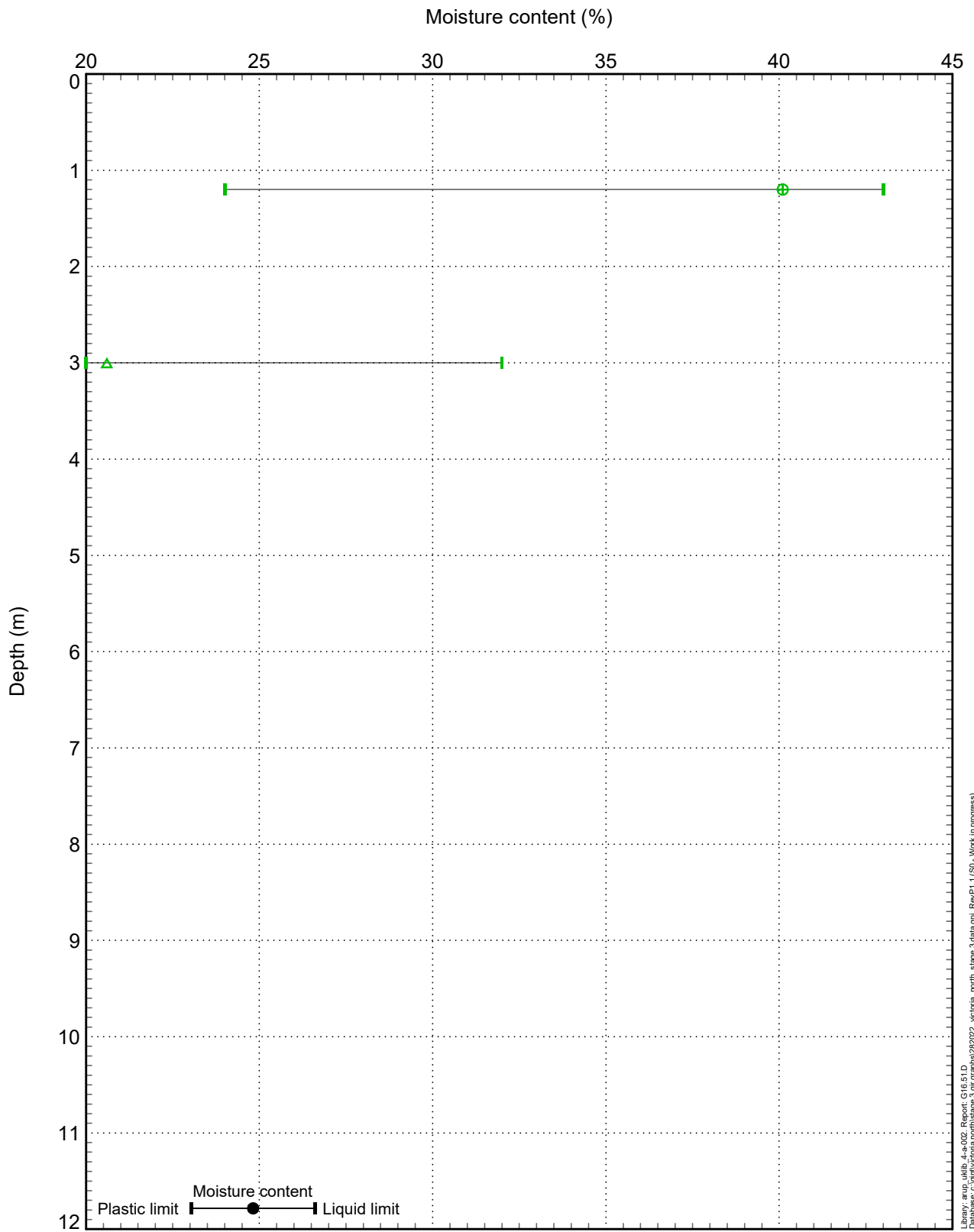
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
MADE GROUND
St Catherine's Wood

Job No
282022

Figure No
Chart 3H



- Dynamic (windowless) sampler
- △ 01_WS104
- ⊕ 01_WS106

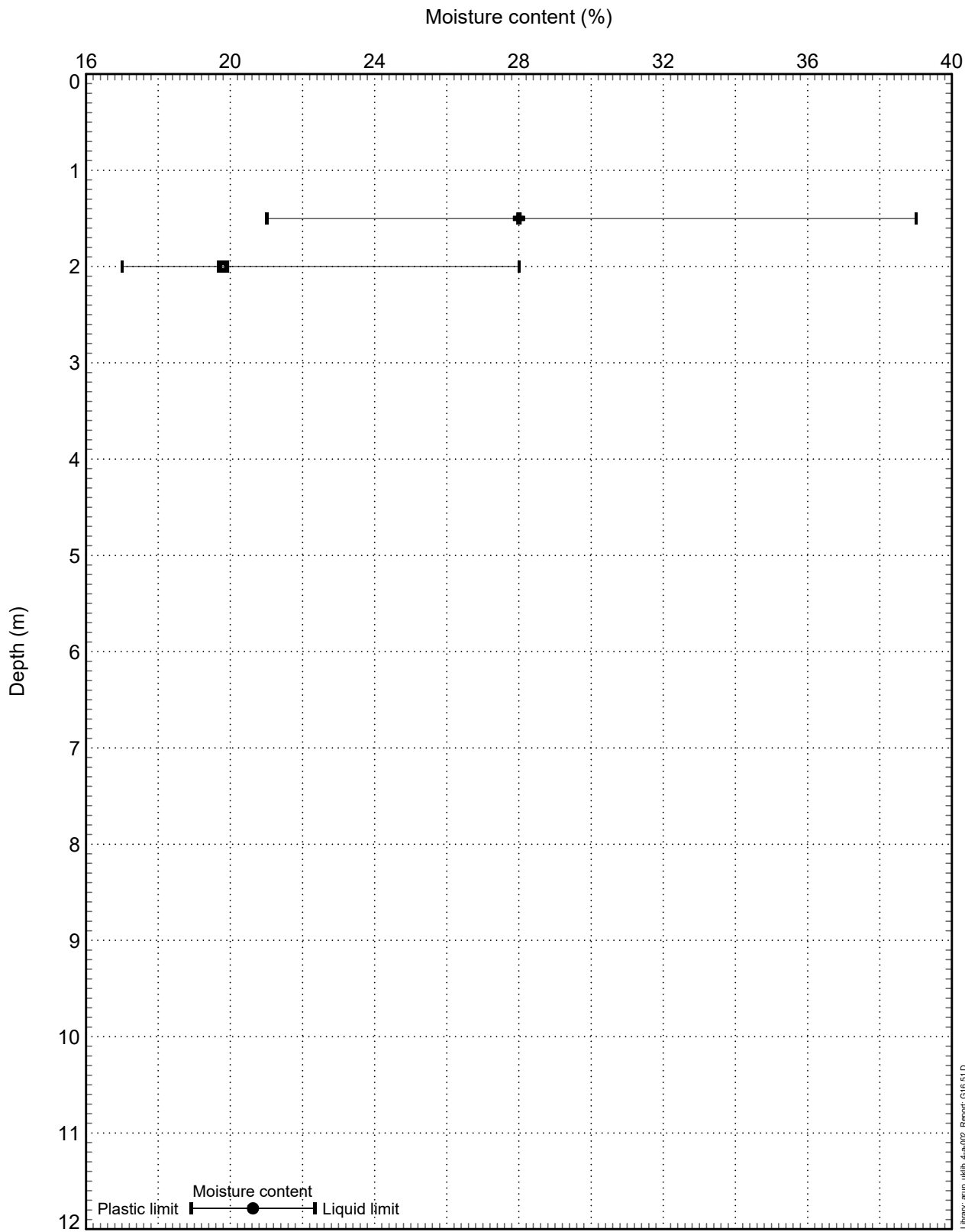
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
MADE GROUND
Travis Island

Job No
282022

Figure No
Chart 3I



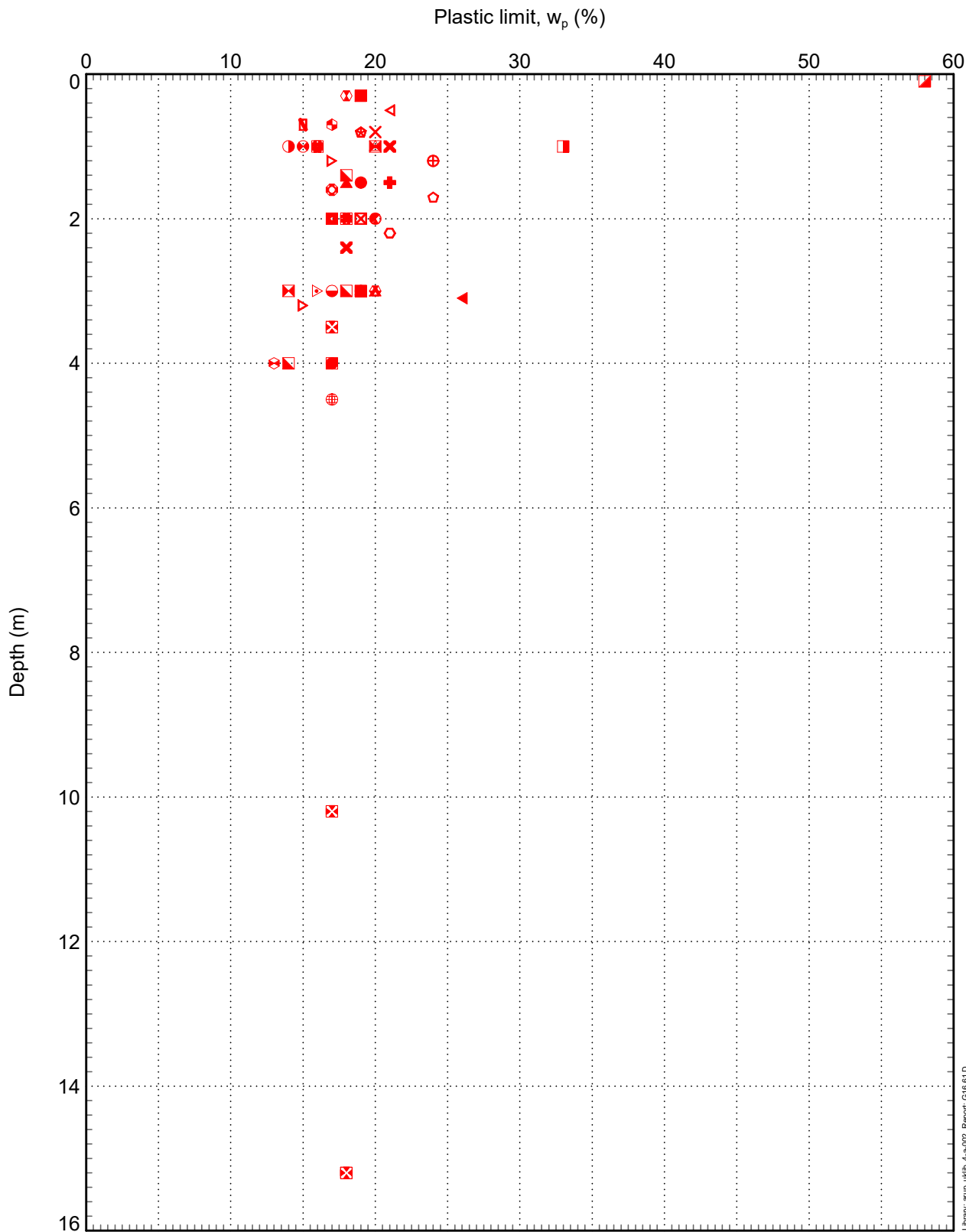
ARUP

Job Title
Victoria North

Figure Title
Atterberg limits
MADE GROUND
New Town Plots

Job No
282022

Figure No
Chart 3J



Users: arup, jltb, 4-4-2022, Report: C16.61.D
Database: c:\gint\vicoria north\data\stage 3\data.gpi Rev/P1.1 (SD - Work in progress)

- | | | |
|--------------------|--------------|-------------|
| ■ Made Ground (MG) | ◄ GEO_WS202 | ⊗ GEO_TP210 |
| ● 01_BH101 | ⊗ GEO_WS203A | ⊗ GEO_TP211 |
| ■ 01_BH102 | ◊ GEO_WS204 | ◻ GEO_TP212 |
| ▲ 01_BH103 | × GEO_WS207 | ⊗ GEO_TP213 |
| ⊕ 01_BH107 | ◄ GEO_WS208 | ◉ GEO_TP214 |
| ■ 01_BH109 | ⊗ GEO_WS210 | ⊗ GEO_TP216 |
| ▲ 01_BH110 | ◻ GEO_WS214 | ⊗ GEO_TP217 |
| ⊗ GEO_BH202 | ⊗ 01_TP124 | ◄ GEO_TP218 |
| ⊗ GEO_BH204 | ◻ GEO_TP202C | |
| ◻ GEO_BH203 | ◉ GEO_TP203 | |
| ◉ GEO_BH209 | ◄ GEO_TP204 | |
| ◉ GEO_BH212 | ⊗ GEO_TP205 | |
| ▲ 01_WS104 | ◻ GEO_TP206A | |
| ◉ 01_WS105A | ⊗ GEO_TP207 | |
| ⊕ 01_WS106 | ⊗ GEO_TP208 | |

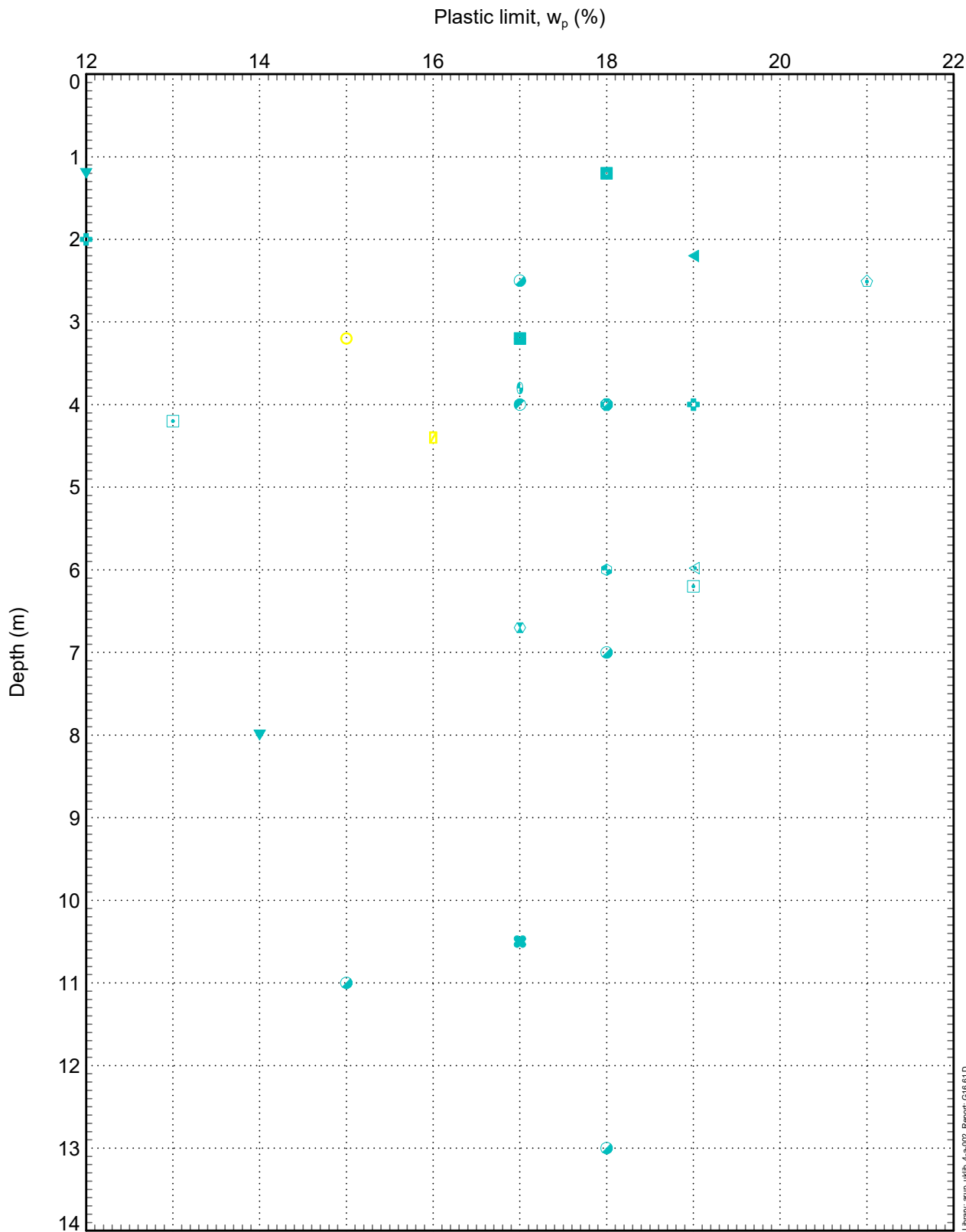
ARUP

Job Title
Victoria North

Figure Title
Plastic limit
MADE GROUND

Job No
282022

Figure No
Chart 3K



Library: arup_v10.00.01.07, Made by Jonny Tyler on 6-Jan-22
 Database: c:\gnr\vicoria north\data\stage 3 data\api RevP1.1 (SD - Work in progress)

- Alluvium (ALV)
- Glacial Till Deposits (GTD)
- 01_BH104
- ▼ 01_BH106
- GEO_BH202
- GEO_BH206
- GEO_BH215
- ◇ GEO_BH201
- ◇ GEO_BH205
- ◇ GEO_BH209
- ◇ GEO_BH210
- 01_WS102
- GEO_WS206
- ▼ 01_TP101

- 01_TP103
- ▲ 01_TP104
- GEO_TP201
- GEO_TP210
- GEO_TP211

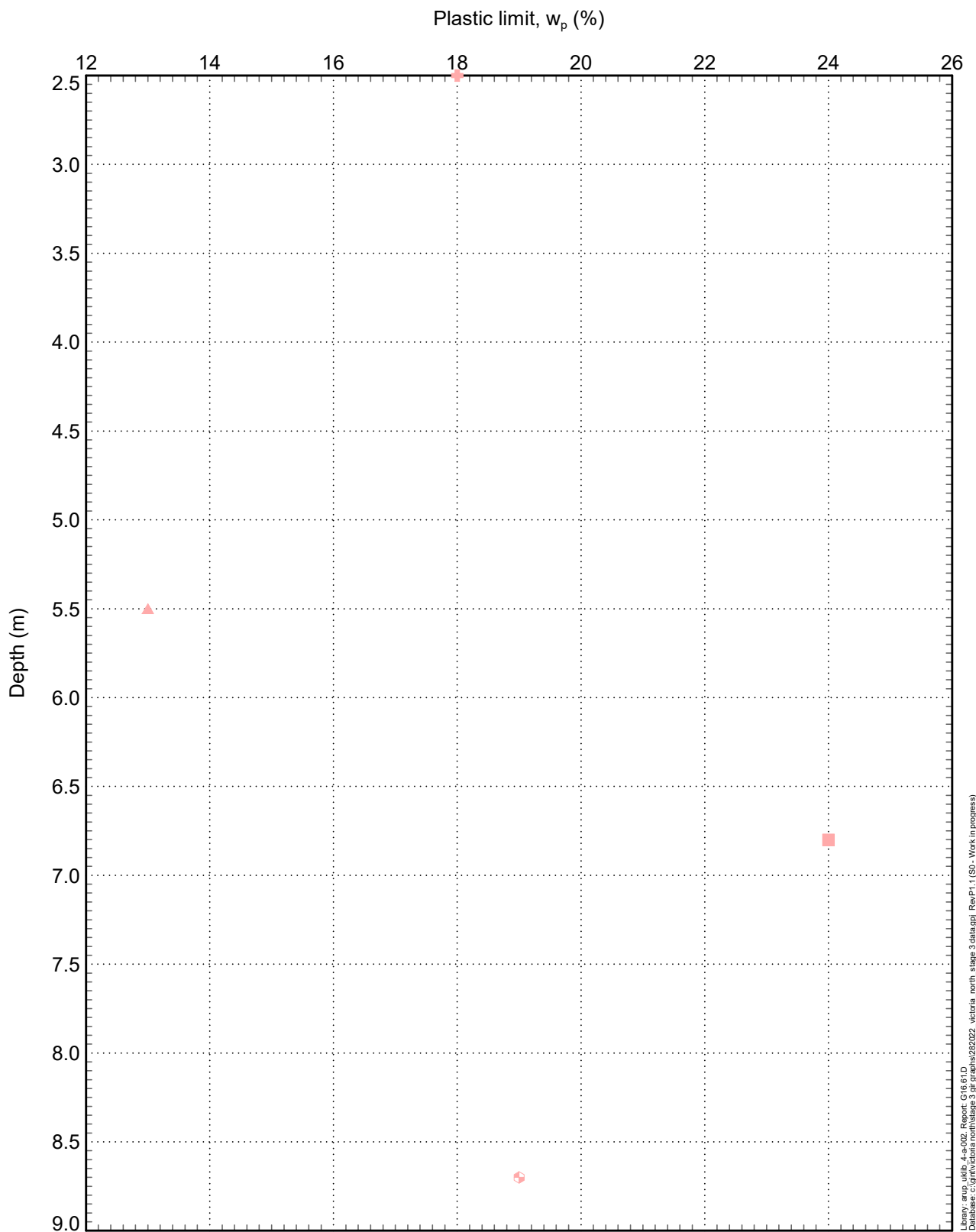
ARUP

Job Title
Victoria North

Figure Title
Plastic limit
GLACIAL TILL DEPOSITS &
ALLUVIUM

Job No
282022

Figure No
Chart 3L



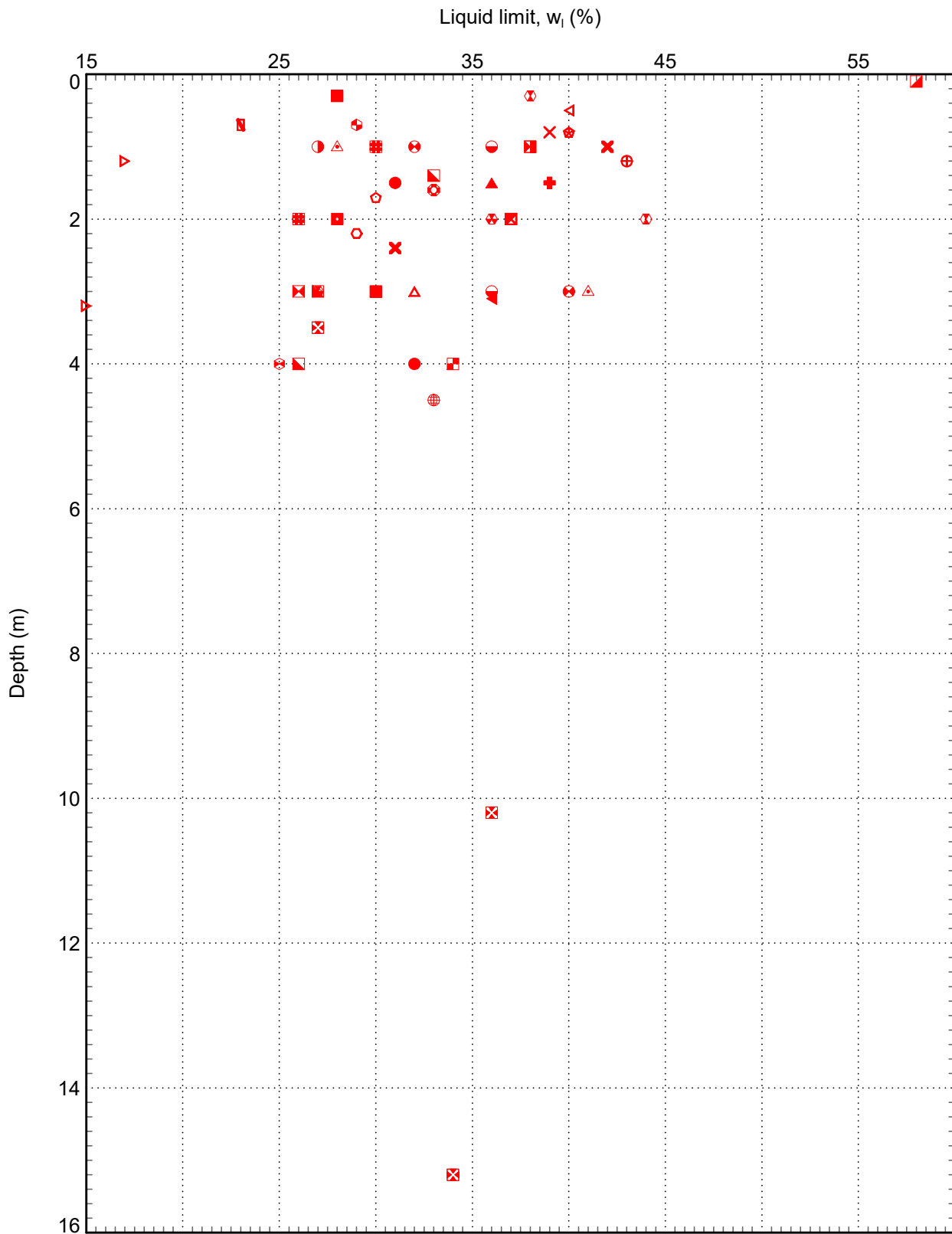
ARUP

Job Title
Victoria North

Figure Title
Plastic limit
MANCHESTER MARLS
FORMATION

Job No
282022

Figure No
Chart 3M



Users: arup_v10.00.01.07, 4-4-2022, Report: C16.62.D
Database: c:\gint\vicoria\northstage 3\gr_graph\h282022_victoria_north_stage 3\data.gpi Rev/P1.1 (SD - Work in progress)

- Made Ground (MG)
- 01_BH101
- 01_BH102
- ▲ 01_BH103
- ⊕ 01_BH107
- ⊗ 01_BH109
- ▲ 01_BH110
- ⊕ GEO_BH202
- ⊗ GEO_BH204
- ⊗ GEO_BH203
- ⊗ GEO_BH209
- ⊗ GEO_BH212
- ▲ 01_WS104
- 01_WS105A
- ⊕ 01_WS106

- ◁ GEO_WS202
- ⊗ GEO_WS203A
- ◊ GEO_WS204
- × GEO_WS207
- ▷ GEO_WS208
- ⊗ GEO_WS210
- ⊗ GEO_WS214
- × 01_TP124
- ◻ GEO_TP202C
- ◐ GEO_TP203
- ◐ GEO_TP204
- × GEO_TP205
- ◻ GEO_TP206A
- ⊗ GEO_TP207
- ⊗ GEO_TP208

- ⊗ GEO_TP210
- ◐ GEO_TP211
- ◻ GEO_TP212
- ⊗ GEO_TP213
- ◐ GEO_TP214
- ⊗ GEO_TP216
- ⊗ GEO_TP217
- ▷ GEO_TP218

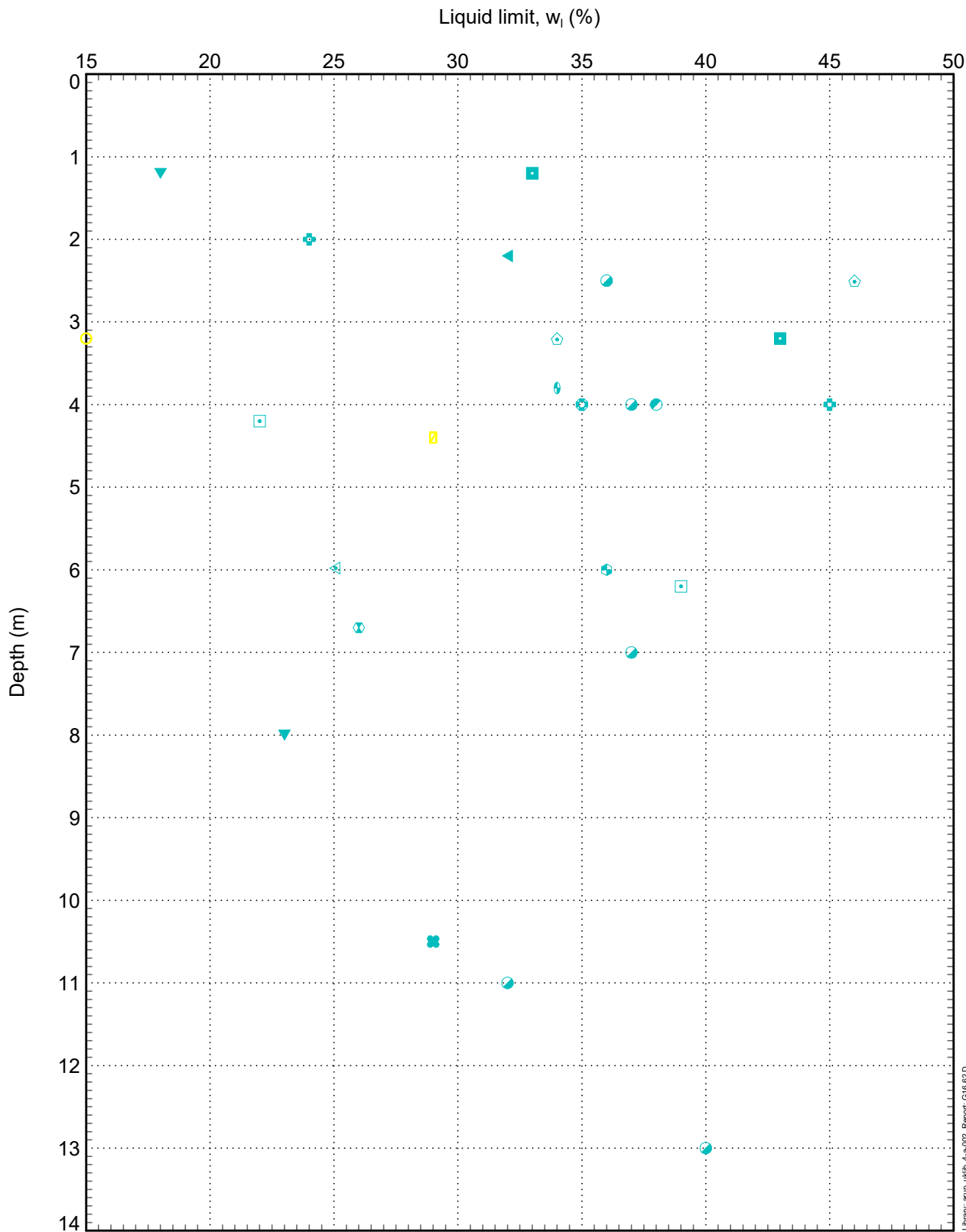
ARUP

Job Title
Victoria North

Figure Title
Liquid limit
MADE GROUND

Job No
282022

Figure No
Chart 3N



Library: arup_v10.00.01.07, Made by Jonny Tyer on 6-Jan-22
 Database: c:\gnr\vicoria\northstage 3\gr graph\282022_vicoria_north_stage 3\data.gpi Rev/P1.1 (SD - Work in progress)

- Alluvium (ALV)
- Glacial Till Deposits (GTD)
- ✱ 01_BH104
- ▼ 01_BH106
- ⊕ GEO_BH202
- GEO_BH206
- ⊙ GEO_BH215
- ◇ GEO_BH201
- ⊖ GEO_BH205
- ⊗ GEO_BH209
- △ GEO_BH210
- 01_WS102
- ⊞ GEO_WS206
- ▼ 01_TP101
- 01_TP103
- ▲ 01_TP104
- ⊕ GEO_TP201
- ⊙ GEO_TP210
- GEO_TP211

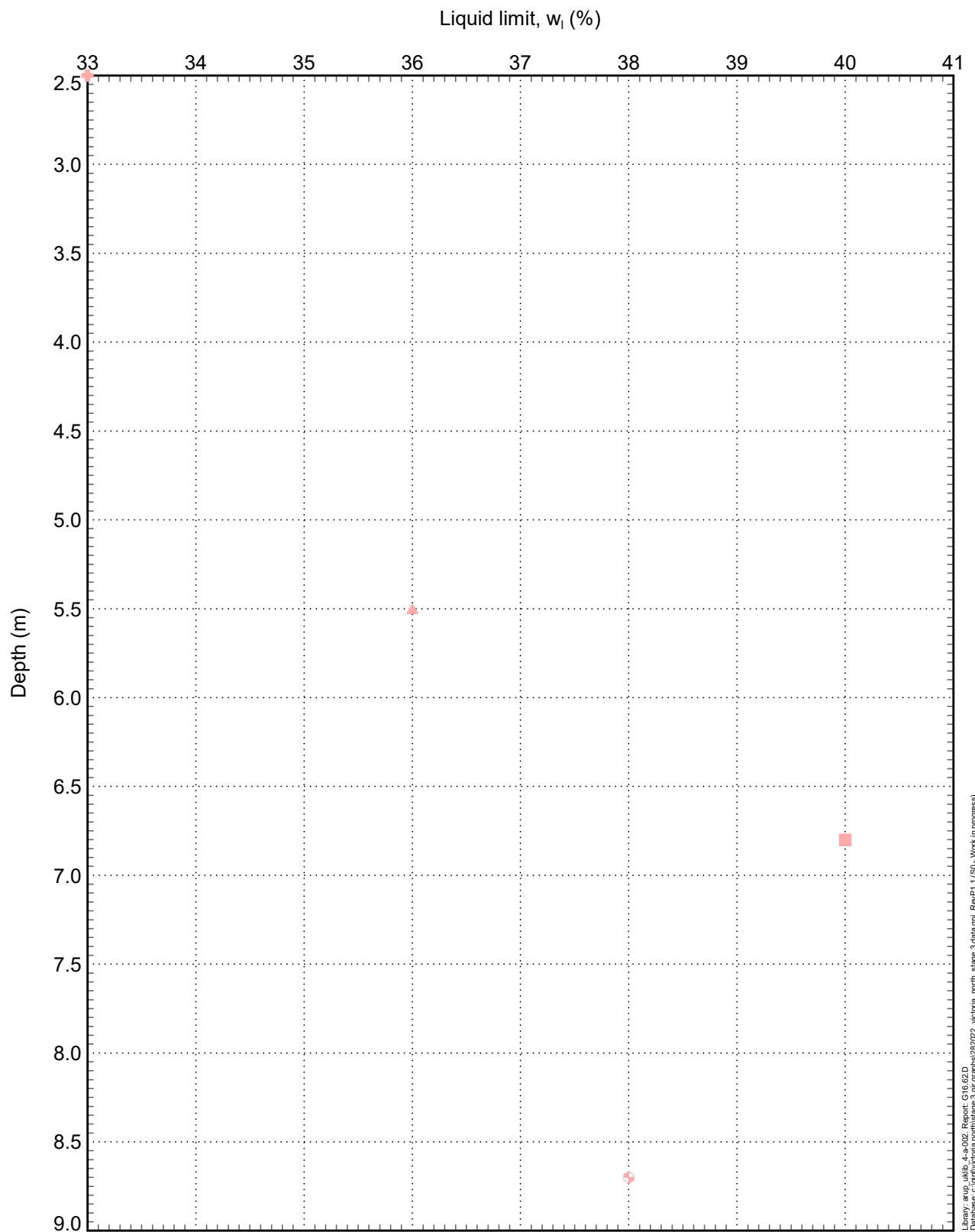
ARUP

Job Title
Victoria North

Figure Title
Liquid limit
GLACIAL TILL DEPOSITS &
ALLUVIUM

Job No
282022

Figure No
Chart 30



Library: arup_uklib_4-a-002. Report: G16.62.D
Database: c:\gnt\victoria\north\stage 3 gfr\graphs\282022_victoria_north_stage 3 data\data.gpj RevP1.1 (S0 - Work in progress)

■ Manchester Marls Formation (MM)
■ 01_BH102
▲ 01_BH103
+ 01_BH107
⬢ GEO_BH202

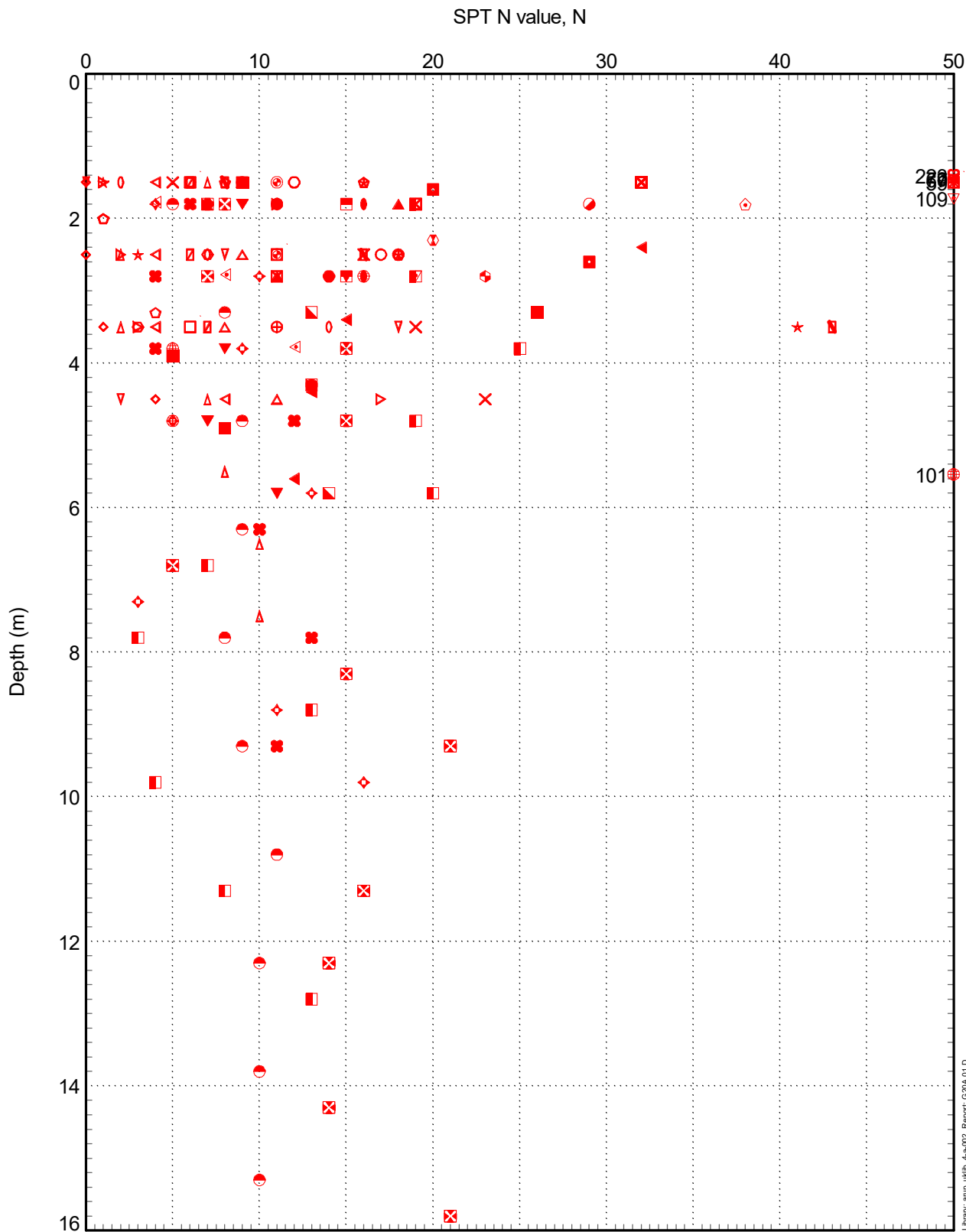
ARUP

Job Title
Victoria North

Figure Title
Liquid limit
MANCHESTER MARLS
FORMATION

Job No
282022

Figure No **Chart 3P**



Library: arup_v10.00.01.07, 4-4-2022, Report: G2022_01.D
Database: c:\gnivictoria\northstage 3.gi\grapha\282022_victoria_north_stage 3 data.gpi RevP1.1 (SO - Work in progress)

- | | | | |
|--------------------|--------------|--------------|--------------|
| ■ Made Ground (MG) | ■ GEO_BH208 | ⊗ 01_WS105 | ▼ GEO_WS211 |
| ● 01_BH101 | ◆ GEO_BH211A | ⊕ 01_WS105A | ◇ GEO_WS212 |
| ■ 01_BH102 | ▽ GEO_BH212A | ⊖ 01_WS106 | ○ GEO_WS213A |
| ▲ 01_BH103 | ● GEO_BH213 | ▽ GEO_WS201 | ■ GEO_WS214 |
| ⊗ 01_BH104 | ■ GEO_BH214A | ⊗ GEO_WS201A | |
| ● 01_BH105 | ● GEO_BH215 | ✱ GEO_WS201B | |
| ▼ 01_BH106 | ◆ GEO_BH201 | △ GEO_WS202 | |
| ⊕ 01_BH107 | ■ GEO_BH203 | ⊗ GEO_WS203A | |
| ■ 01_BH109 | ⊗ GEO_BH209 | △ GEO_WS204 | |
| ▲ 01_BH110 | △ GEO_BH210 | △ GEO_WS205 | |
| ▼ 01_BH112 | ● GEO_BH212 | ■ GEO_WS206 | |
| ● GEO_BH202 | ⊗ 01_WS101 | ✱ GEO_WS207 | |
| ⊗ GEO_BH204 | ○ 01_WS102 | ▽ GEO_WS208 | |
| ● GEO_BH207 | □ 01_WS103 | ★ GEO_WS209 | |
| | △ 01_WS104 | ● GEO_WS210 | |

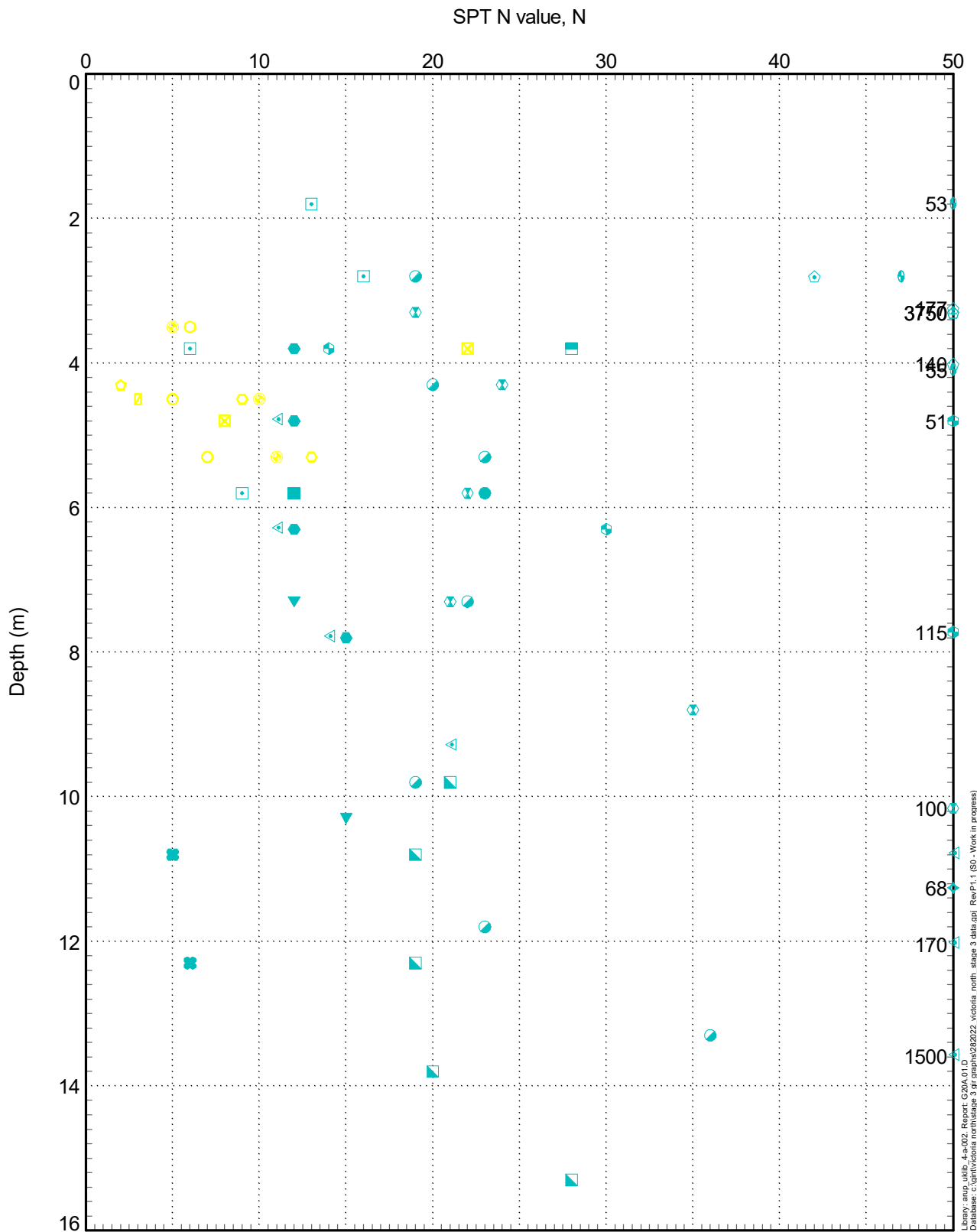
ARUP

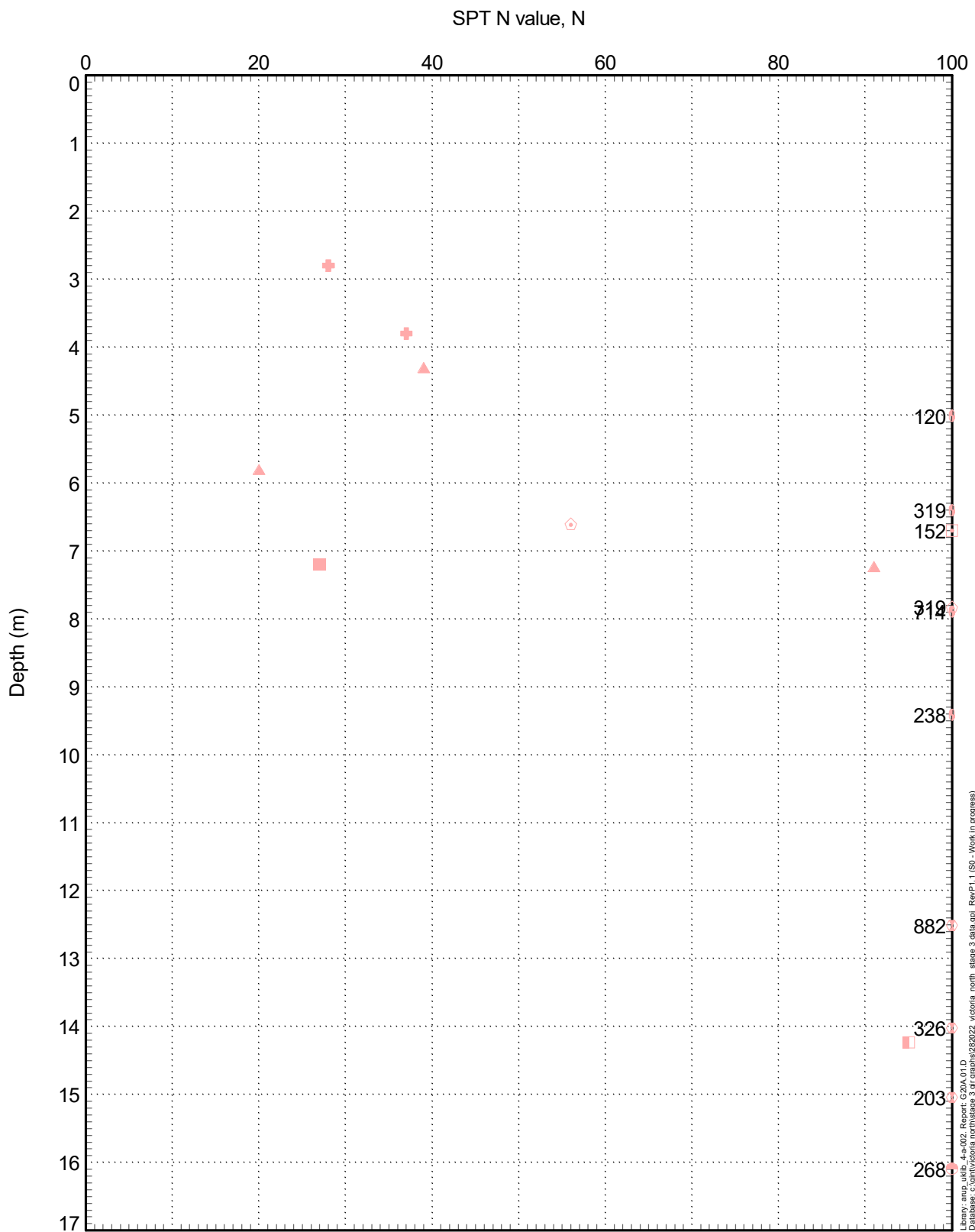
Job Title
Victoria North

Figure Title
Standard penetration tests
MADE GROUND

Job No
282022

Figure No
Chart 4A





- Manchester Marls Formation (MM)
- 01_BH102
- 01_BH103
- 01_BH107
- GEO_BH206
- GEO_BH207
- GEO_BH208
- GEO_BH201
- GEO_BH205
- GEO_BH209

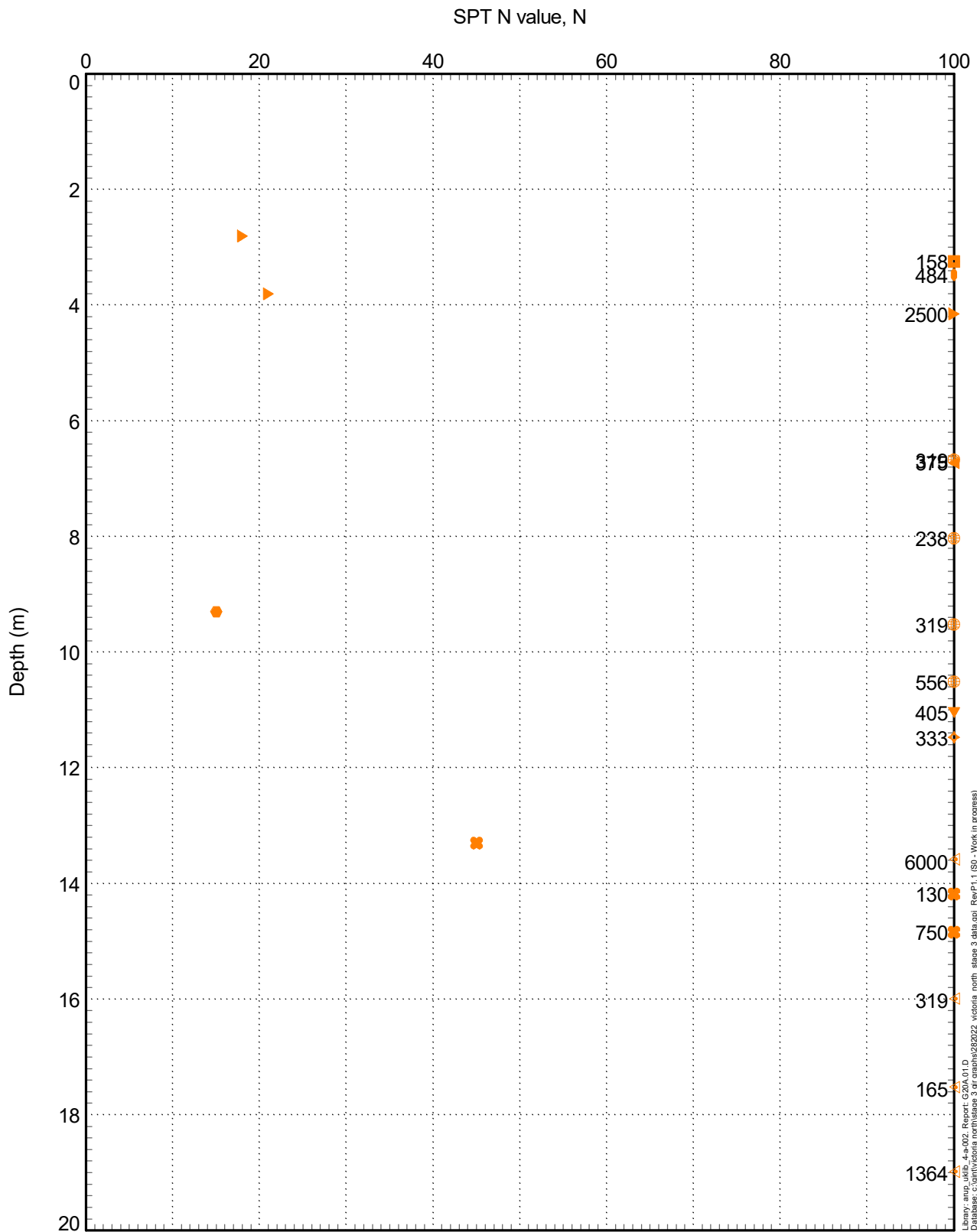
ARUP

Job Title
Victoria North

Figure Title
Standard penetration tests
MANCHESTER MARLS FORMATION

Job No
282022

Figure No
Chart 4C



- Chester Formation (CHES)
- 01_BH104
- 01_BH105
- ▼ 01_BH106
- 01_BH109
- ▲ 01_BH110
- ▼ 01_BH112
- ◆ GEO_BH211A
- GEO_BH213
- ▲ GEO_BH210
- GEO_BH212

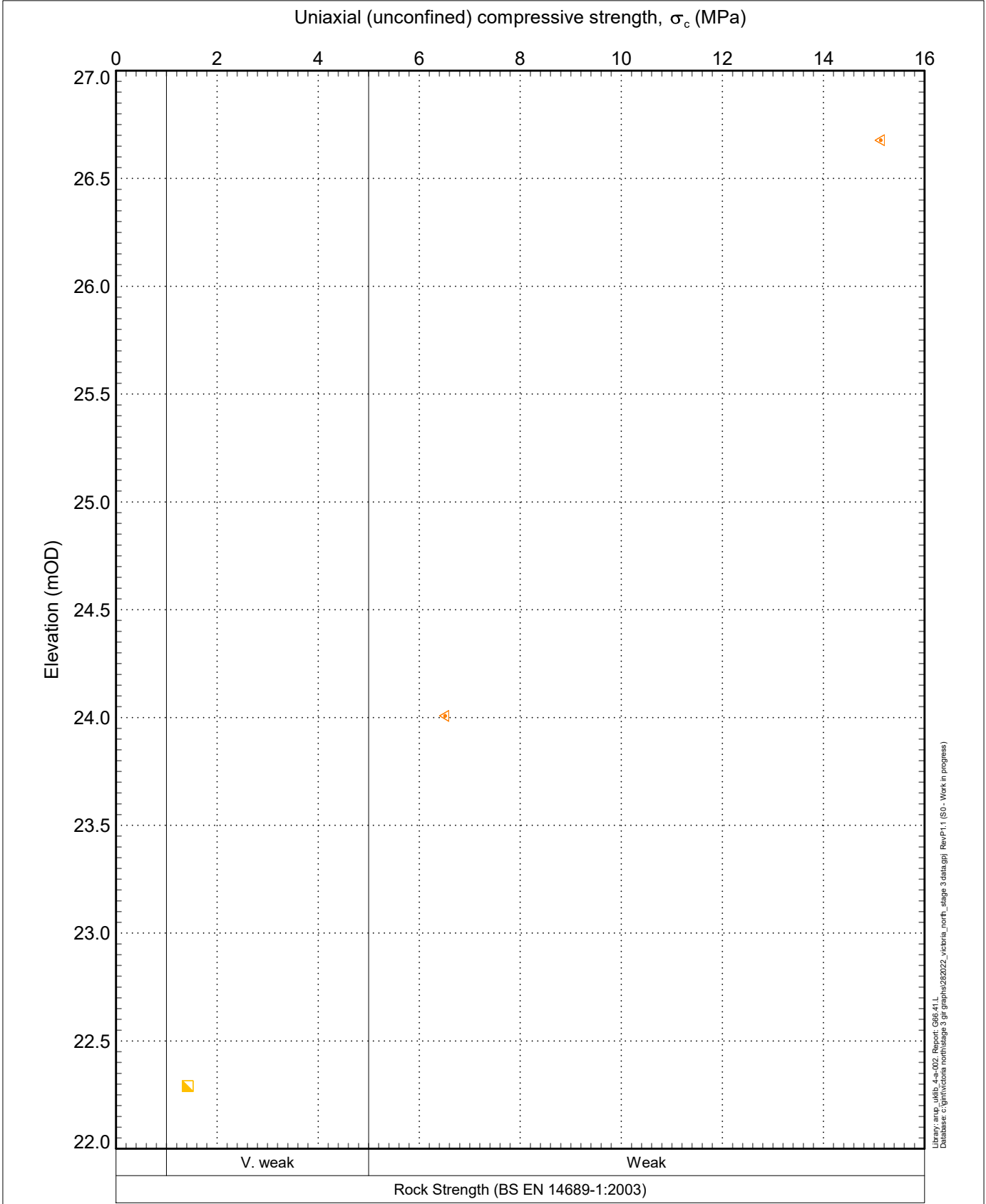
ARUP

Job Title
Victoria North

Figure Title
Standard penetration tests
CHESTER FORMATION

Job No
282022

Figure No
Chart 4D



- Chester Formation (CHES)
- Collyhurst Sandstone Formation (CS)
- GEO_BH203
- GEO_BH210

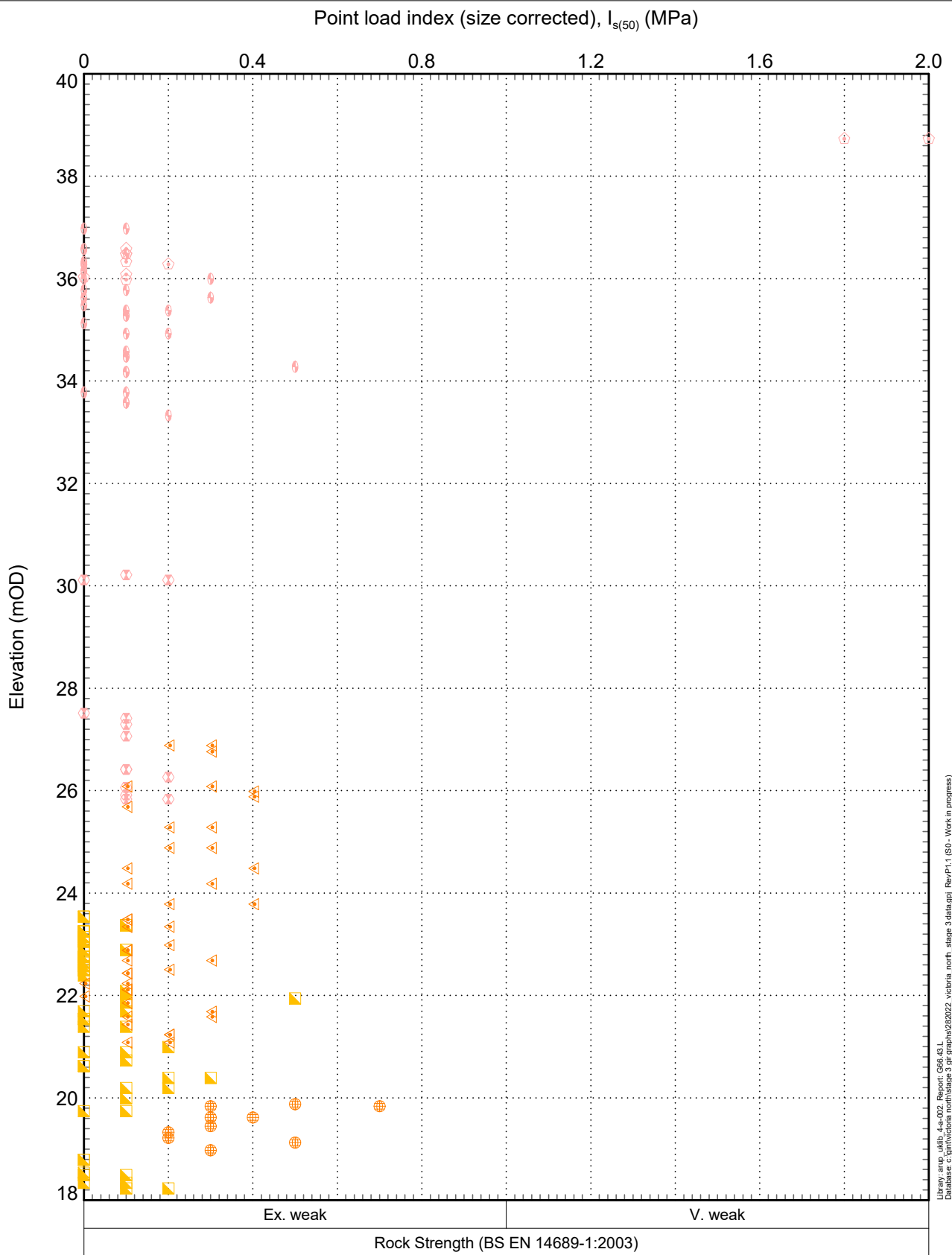
ARUP

Job Title
Victoria North

Figure Title
Uniaxial compressive strength
BEDROCK

Job No
282022

Figure No
Chart 5A



ARUP

Job Title
Victoria North

Figure Title
Point load index (size corrected)
BEDROCK

Job No
282022

Figure No
Chart 5B

Range of acceptable moisture content indicated for suitable structural and general fill (TP103 - 1.5m depth)

Chart 6A

Optimum Moisture Content (%) = 14.3

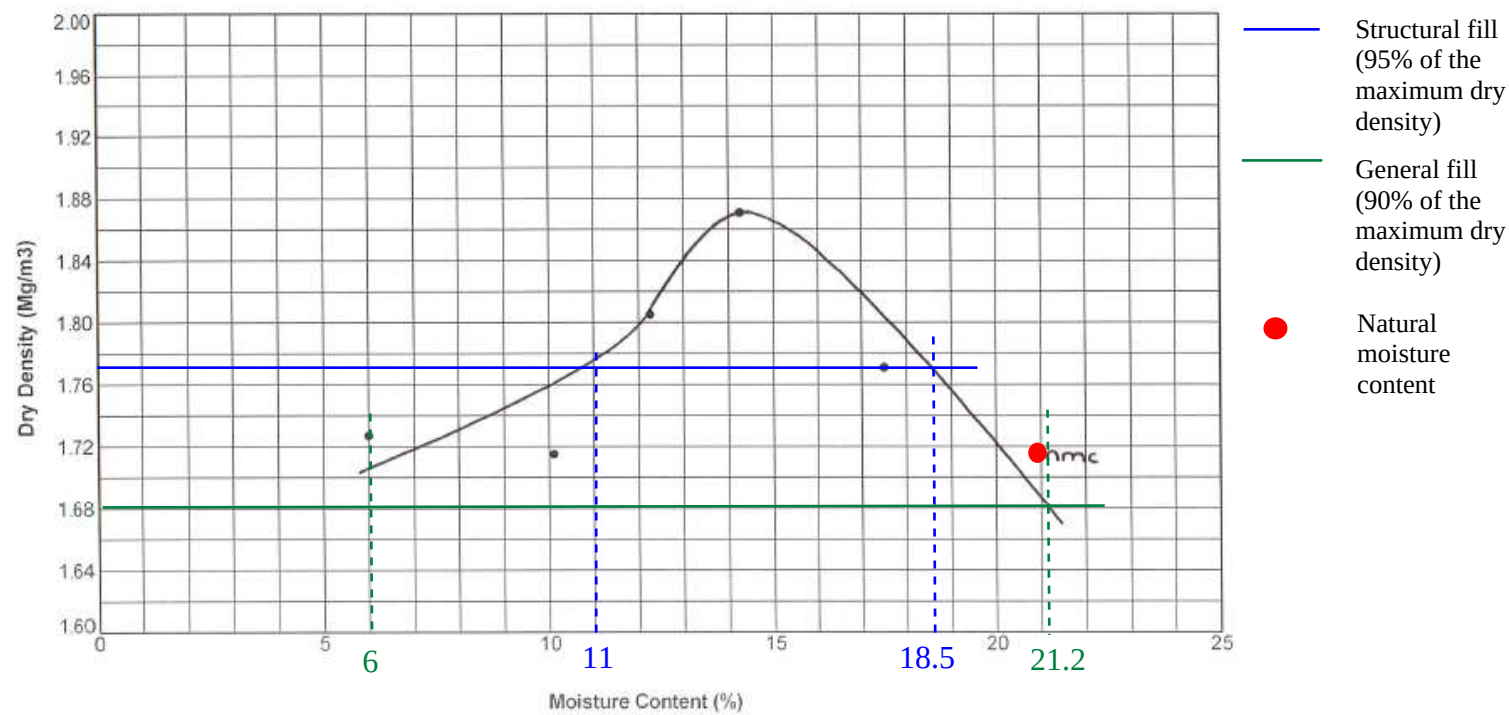
Particle Density (Assumed) = 2.70

Maximum Dry Density (Mg/m3) = 1.87

Retained on 20mm Sieve (%) = 0.8

Date Tested = 25/02/2019

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (TP121 - 0.8m depth)

Chart 6B

Optimum Moisture Content (%) = 11.2

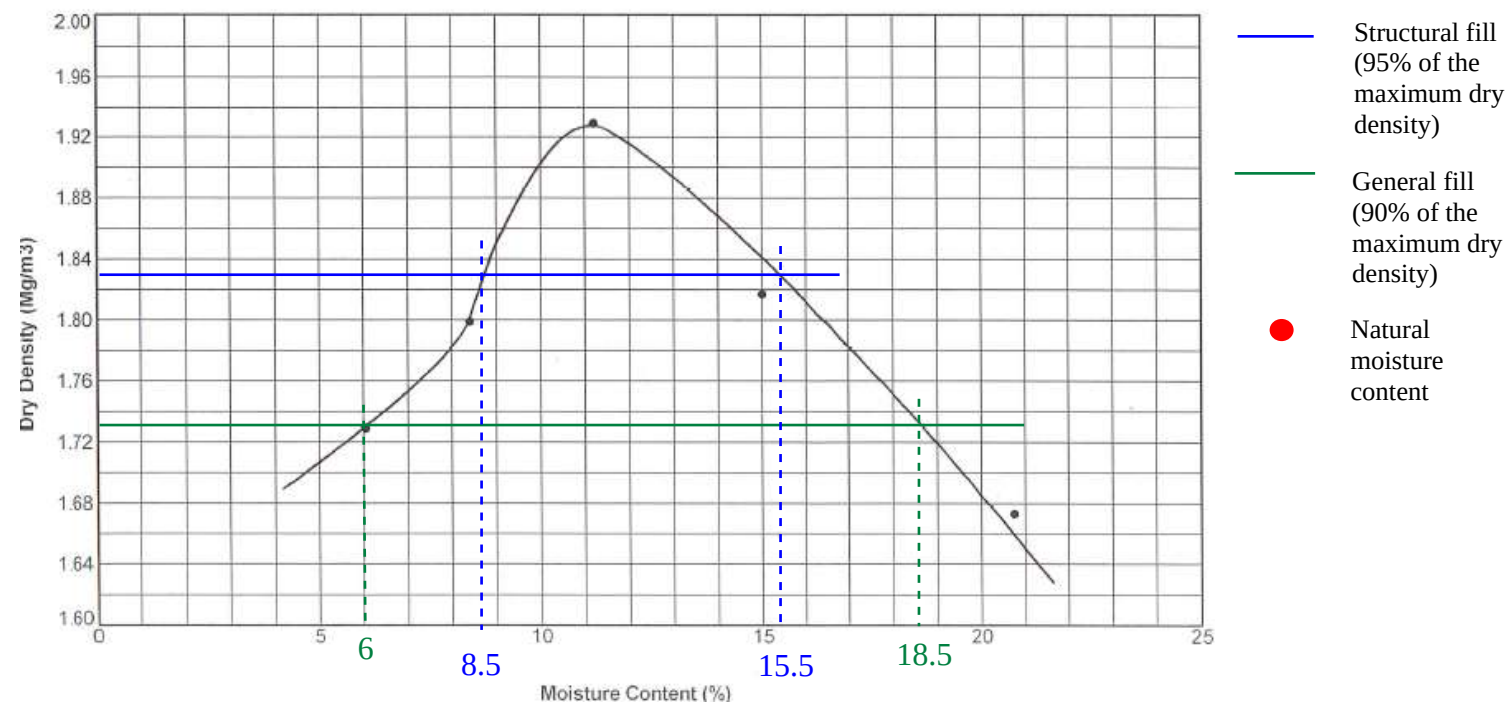
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m3) = 1.93

Retained on 20mm Sieve (%) = 7.0

Date Tested = 25/02/2019

Retained on 37.5mm Sieve (%) = 2.0



Range of acceptable moisture content indicated for suitable structural and general fill BH204 A - 10.2 depth

Chart 6C

Optimum Moisture Content (%) = 14

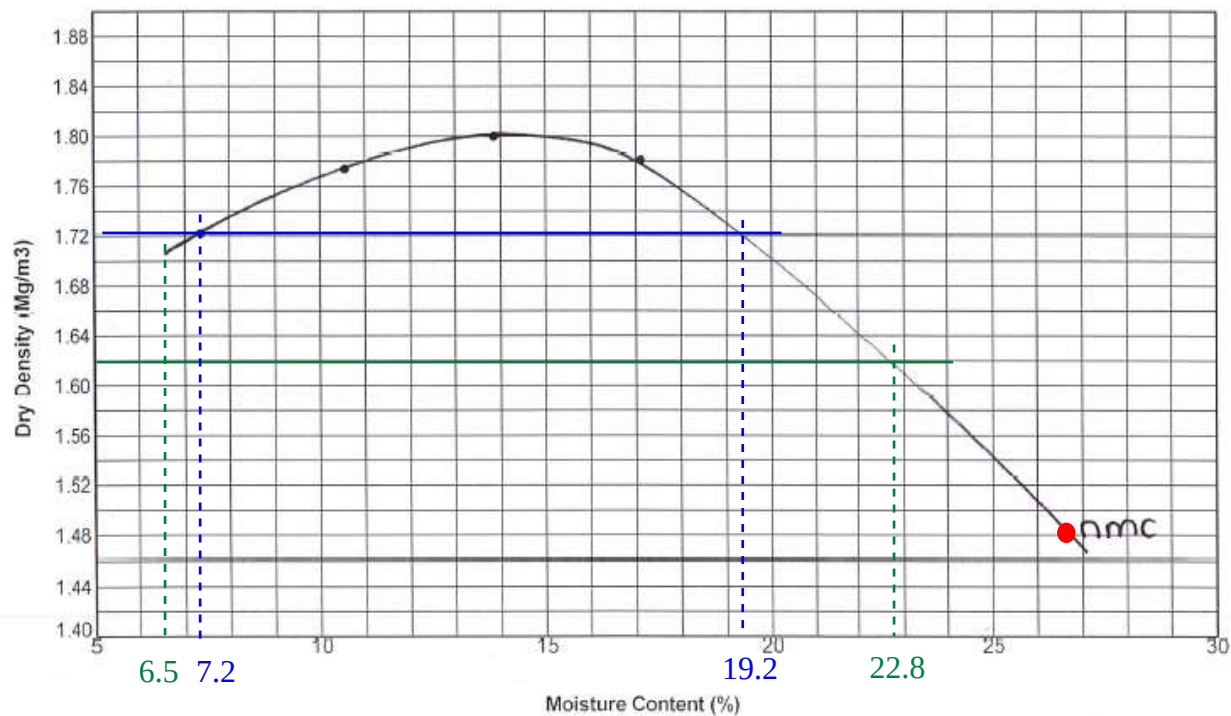
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.80

Retained on 20mm Sieve (%) = 4.0

Date Tested = 22/09/2021

Retained on 37.5mm Sieve (%) = 0.0



- Structural fill (95% of the maximum dry density)
- General fill (90% of the maximum dry density)
- Natural moisture content

Range of acceptable moisture content indicated for suitable structural and general fill (BH204 B - 14m depth)

Chart 6D

Optimum Moisture Content (%) = 17

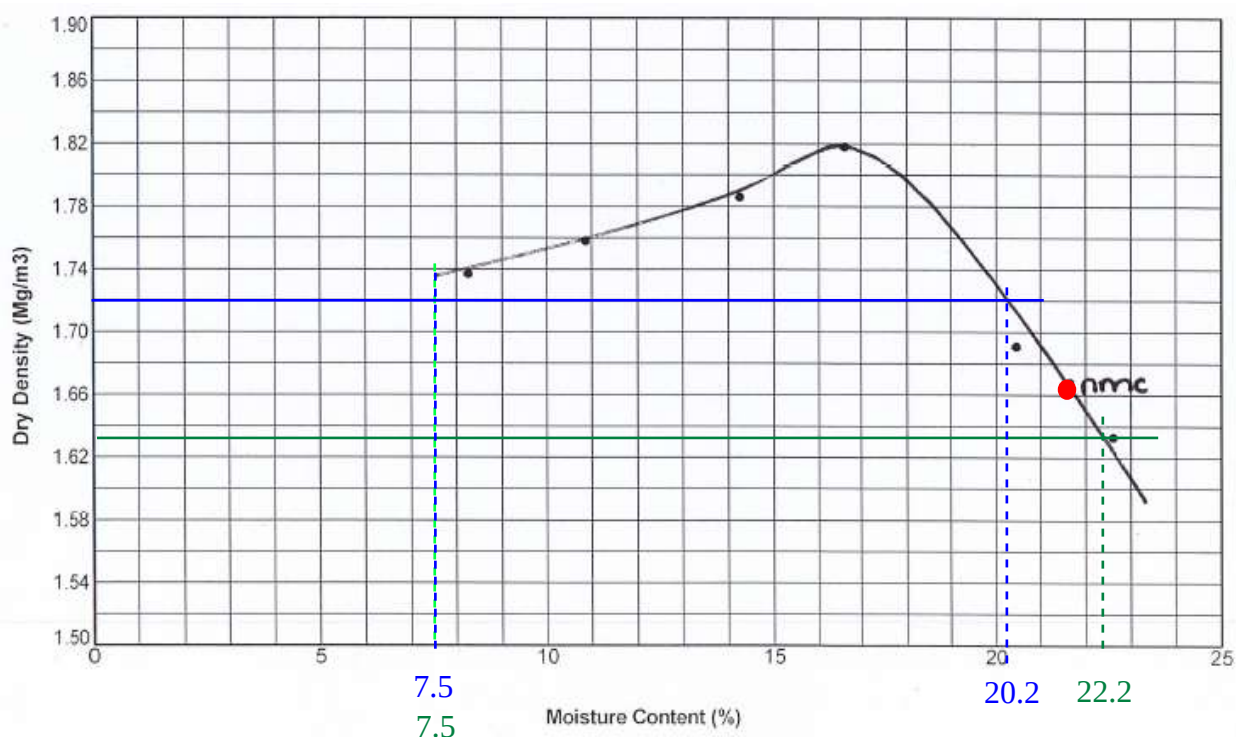
Particle Density (Assumed) = 2.70

Maximum Dry Density (Mg/m³) = 1.82

Retained on 20mm Sieve (%) = 0.4

Date Tested = 21/09/2021

Retained on 37.5mm Sieve (%) = 0.0



- Structural fill (95% of the maximum dry density)
- General fill (90% of the maximum dry density)
- Natural moisture content

Range of acceptable moisture content indicated for suitable structural and general fill (BH205 - 3.8m depth)

Chart 6E

Optimum Moisture Content (%) = 14

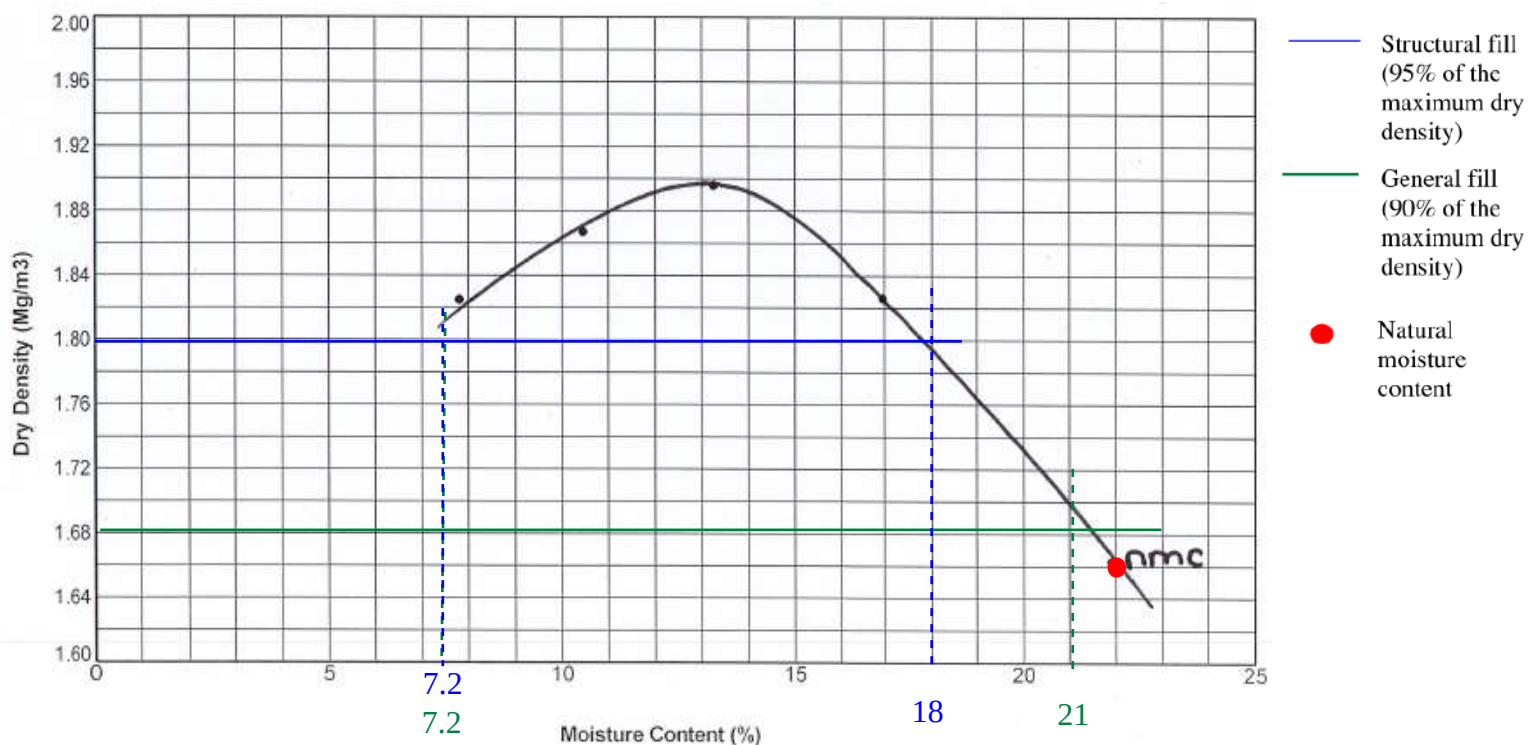
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.90

Retained on 20mm Sieve (%) = 1.0

Date Tested = 20/09/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (BH209 A - 7m depth)

Chart 6F

Optimum Moisture Content (%) = 12

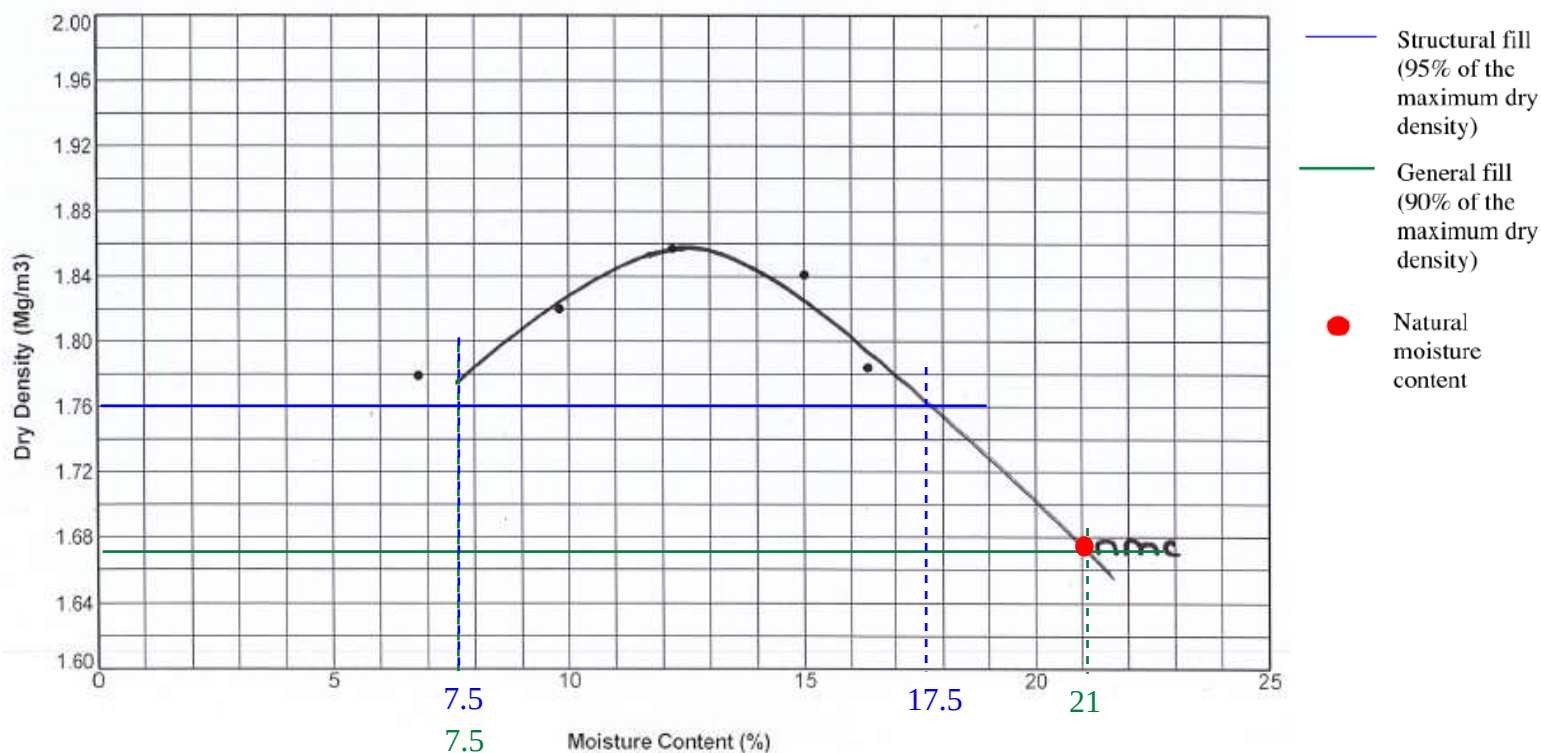
Particle Density (Assumed) = 2.60

Maximum Dry Density (Mg/m³) = 1.86

Retained on 20mm Sieve (%) = 0.0

Date Tested = 21/09/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (BH209 B- 10m depth)

Chart 6G

Optimum Moisture Content (%) = 12

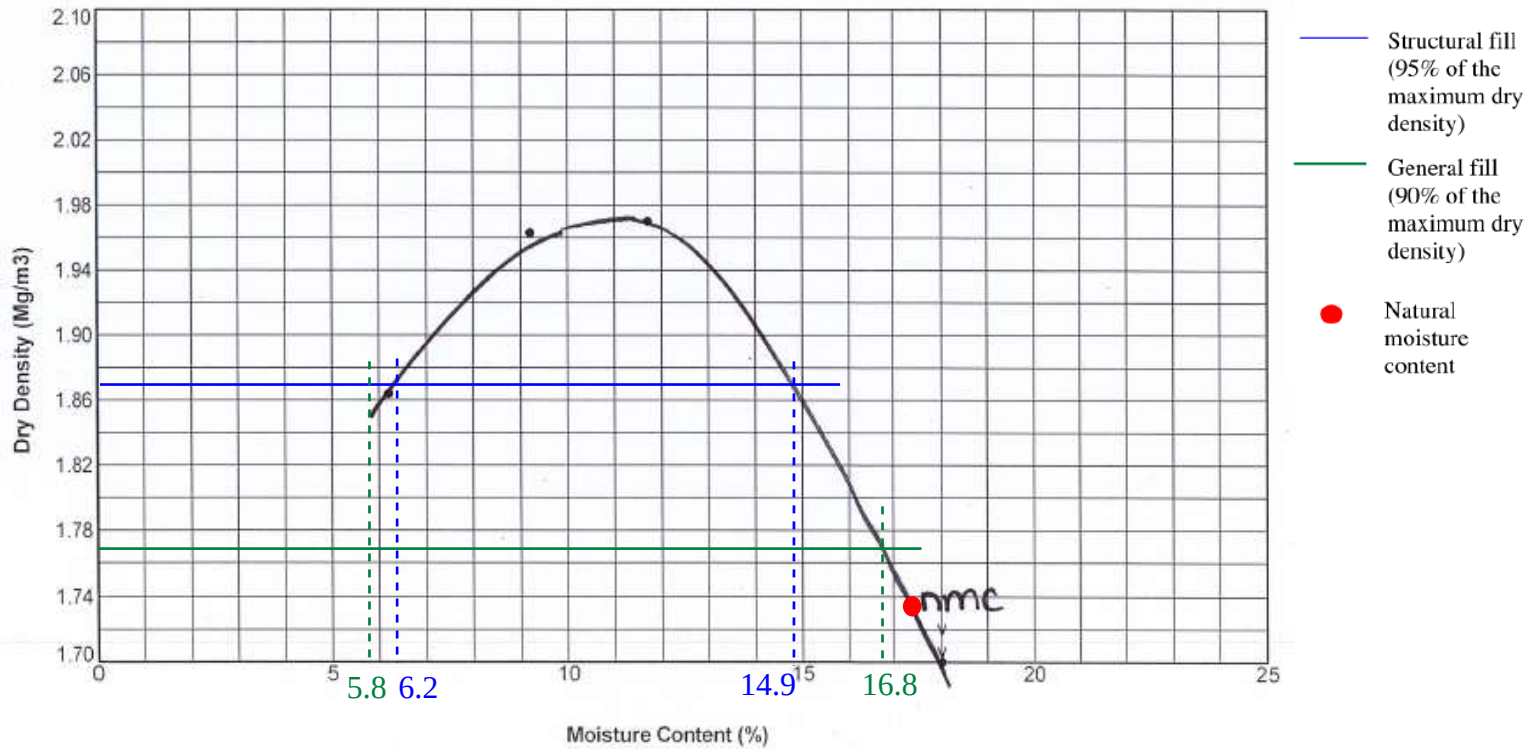
Particle Density (Assumed) = 2.60

Maximum Dry Density (Mg/m³) = 1.97

Retained on 20mm Sieve (%) = 1.3

Date Tested = 21/09/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (BH213 - 2.5m depth)

Chart 6H

Optimum Moisture Content (%) = 11

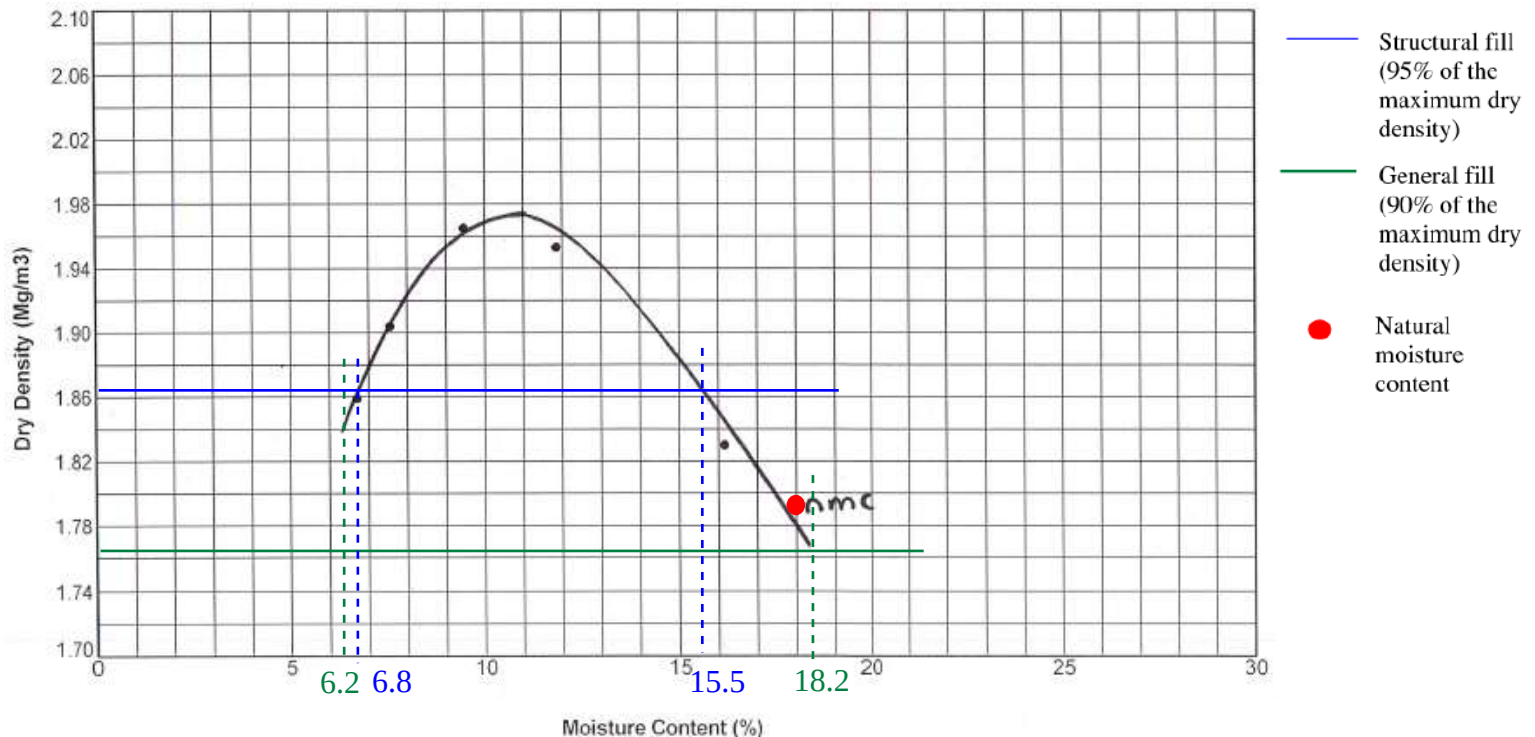
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.97

Retained on 20mm Sieve (%) = 8.8

Date Tested = 27/05/2021

Retained on 37.5mm Sieve (%) = 2.0



Range of acceptable moisture content indicated for suitable structural and general fill (BH215 A- 1.5m depth)

Chart 6I

Optimum Moisture Content (%) = 9.0

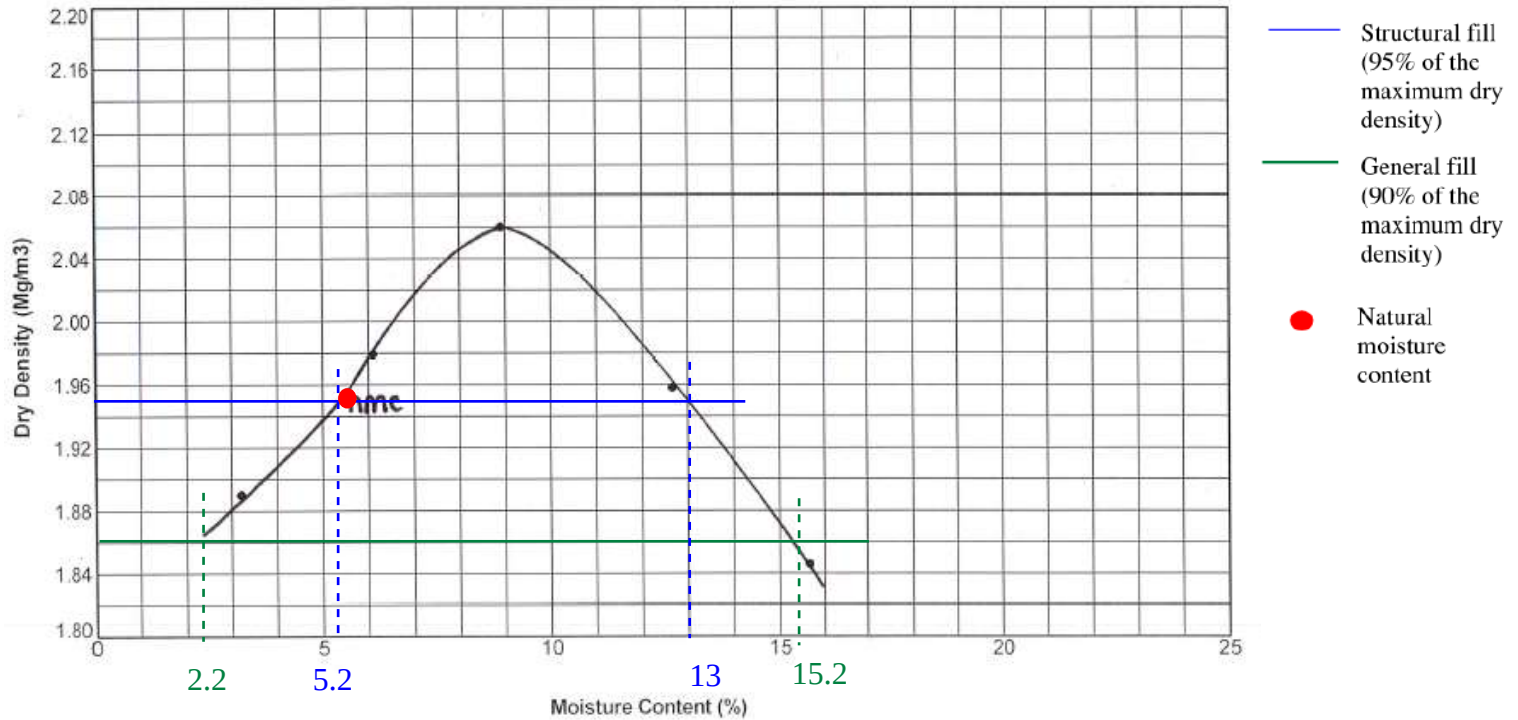
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 2.06

Retained on 20mm Sieve (%) = 7.4

Date Tested = 27/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (BH215 B- 2.5m depth)

Chart 6J

Optimum Moisture Content (%) = 15

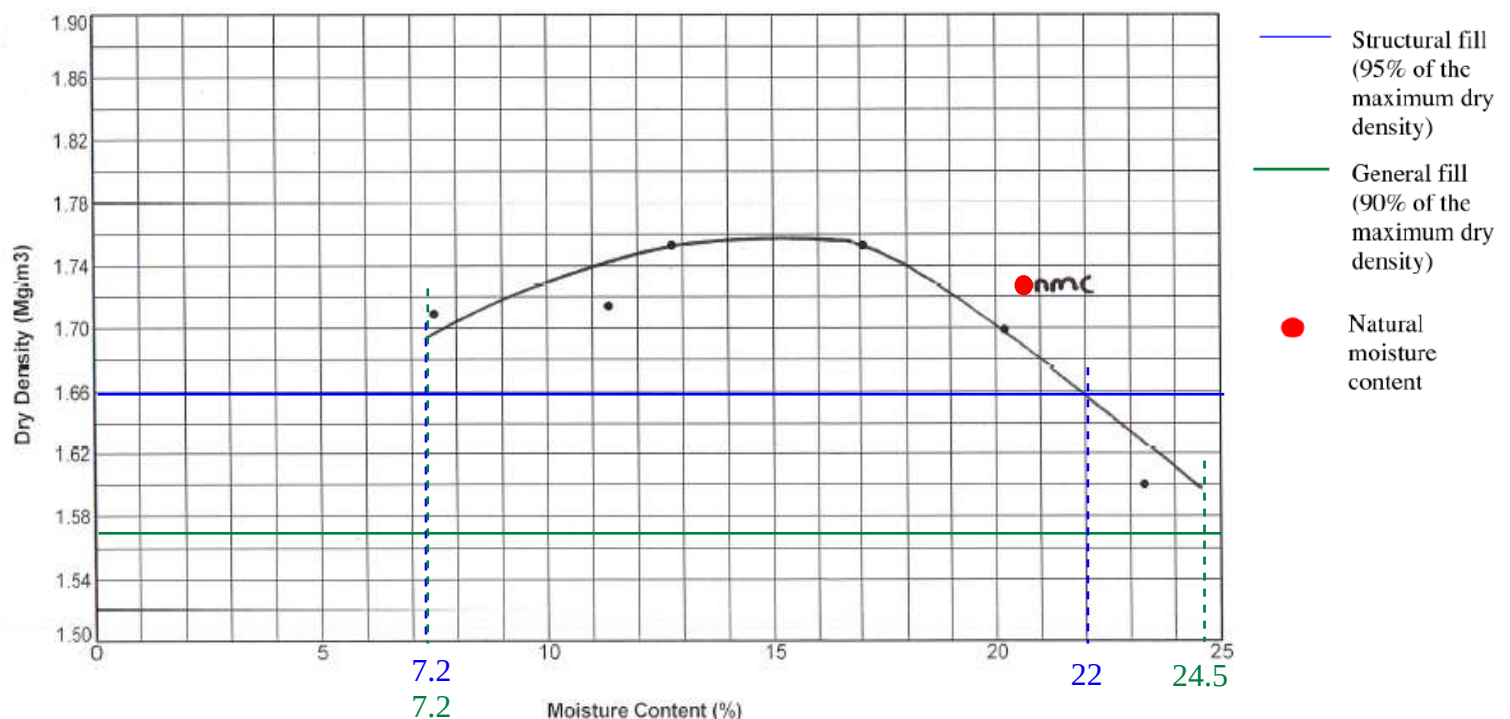
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.75

Retained on 20mm Sieve (%) = 0.0

Date Tested = 25/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill
(TP201 - 2.0m depth)

Chart 6K

Optimum Moisture Content (%) = 12

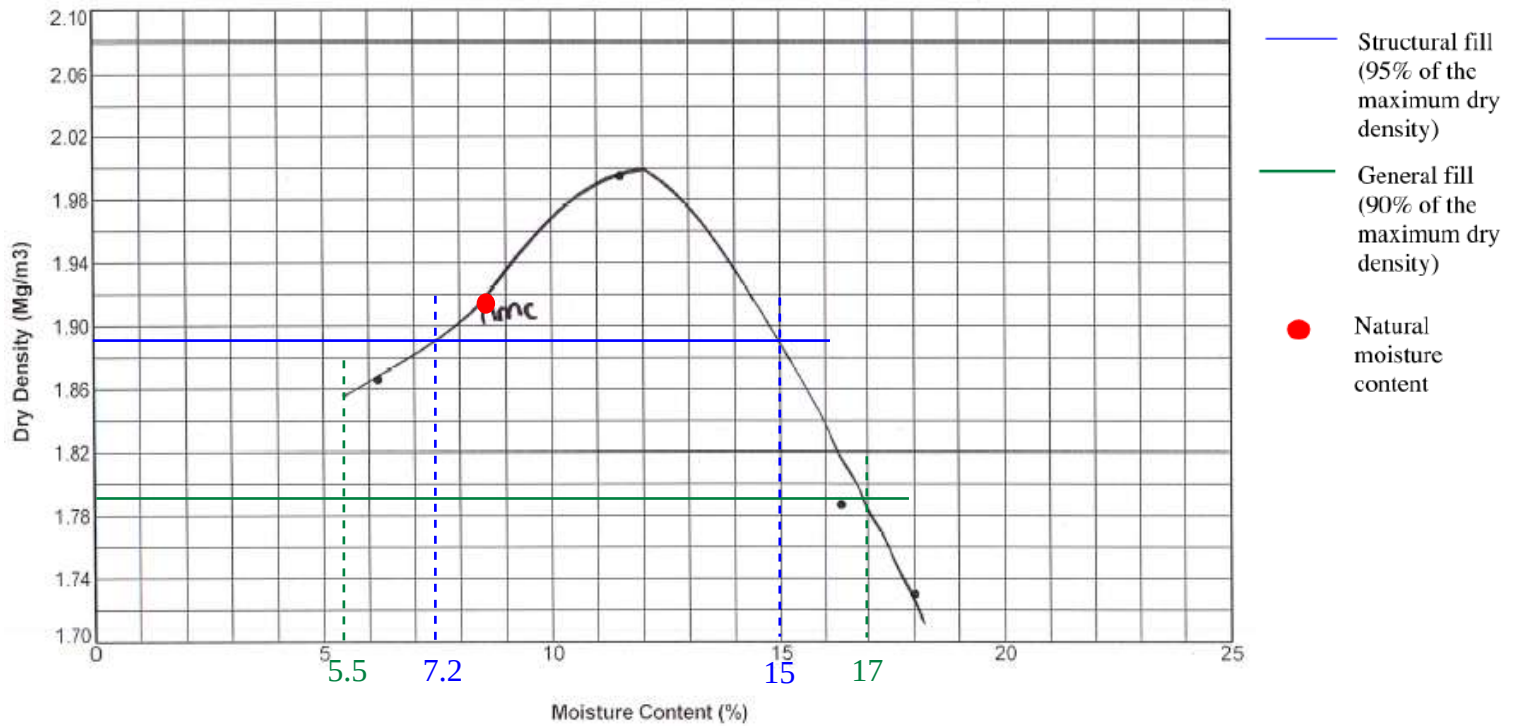
Particle Density (Assumed) = 2.60

Maximum Dry Density (Mg/m³) = 2.00

Retained on 20mm Sieve (%) = 0.0

Date Tested = 03/06/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill
(TP201 - 4.0m depth)

Chart 6L

Optimum Moisture Content (%) = 18

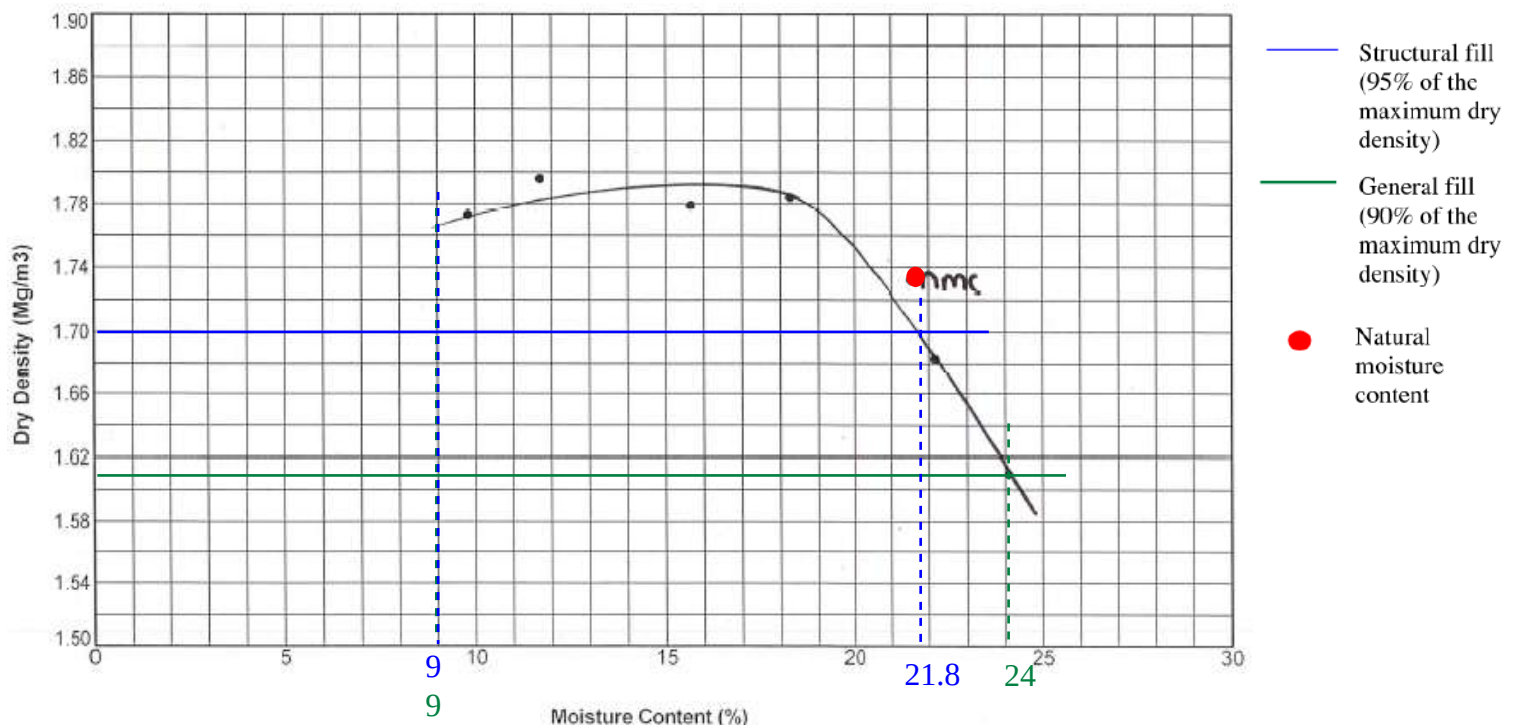
Particle Density (Assumed) = 2.80

Maximum Dry Density (Mg/m³) = 1.79

Retained on 20mm Sieve (%) = 1.0

Date Tested = 25/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (TP207 - 3.0m depth)

Chart 6M

Optimum Moisture Content (%) = 17

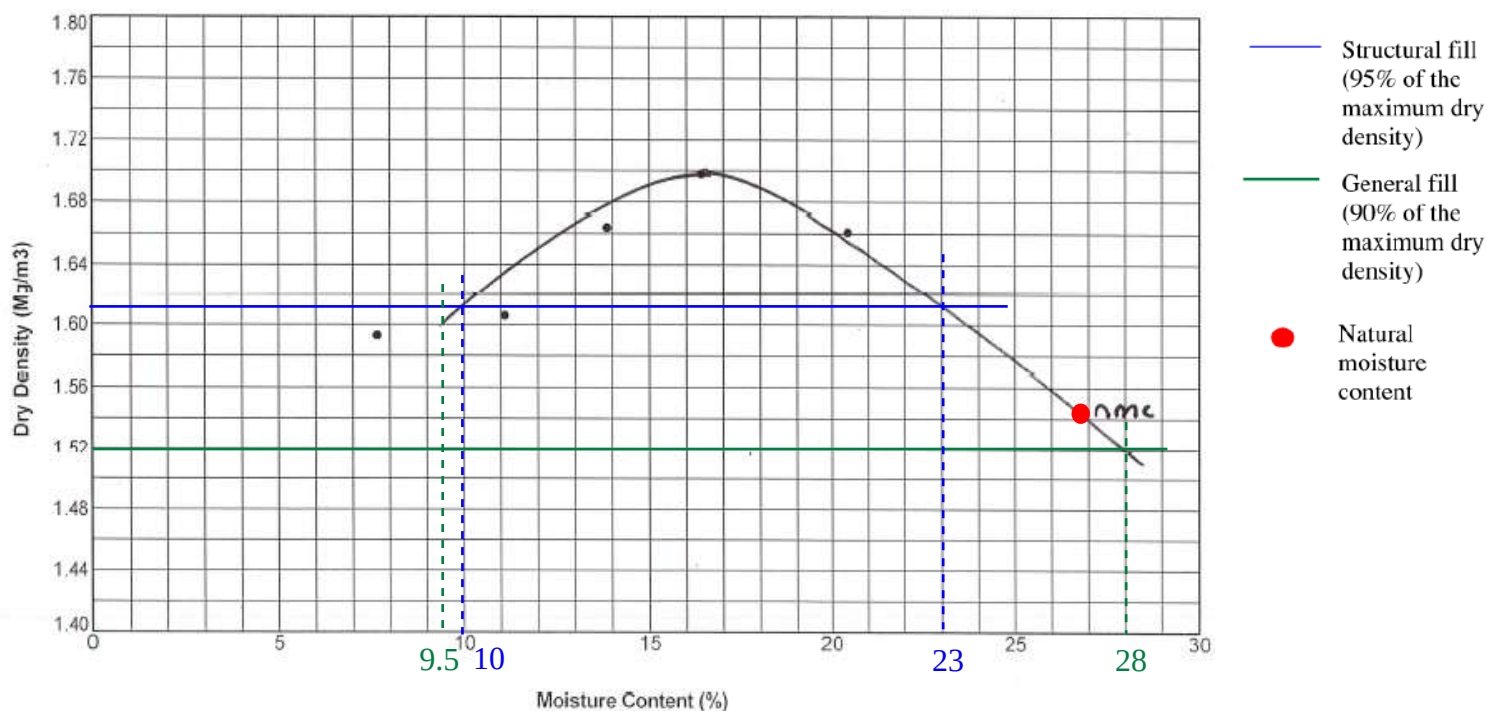
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.70

Retained on 20mm Sieve (%) = 0.0

Date Tested = 26/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (TP209 - 3.0m depth)

Chart 6N

Optimum Moisture Content (%) = 15

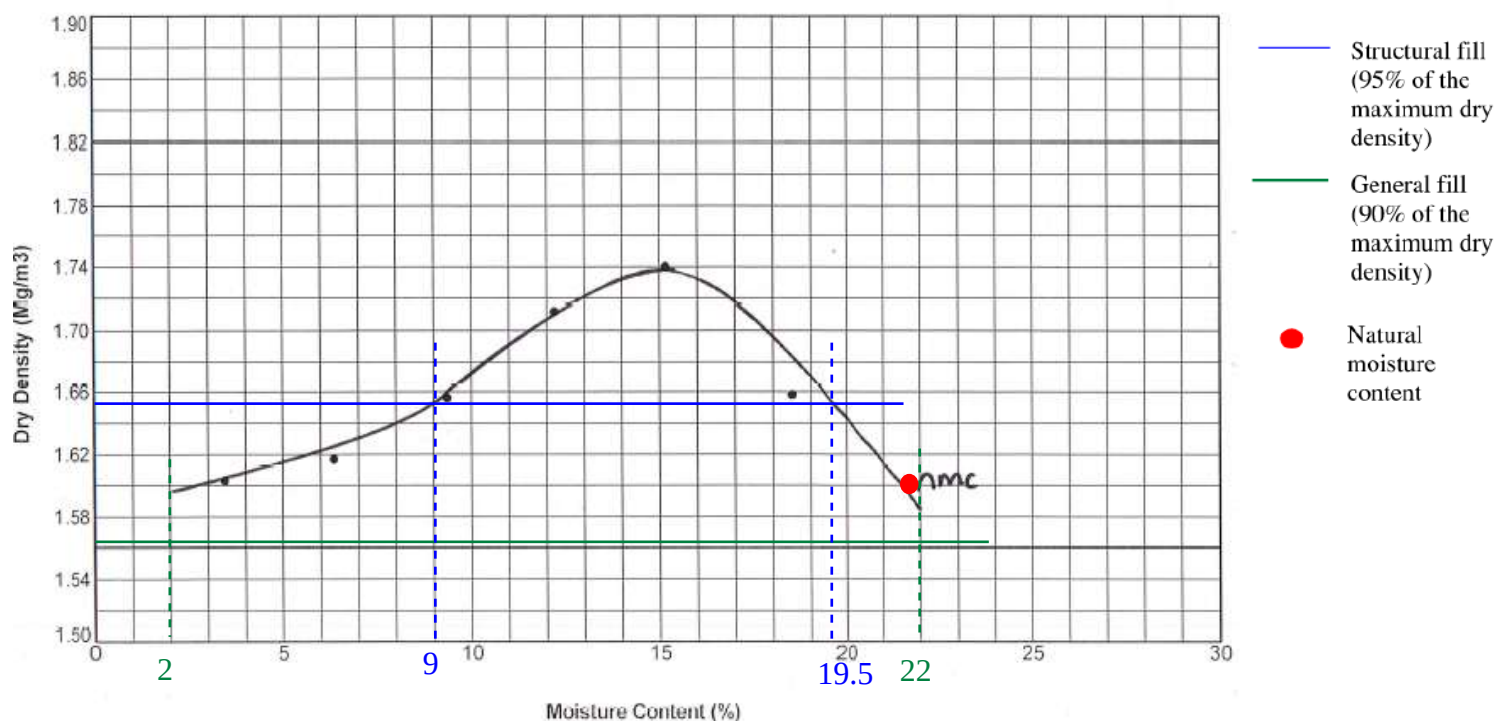
Particle Density (Assumed) = 2.50

Maximum Dry Density (Mg/m³) = 1.74

Retained on 20mm Sieve (%) = 0.0

Date Tested = 26/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (TP211 - 3.0m depth)

Chart 6O

Optimum Moisture Content (%) = 17

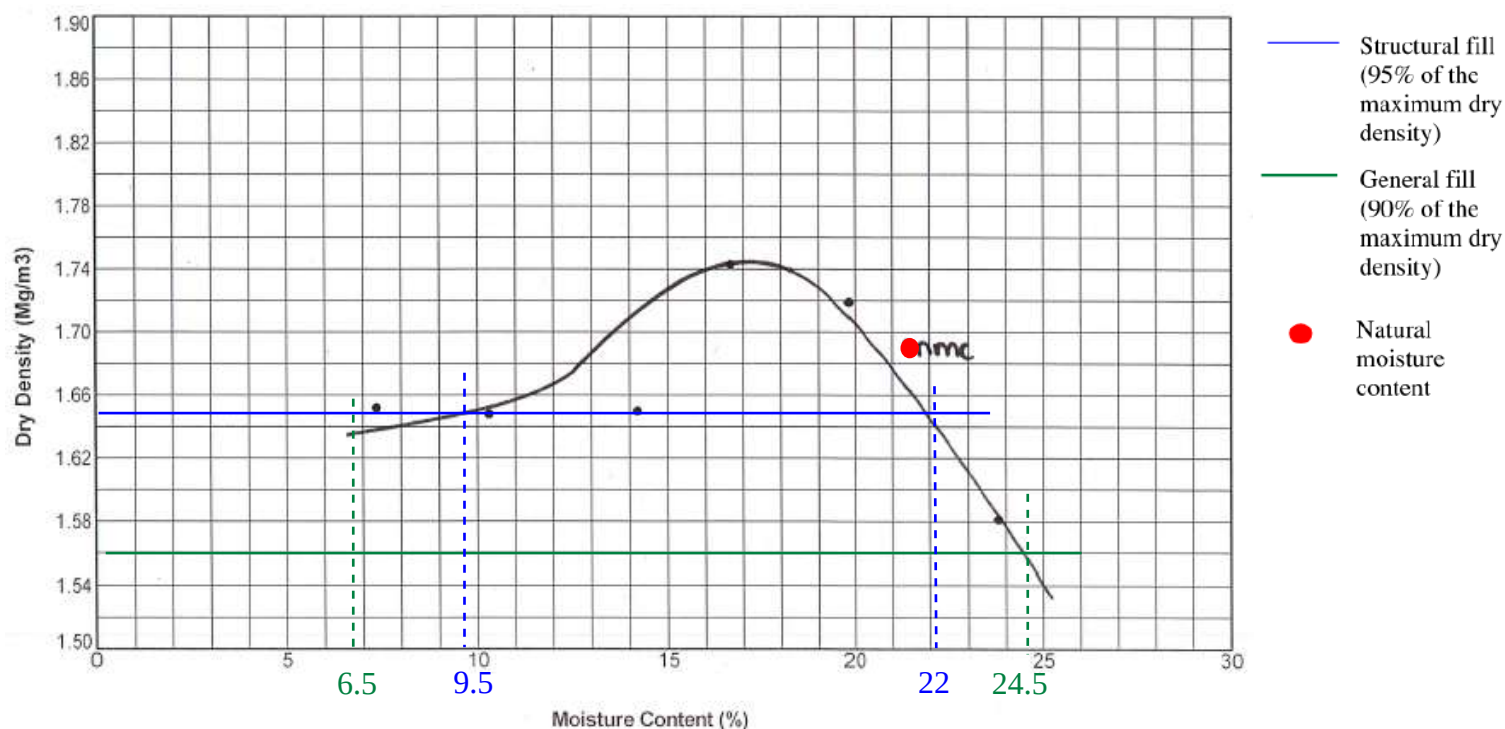
Particle Density (Assumed) = 2.70

Maximum Dry Density (Mg/m³) = 1.75

Retained on 20mm Sieve (%) = 0.9

Date Tested = 26/05/2021

Retained on 37.5mm Sieve (%) = 0.0



Range of acceptable moisture content indicated for suitable structural and general fill (TP212 - 2.0m depth)

Chart 6P

Optimum Moisture Content (%) = 23

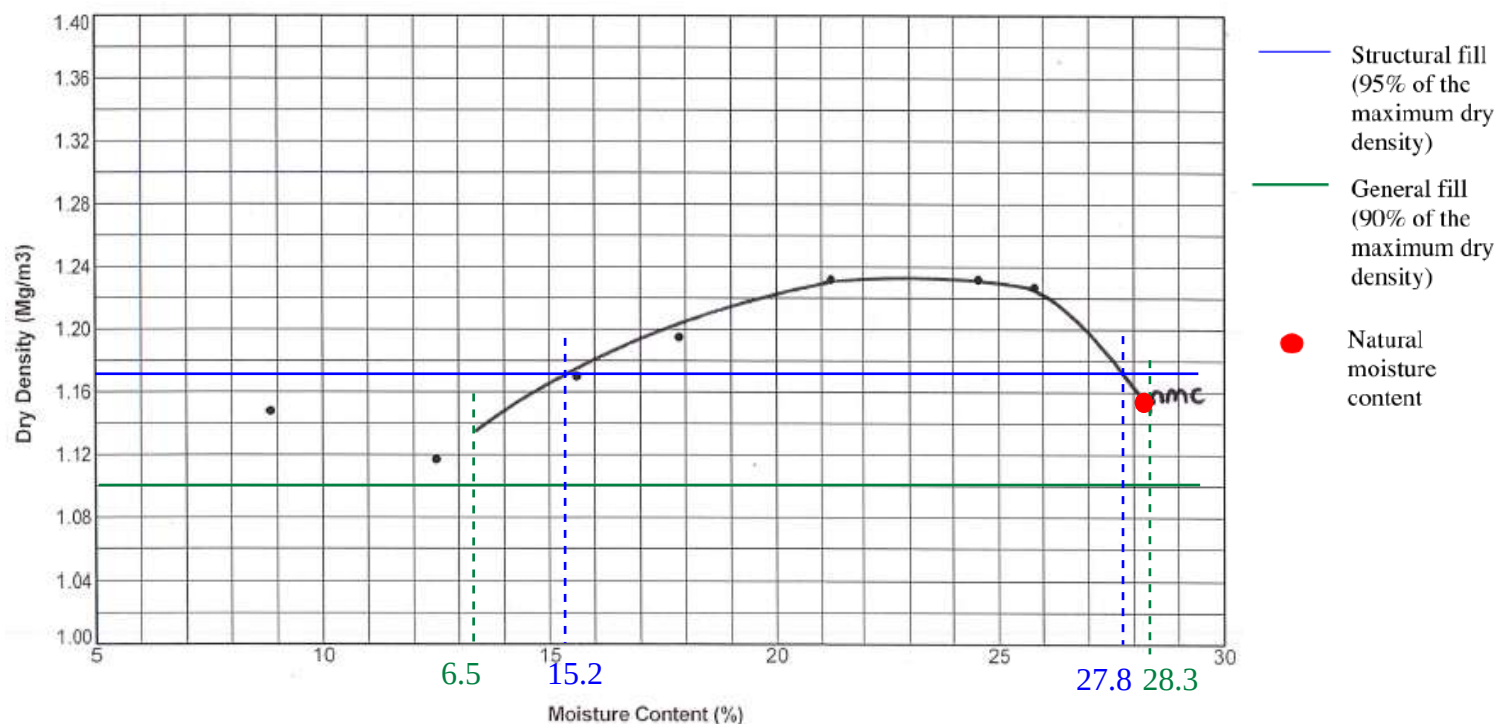
Particle Density (Assumed) = 1.80

Maximum Dry Density (Mg/m³) = 1.23

Retained on 20mm Sieve (%) = 4.6

Date Tested = 26/05/2021

Retained on 37.5mm Sieve (%) = 1.4



Range of acceptable moisture content indicated for suitable structural and general fill (TP215 - 3.0m depth) **Chart 6Q**

Optimum Moisture Content (%) = 11

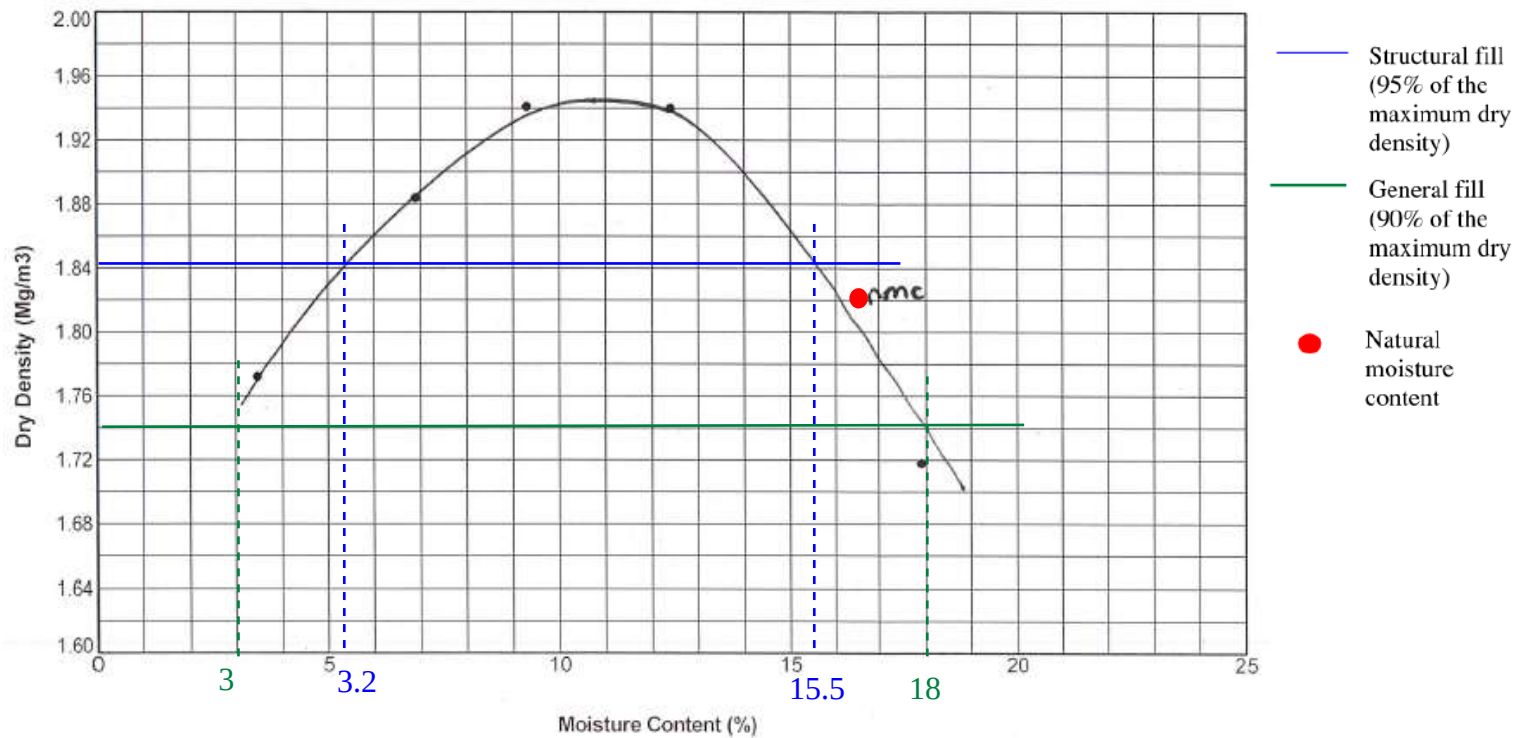
Particle Density (Assumed) = 2.65

Maximum Dry Density (Mg/m³) = 1.94

Retained on 20mm Sieve (%) = 9.1

Date Tested = 27/05/2021

Retained on 37.5mm Sieve (%) = 6.7



Appendix C - Soil and groundwater analysis and ground gas screening

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1 Generic quantitative risk assessment (GQRA) approach

The approach to assessing risks posed by contamination is outlined in the Environment Agency's land contamination guidance [1]. Assessment of risks to water resources is completed in general accordance with the Environment Agency 2017, Groundwater Protection guides [2] for England and Wales and with reference to Scottish Environment Protection Agency (SEPA) guidance WAT-PS-10-01 in Scotland [3].

The Environment Agency has developed specific guidance known as the Remedial Targets Methodology (RTM) [4] for the tiered assessment of risks to controlled waters. The first stage of quantitative risk assessment is undertaken by an initial screening of reported leachate and/or groundwater/surface water concentrations against selected published water quality standards (WQS) for potential contaminants of concern to identify those contaminants which warrant further detailed investigation.

The WQS are selected to assess potential risks to the controlled water receptors identified in the preliminary conceptual site model. The WQS can be derived in several ways with consideration to:

- whether the substance is classified as hazardous or non-hazardous under the Water Framework Directive (2000/60/EC) and Groundwater Daughter Directive (2006/118/EC);
- background concentrations in the aquifer; and
- published guidance such as Environmental Quality Standards (EQS) that are protective of surface waters or the Water Supply (Water Quality) Regulations 2016 that are protective of drinking water.

Where groundwater contamination has been identified, the general approach is to use a published environmental standard which is relevant to the current or intended use of the aquifer. The following regulations and guidance have been referenced to select appropriate WQS for controlled waters:

- Environmental Quality Standards (EQS) for fresh water and salt water
 - EQS listed in the Water Framework Directive (WFD) 2015 [5]
 - Other values not listed in WFD and taken from EA operational EQS [6] and/or SEPA non-statutory EQS [7]
- UK Drinking Water Standards (UK DWS) [8]
- EU Drinking Water Standards (EU DWS) [9]
- World Health Organisation (WHO) drinking water standards [10], [11]
- United States Environmental Protection Agency (USEPA) 2018 drinking water standards [12] and national aquatic life criteria [13]

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The use of published conservative WQS allows for an initial assessment of results. Results that are above the WQS do not necessarily represent a risk to controlled waters; alternative lines of evidence should be considered, such as (but not limited to):

- Background / upgradient groundwater and surface water concentrations or regional water quality. Assessment of the downgradient water quality.
- Assessment against alternative EQS, for example based on an average or hardness corrected WQS.
- Review of trends in concentrations (e.g. seasonal, tidal) and lateral/vertical distribution.
- Assessment of whether the concentration is erroneous or anomalous and has been biased, for example, because of high sediment content.
- Comparison against compound properties, such as solubility limit.
- Review of soil, soil leachate and groundwater concentrations and field records (e.g. logs, in situ monitoring) to establish whether there is a correlation.
- Consideration of the conceptual site model with assessment of contaminant linkages to establish whether there is a plausible pathway and/or receptor.
- Where a potentially unacceptable linkage remains, generation of site specific controlled waters assessment criteria should be considered based on a detailed quantitative risk assessment.

2 Water quality standards

As the controlled water receptors include groundwater within a Secondary aquifer and/or a freshwater surface watercourse, the freshwater EQS value has been prioritised as the most appropriate WQS for the potential contaminants of concern. Where no UK published value exists then other published values have been selected in the following hierarchy:

- UK DWS
- EU DWS
- WHO
- USEPA

The selected WQS used in this assessment are summarised in Table 1.

Table 1 Controlled waters WQS used for assessment

Determinant	Units	Screening criteria	Source	Justification
Metals				
Aluminium	µg/l	15	EQS ^A	EQS prioritised
Antimony	µg/l	5	DWS	DWS, as no EQS available
Arsenic	µg/l	50	EQS	EQS prioritised
Barium	mg/l	0.7	WHO	WHO, as no EQS available
Beryllium	µg/l	4	USEPA	USEPA, as no EQS available
Boron	mg/l	2	EQS ^A	EQS prioritised

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Determinant	Units	Screening criteria	Source	Justification
Cadmium	µg/l	≤0.08	EQS	EQS prioritised. Criteria dependent on hardness of receiving surface watercourse, lowest criteria assumed
Chromium	µg/l	4.7	EQS	EQS prioritised, total assumes Cr(III) and no Cr(VI)
Chromium (VI)	µg/l	3.4	EQS	EQS prioritised
Cobalt	µg/l	3	EQS ^A	EQS prioritised
Copper	µg/l	1	EQS	EQS prioritised. Based on bioavailable concentration assessed using M-BAT tool [15]
Iron	mg/l	1	EQS	EQS prioritised
Lead	µg/l	1.2	EQS	EQS prioritised. Based on bioavailable concentration assessed using Pb Screening tool [15]
Manganese	µg/l	123	EQS	EQS prioritised. Based on bioavailable concentration assessed using M-BAT tool [15]
Mercury	ug/l	1	DWS	DWS, as no EQS available
Nickel	µg/l	4	EQS	EQS prioritised. Based on bioavailable concentration assessed using M-BAT tool [15]
Selenium	ug/l	10	DWS	DWS, as no EQS available
Sodium	mg/l	200	EUDWS	EUDWS, as no EQS available
Vanadium	ug/l	20	EQS ^A	EQS prioritised. Criteria dependent on hardness of receiving surface watercourse, worst case criteria assumed
Zinc	µg/l	12.3	EQS	EQS prioritised. Based on bioavailable concentration assessed using M-BAT tool [15]. Criteria calculated based on ambient background concentration (ABC) of receiving surface watercourse and assumes ABC for non-listed freshwater in England and Wales
General Inorganics				
Ammoniacal nitrogen as NH ₄	mg/l	0.3	EQS	EQS prioritised
Bromate	µg/l	10	DWS	DWS, as no EQS available
Bromine	µg/l	2	EQS ^A	EQS prioritised
Chloride	mg/l	250	EQS ^A	EQS prioritised
Chlorine	µg/l	2	EQS	EQS prioritised
Conductivity	uS/cm	2500	DWS	DWS, as no EQS available
Cyanide	µg/l	1	EQS	EQS prioritised
Fluoride	mg/l	1	EQS ^A	EQS prioritised. Criteria dependent on hardness of receiving surface watercourse, lowest criteria assumed
Nitrate	mg/l	50	DWS	DWS, as no EQS available
Nitrite	mg/l	0.5	DWS	DWS, as no EQS available
pH	µg/l	6 to 9	EQS ^A	EQS prioritised
Sulphate	mg/l	400	EQS ^A	EQS prioritised
BTEX				
Benzene	µg/l	10	EQS	EQS prioritised

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Determinant	Units	Screening criteria	Source	Justification
Toluene	µg/l	74	EQS	EQS prioritised
Ethylbenzene	µg/l	20	EQS ^A	EQS prioritised
Xylene	µg/l	30	EQS ^A	EQS prioritised
Methyl tert butyl ether (MTBE)	µg/l	15	WHO	WHO, as no EQS available, threshold for taste and odour in drinking water
Petroleum Products				
Free product	No visible product		EQS*	EQS from CL:AIRE 2017 or assess against WHO TPH criteria
TPH				
TPH EC5-EC6 Aliphatic	µg/l	15000	WHO	WHO, as no EQS available
TPH >EC6-EC8 Aliphatic	µg/l	15000	WHO	WHO, as no EQS available
TPH >EC8-EC10 Aliphatic	µg/l	300	WHO	WHO, as no EQS available
TPH >EC10-EC12 Aliphatic	µg/l	300	WHO	WHO, as no EQS available
TPH >EC12-EC16 Aliphatic	µg/l	300	WHO	WHO, as no EQS available
TPH EC5-EC6 Aromatic	µg/l	10	WHO	WHO, as no EQS available
TPH >EC6-EC8 Aromatic	µg/l	700	WHO	WHO, as no EQS available
TPH >EC8-EC10 Aromatic	µg/l	300	WHO	WHO, as no EQS available
TPH >EC10-EC12 Aromatic	µg/l	90	WHO	WHO, as no EQS available
TPH >EC12-EC16 Aromatic	µg/l	90	WHO	WHO, as no EQS available
TPH >EC16-EC21 Aromatic	µg/l	90	WHO	WHO, as no EQS available
TPH >EC21-EC35 Aromatic	µg/l	90	WHO	WHO, as no EQS available
PAHs				
Acenaphthene	µg/l	2000	USEPA	USEPA, as no EQS available
Anthracene	µg/l	0.1	EQS	EQS prioritised
Benzo(a)pyrene	µg/l	0.00017	EQS	EQS prioritised. Benzo(a)pyrene is considered as a marker for other PAHs (benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene & indeno(123-cd)pyrene)
Fluoranthene	µg/l	0.0063	EQS	EQS prioritised
Naphthalene	µg/l	2	EQS	EQS prioritised
Phenols	µg/l			
Phenol	µg/l	7.7	EQS	EQS prioritised
2-chlorophenol	µg/l	50	EQS ^A	EQS prioritised
2,4 Dichlorophenol	µg/l	4.2	EQS	EQS prioritised
4-chloro-3-methylphenol	µg/l	40	EQS ^A	EQS prioritised
3-chlorophenol 4-chlorophenol total or individual monochlorophenols	µg/l	50	EQS ^A	EQS prioritised
Methylphenols	µg/l	100	EQS ^A	EQS prioritised
Nonylphenols	µg/l	0.3	EQS	EQS prioritised

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Determinant	Units	Screening criteria	Source	Justification
Octylphenols	µg/l	0.1	EQS	EQS prioritised
Pentachlorophenol	µg/l	0.4	EQS	EQS prioritised
VOCs				
1,1-Dichloroethene	µg/l	50	WHO	WHO, as no EQS available
1,2-Dibromoethane	µg/l	0.4	WHO	WHO, as no EQS available
1,2-Dichloroethane	µg/l	10	EQS	EQS prioritised
1,2-Dichlorobenzene	µg/l	1000	WHO	WHO, as no EQS available
1,2-Dichloropropane	µg/l	40	WHO	WHO, as no EQS available
1,2-Dibromo-3-chloropropane	µg/l	1	WHO	WHO, as no EQS available
1,3-Dichlorobenzene	µg/l	3000	USEPA	USEPA, as no EQS available
1,3-Dichloropropene	µg/l	20	WHO	WHO, as no EQS available
1,4-Dichlorobenzene	µg/l	300	WHO	WHO, as no EQS available
1,1,1-trichloroethane	µg/l	100	EQS ^A	EQS prioritised
1,1,2-trichloroethane	µg/l	400	EQS ^A	EQS prioritised
1,2,4-Trichlorobenzene	µg/l	70	USEPA	USEPA, as no EQS available
1,1,2,2-Tetrachloroethane	µg/l	400	USEPA	USEPA, as no EQS available
Bromodichloromethane	µg/l	60	WHO	WHO, as no EQS available
Bromoform	µg/l	100	WHO	WHO, as no EQS available
Carbon-tetrachloride (Tetrachloromethane)	µg/l	12	EQS	EQS prioritised
Chlorodibromomethane	µg/l	80	USEPA	USEPA, as no EQS available
Chloronitro toluenes	µg/l	10	EQS ^A	EQS prioritised
Dichloromethane	µg/l	20	EQS	EQS prioritised
Dibromochloromethane	µg/l	100	WHO	WHO, as no EQS available
Dichlorobromomethane	µg/l	80	USEPA	USEPA, as no EQS available
Dibromochloropropane	µg/l	0.2	USEPA	USEPA, as no EQS available
Hexachlorobutadiene	µg/l	0.6	WHO	WHO, as no EQS available
Tetrachloroethane	µg/l	140	EQS	EQS prioritised
Tetrachloroethene (PCE)	µg/l	10	EQS	EQS prioritised
Total Trihalomethanes (chloroform, bromoform, dibromomethane, bromodichloromethane)	µg/l	100	DWS	DWS, as no EQS available. Sum of concentrations for four listed determinants, chloroform has an individual EQS
Trichlorobenzenes	µg/l	0.4	EQS	EQS prioritised
Trichloroethene (TCE)	µg/l	10	EQS	EQS prioritised
Trichloromethane (Chloroform)	µg/l	2.5	EQS	EQS prioritised
Styrene	µg/l	50	EQS ^A	EQS prioritised
Vinyl chloride	µg/l	0.5	DWS	DWS, as no EQS available
SVOCs				
2,4-Dinitrotoluene	µg/l	100	USEPA	USEPA, as no EQS available
Bis(2-Chloro-1-methylethyl) Ether	µg/l	1000	USEPA	USEPA, as no EQS available

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Determinant	Units	Screening criteria	Source	Justification
Butylbenzyl phthalate	µg/l	7.5	EQS	EQS prioritised
Cypermethrin	µg/l	0.0001	EQS	EQS prioritised
Di(2-ethylhexyl)-phthalate	µg/l	1.3	EQS	EQS prioritised
Dibutyl phthalate	µg/l	8	EQS ^A	EQS prioritised
Dichlorobenzene - total dichlorobenzene isomers	µg/l	20	EQS ^A	EQS prioritised
Diethyl phthalate	µg/l	200	EQS ^A	EQS prioritised
Dimethyl phthalate	µg/l	800	EQS ^A	EQS prioritised
Dioctyl phthalate	µg/l	20	EQS*	EQS prioritised
Hexachlorobenzene	µg/l	1	USEPA	USEPA, as no EQS available
Hexachlorocyclopentadiene	µg/l	50	USEPA	USEPA, as no EQS available
Hexachloroethane	µg/l	40	USEPA	USEPA, as no EQS available
Isophorone	µg/l	7000	USEPA	USEPA, as no EQS available
Pentachloro-benzene	µg/l	0.007	EQS	EQS prioritised
PCBs				
Biphenyl	µg/l	25	EQS ^A	EQS prioritised
Notes: ^A EQS not listed in WFD and is based on EA operational EQS and/or SEPA non-statutory EQS ^B Freshwater EQS developed for copper, manganese, nickel and zinc have been derived as bioavailable EQS and takes into consideration pH, DOC and calcium concentrations of the water. The freshwater EQS for lead is not a full bioavailable EQS, and takes into account the influence of DOC on toxicity. The M-BAT tool and Pb screening tool are used to determine the bioavailable concentrations of these metals based on local water chemistry data				

3 References

- [1] Environment Agency, 2019. Land contamination: risk management
<https://www.gov.uk/guidance/land-contamination-how-to-manage-the-risks>
- [2] Environment Agency, 2017. Groundwater protection
<https://www.gov.uk/government/collections/groundwater-protection>
- [3] Scottish Environment Protection Agency (SEPA), 2014. Position Statement (WAT-PS-10-01) Assigning groundwater assessment criteria for pollutant inputs, v3.0
August 2014
- [4] Environment Agency, 2006. Remedial targets methodology, hydrogeological risk assessment for land contamination
- [5] Water Framework Directive (Standards and Classification) Directions (England and Wales)
2015
- [6] Environment Agency. Surface water pollution risk assessment for your environmental permit
<https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit>

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- [7] Scottish Environment Protection Agency (SEPA), 2018. Supporting Guidance (WAT-SG-53) Environmental Quality Standards and Standards for Discharges to Surface Waters. v6.1 February 2018
- [8] Water Supply (Water Quality) Regulations 2016
- [9] Drinking Water Directive 98/83/EC, November 1998, amended October 2015
- [10] World Health Organisation (WHO), 2017. Guidelines for drinking water quality: fourth edition incorporating the first addendum
- [11] World Health Organisation (WHO), 2008. Petroleum products in drinking-water. WHO/SDE/WSH/05.08/123
- [12] United States Environmental Protection Agency (USEPA), 2018. 2018 edition of the drinking water standards and health advisories tables, EPA 822-F-18-001
- [13] United States Environmental Protection Agency (USEPA). National recommended water quality criteria - aquatic life criteria table <https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table> [accessed January 2019]
- [14] CL:AIRE, 2017. Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies. CL:AIRE, London
- [15] Water Framework Directive - United Kingdom Technical Advisory Group (WFD-UKTAG), 2014. UKTAG river and lake assessment method specific pollutants (metals) metals bioavailability assessment tool (M-BAT)

Generic assessment criteria (GAC)

Generic assessment criteria (GAC) and Category 4 screening levels (C4SL) have been used as initial screening tool to assess whether further action may be necessary to mitigate an identified pollutant linkage, based on the results of the investigation of the potential sources and plausible pollutant linkages identified by the conceptual model.

Where all reported sample concentrations are below the screening values and the site complies with the assumptions behind the assessment criteria, then it can be regarded as suitable for use without remediation.

If the results exceed the screening assessment criteria then either further detailed assessment is provided or recommendations for mitigation such as risk management procedures and remediation have been provided.

GAC values have been calculated using the Contaminated Land Exposure Assessment (CLEA) model software (v1.07) developed by the Environment Agency and published in 2015. The model estimates human exposure to soil contaminants for those potentially living, working and/or playing on contaminated sites over long time periods (chronic exposure). The CLEA model does not include short-term (acute) risks to humans or risks from groundwater to humans.

The CLEA model includes the following generic land uses, for which GAC can be developed by the user:

- Residential development including homegrown produce consumption (assumed to be from private gardens within the development)
- Residential development without homegrown produce consumption
- Allotments
- Commercial
- POSresi Public Open Space forming part of a residential development
- POSpark Public Open Space park

Soil organic matter content can influence the retention and transport of organic contaminants in soils and generic criteria have been developed for soil organic matter content of 1, 2.5 and 6%. This is in line with UK guidelines. The soil testing results have been compared to generic screening criteria based on the proposed land use at the site and conservative organic matter content assumptions.

Chemical, physical and toxicological data sources

Data published by the Environment Agency for CLEA

Full toxicological and physical/chemical data has been published by the Environment Agency for eleven chemicals. The data for these chemicals is embedded within the CLEA v1.07 software. In addition, physical/chemical data for selected organic pollutants for use in

environmental risk assessment has been published by the Environment Agency^{1,2} which has been used where available.

Category 4 Screening Levels and Lead

The revised Statutory Contaminated Land Guidance published in April 2012³ presented a new “four category system” for considering land under Part 2A. This ranged from Category 4, where there is no risk that land poses a significant possibility of significant harm (SPOSH), to Category 1, where the risk that land poses SPOSH is unacceptably high. The Statutory Guidance stated that “new technical tools and advice may be developed and used.... to help regulators and others conform to this Guidance.” To support this, Defra funded a research project to deliver:

- A methodology for deriving C4SLs for five generic land-uses comprising residential, commercial, allotments and public open space (park and residential); and
- A demonstration of the methodology, via the derivation of C4SLs for six substances: arsenic, benzene, benzo(a)pyrene, cadmium, chromium (VI) and lead.

The output of this research has been published as a Final Project Report with appendices detailing the individual contaminants and a Defra Policy Companion Document⁴. C4SLs “are designed to reflect a more pragmatic approach to contaminated land risk assessment (albeit still strongly precautionary)”. They represent a risk that is higher than “minimal” and describes land that is clearly not contaminated land.

It is recognised that C4SLs were designed to support the Statutory Contaminated Land framework i.e. Part 2A assessments and were not specifically designed for use within the National Planning Policy Framework. In their Policy Companion Document⁴, Defra stated that C4SLs could be used in planning matters. This was later clarified in a letter from Lord de Mauley to Local Authorities⁵, which stated that the “Impact Assessment agreed during the revision of the Part 2A Statutory Guidance was developed on the basis that C4SLs could be used under the planning regime, as well as within Part 2A. This intent is reflected within DCLG’s Planning Practice Guidance on Land Affected by Contamination, which was revised on 12 June 2014 and now includes reference to the use of C4SLs in risk assessment under planning”.

As a precautionary measure, because C4SLs do not represent “minimal risk”, Arup continues to use GACs as an initial screen and then C4SLs to further assess the risk if necessary. The exception to this is lead, for which Arup has not developed a GAC and therefore uses the C4SL for lead as a GAC in the generic screening of soil data. For several land uses, the lead C4SL is lower than the published background level for lead. As such Defra recommends a “pragmatic approach” whereby the use of the ‘normal’ background concentration is used as

¹ Environment Agency (2003) Review of the Fate and Transport of Selected Contaminants in the Soil Environment. Technical Report P5-079/TR1

² Environment Agency (2008) Compilation of data for priority organic pollutants for derivation of Soil Guideline Values. Science Report: SC050021/SR7

³ Defra (2012) Environmental Protection Act 1990: Part 2A: Contaminated Land Statutory Guidance.

⁴<http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18341>

⁵ Defra, 3rd September 2014, Letter from Lord de Mauley, Parliamentary Under Secretary to All Local Authorities.

an assessment criterion when the land-use and domain permit it, “so as not to disproportionately target land where there is widespread diffuse pollution of lead”.⁶

LQM/CIEH S4ULs

Generic Assessment Criteria (GAC) together with supporting physical/chemical and health criteria values have been published by LQM/CIEH in the document “The LQM/CIEH S4ULs for Human Health Risk Assessment”⁷. Arup has critically reviewed the data within this document and generated GACs using CLEA v1.07 for the contaminants within it, using the input parameters provided in the S4UL document. In some cases, the Arup GACs differ to those generated by LQM, as a result of different exposure assumptions and input parameters being used, where Arup felt these were more appropriate or precautionary.

CL:AIRE/EIC/AGS GAC

In January 2010, CL:AIRE, together with the AGS and EIC, published peer-reviewed GACs for 35 contaminants, together with the supporting chemical, physical and toxicological data⁸ using the CLEA methodology. Arup has critically reviewed the data within this document and generated GACs using CLEA v1.07 for the contaminants within it. The Arup GACs differ to some of those generated by CL:AIRE/EIC/AGS, as a result of the use of an updated version of the CLEA software and different exposure assumptions.

Exposure assumptions made in Generating Arup GACs

In generating the Arup GAC, the exposure assumptions used to develop the C4SLs have been adopted in preference to those described in the Environment Agency’s SR3 publication⁹. These revised exposure assumptions are embedded within the CLEA v1.07 software, alongside the unmodified SR3 exposure assumptions.

When reporting GAC for many organic compounds, the CLEA software does not cap exposure at the solubility or vapour saturation limits, meaning that GACs can be generated which exceed the theoretical saturation limit. Where this has occurred when generating the Arup GACs, the saturation limit has been quoted in parentheses next to the GAC. For sites where the vapour pathway will dominate the exposure in the developed condition of the site, if no other pathways are considered to be active (the soil being covered with buildings and hardstanding) and where the soil concentrations measured on site exceed the theoretical saturation limits, consideration has been given to the possibility that free product may be present. The Environment Agency advises that where the vapour pathway is the only route of exposure considered, and the resulting assessment criterion exceeds the theoretical saturation limit, exposure is unlikely to reach the relevant HCV and the risk based on the assumed conceptual model is likely to be negligible.

The Arup GAC for phenol are based on the approach taken by LQM/CIEH in developing their S4ULs, namely in order to be protective of direct bodily contact with phenol-contaminated soils and account for uncertainties in the modelling, the GAC has been limited

⁶ Defra (2014) Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination (SP1010): Policy Companion Document, March 2014

⁷ Copyright Land Quality Management Limited reproduced with permission; Publication number S4UL3213. All rights reserved.

⁸ CL:AIRE/EIC/AGS (2010) Soil Generic Assessment Criteria for Human Health Risk Assessment

⁹ Environment Agency (2009) Updated technical background to the CLEA model. Science Report: SC050021/SR3.

to a level at which the corresponding soil solution concentration would be 1g/L (i.e. 0.1% by weight). Two GACs have therefore been derived for phenol; one set at the chronic exposure level calculated using CLEA v1.07 or the soil concentration associated with a soil solution of 0.1% by weight. Depending on the conceptual site model, either GAC could be selected.

Arup GAC for chronic and acute inorganic cyanide exposure

A chronic exposure GAC has been derived by Arup using the CLEA v1.07 software and toxicological information published by the Environment Agency for this contaminant in the TOX5 report¹⁰. Physical/chemical information for inorganic cyanide has been collated by Arup for the purposes of deriving a GAC.

An acute exposure GAC has also been derived by Arup. The TOX 5 report notes that free and simple cyanide have a high acute toxicity and that the conceptual exposure model should be based on a single short-term exposure event, although an approved methodology for this assessment is not provided. In the absence of further guidance from the Environment Agency/DEFRA the TOX5 assumptions for toxicity have been used.

A soil ingestion rate for an acute, one-off episode of pica (the exploratory, deliberate eating of soil) has been ascertained from a review of suitable reference documents. The technical support document to the CLEA model (SR3) summarises some of the literature in this area and highlights how approximately one child out of 600 children whose soil ingestion rates were studied exhibited pica behaviour at an observed ingestion rate of up to 13.6 g/day, although the same child was found to have an overall mean ingestion rate of five to six grams per day¹¹. ATSDR assume that soil-pica children ingest 5000mg (5g) of soil per day, although an expert panel noted that this ingestion rate appeared to be supported by only a few subjects in soil ingestion studies (two children in Massachusetts and several children in Jamaica). It was agreed that ATSDR should err on the side of caution and use the 5g ingestion rate until more data had been collected.¹²

Based on this information, the One Time Soil Ingestion Rate (OTSIR) adopted for an acute episode of pica (the exploratory, deliberate eating of soil) is based on a one-off dose of 5g (equivalent to one teaspoon), a value which has also been used by the UK Health Protection Agency in the assessment of acute cyanide exposure¹³.

It is noted that the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) methodology for the calculation of an acute cyanide value has now been withdrawn (2003)¹⁴. However, in the absence of further guidance the methodology described below (taken from the SNIFFER cyanide worksheet has been used to derive a numeric assessment value for short-term exposure (soil ingestion) of free cyanide.

The relevant equation is: $RTC = (TF \times BW) / OTSIR$

¹⁰ Defra and the Environment Agency (2002) Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. R&D Publication TOX5.

¹¹ Defra and Environment Agency (2009) Updated technical background to the CLEA model. Science Report: SC050021/SR3

¹² http://www.atsdr.cdc.gov/child/executive_summary.html

¹³ <http://www.sobra.org.uk/content/presentations/Dec%202012%20conference/Yolande%20Mackin.pdf>

¹⁴ SNIFFER (April 2000). Framework for Deriving Numeric Targets to Minimise the Adverse Human Health Effects of Long-term Exposure to Contaminants in Soil (Report No: SR 99(0) F). The second edition of the SNIFFER method was published in April 2003 (Report No: LQ01).

where:

RTC = reference target concentration (mg kg⁻¹ bw) or Acute Generic Assessment Criteria (Acute GAC)

TF = appropriate toxicological factor (mg kg⁻¹ bw), TF = lowest published lethal dose (LDLO) /uncertainty factor (UF), or Tolerable Daily Intake (TDI)

BW = body weight (kg)

OTSIR = one-time soil ingestion rate (kg soil)

There is very little toxicological data on the lowest known acute dose of cyanide. Defra and the Environment Agency (2002) report a TDI of 0.012mg/kg bw/day.

For a residential scenario, a female child is assumed to be the critical receptor, in line with CLEA guidance. For a one-time soil ingestion it is suggested that 9.8kg should be used as a default body weight (mean female body weight for an 18-month-old child given in SR1), given that children of this age would be expected to exhibit the type of hand-to-mouth exploratory behaviour which could lead to acute soil ingestion. There is evidence that pica behaviour has been observed in older children, but an 18-month-old is selected for the development of a GAC as a conservative measure, since the bodyweight will be lower. 5g (0.005kg) of soil has been selected as an appropriate OTSIR.

The acute cyanide GAC for an 18-month-old child in a residential/allotment exposure scenario is therefore as follows:

Acute cyanide GAC = (0.012 mg kg⁻¹ bw x 9.8kg bw)/0.005 kg = 23.5 rounded to 24 mg kg⁻¹

For a commercial scenario, the female worker is taken to be the critical receptor in line with CLEA guidance and it is suggested that the 70kg body weight should be used (mean adult body weight SR1) and 5g (0.005kg) of soil as an appropriate OTSIR, as for the child exposure scenario.

The acute cyanide GAC for an adult in a commercial exposure scenario is therefore as follows:

Acute cyanide GAC = (0.012 mg kg⁻¹ bw x 70kg bw)/0.005 kg = 168 mg kg⁻¹

This methodology is not applicable to acute inhalation of inorganic free cyanides. It is noted that the commercial scenario criteria assumes a female worker is the critical receptor and the calculated criteria is therefore not applicable to commercial land-uses which are designed for children, this may include crèche, playground or leisure facilities.

Screening protocol for asbestos

Recent guidance¹⁵ confirms that the assessment of asbestos on the basis of comparison with a generic screening criterion is not appropriate. As a precautionary measure, the asbestos laboratory detection limit (0.001%) has been taken as the initial screening criterion.

¹⁵ Ciria (2014) Asbestos in soil and made ground: a guide to understanding and managing risks. Publication C733.

Screening protocol where no GAC exists

Some contaminants have been analysed but no GAC or other authoritative UK screening value (e.g. C4SL, SGV) exists. Where GACs have not been developed, this is usually due to a low level of confidence in the available data on the toxicity of the contaminant, to the extent that the development of a GAC using the data may not be sufficiently protective of health.

Comparing chemicals against GACs for chemically similar compounds (termed “surrogates” here) can be appropriate in some cases, and is the approach commonly adopted for volatile and semi-volatile chemicals.

Where volatile chemicals are present in excess of their respective laboratory limits of detection, they are considered to be of potential concern to health. Where volatile chemicals are not present above the laboratory limits of detection, they have been ruled out as potential contaminants of concern. This approach is considered to be in line with the principle of ‘As Low As Reasonably Practicable’ (ALARP), in that if the contaminants were present in significant quantity as a result of previous on-site processes, they would be capable of detection in parts per million quantities (the level of detection typically used for VOCs).

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	01_BH103	01_BH105	GEO_BH201	GEO_BH202	GEO_BH204	GEO_BH205
Sample Ref	1	1	200	200	200	200
Easting	384689.014	384463.735	384762.04	384723.888	384815.474	384689.078
Northing	399695.588	399571.588	399820.851	399716.141	399703.59	399735.153
Hole Elevation (mOD)	42.57	40.666	43.4	42.663	43.276	42.578
Sample Depth (mbgl)	0.9	4.52	4.95	4.19	2.36	5.68
Piezometer top (mbgl)	1	3	3	4	1.5	4.8
Piezometer base (mbgl)	3.5	9.5	5	9	10	10.8
Sample Date	24/01/19	24/01/19	11/08/21	11/08/21	11/08/21	11/08/21
Investigation			NW1604	NW1604	NW1604	NW1604
Aquifer						

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile							
Metal															
Antimony	0.005	DWS	mg/l	11 of 13	2	<0.00017	0.010497	0.00921	0.010497	0.008356	0.001377	<0.00017	<0.00017	0.000258	
Arsenic	0.01	DWS	mg/l	13 of 13	1	0.000551	0.019811	0.01217	0.002782	0.000566	0.007084	0.002689	0.002991	0.000551	
Beryllium	0.004	USEPA	mg/l	1 of 13	0	<0.0001	0.000142	0.00012	0.000142	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Cadmium	0.00008	EQS	mg/l	8 of 13	8	<0.00003	0.000968	0.0009	0.000098	0.000126	<0.00003	<0.00003	<0.00003	0.000295	
Calcium	-	-	mg/l	No GAC	-	37	190	184.0	110	120	37	100	160	91	
Chromium	0.0047	EQS	mg/l	8 of 13	1	<0.00025	0.007823	0.00372	0.007823	<0.00025	0.000387	<0.00025	<0.00025	<0.00025	
Copper	0.001	EQS	mg/l	8 of 13	7	<0.0004	0.007768	0.00744	0.003015	0.002675	0.005786	<0.0004	<0.0004	<0.0004	
Lead	0.0012	EQS	mg/l	9 of 13	1	<0.00009	0.001893	0.0013	0.001893	0.000204	0.000119	<0.00009	<0.00009	<0.00009	
Magnesium	-	-	mg/l	No GAC	-	9.9	29	28.60						29	
Manganese	-	-	mg/l	No GAC	-	0.004903	2.7502	2.270	2.7502	0.82475	0.004903	1.248446	1.950535	0.280095	
Mercury	0.001	DWS	mg/l	3 of 13	0	<0.00001	0.000023	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000023	
Nickel	0.004	EQS	mg/l	10 of 13	4	<0.0005	0.014998	0.00987	0.006447	0.003437	<0.0005	0.002072	<0.0005	<0.0005	
Potassium	-	-	mg/l	No GAC	-	7.1	21	19.40						7.2	
Selenium	0.01	DWS	mg/l	9 of 13	1	<0.00025	0.032081	0.01696	0.005043	0.00119	0.000756	<0.00025	<0.00025	0.000611	
Sodium	200	EUDWS	mg/l	5 of 5	0	8.2	120	103.60						8.2	
Vanadium	0.02	EQS*	mg/l	5 of 13	0	<0.0006	0.003487	0.00309	0.003487	0.001072	0.002327	<0.0006	<0.0006	<0.0006	
Zinc	0.0123	EQS	mg/l	10 of 13	8	<0.0013	0.101119	0.10665	0.013066	0.019094	<0.0013	<0.0013	<0.0013	0.015462	
Inorganic															
pH	<6 - >9	EQS*	pH Units	No GAC	-	6.9	8.1	7.740	7.4	7.3	8.1	7.5	7.5	7.5	
Cyanide	0.001	EQS	mg/l	0 of 13	0	<0.04	<0.04	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	
Complex Cyanide	0.001	EQS	mg/l	3 of 3	1	0.00061	0.008794	0.00798							
Cyanide Free	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02							
Thiocyanate	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02							
Chloride	250	EQS*/DW:	mg/l	13 of 13	1	4.4	320	158.60	29	29	4.4	320	15	16	
Ammoniacal Nitrogen as N	0.3	EQS	mg/l	13 of 13	8	0.05	16	9.760	3.8	1.3	0.34	0.12	0.36	0.11	
Dissolved Organic Carbon	-	-	mg/l	No GAC	-	<2	24	19.80	17	2.5	15	7.7	24	<2	
Total hardness	-	-	mg/l	No GAC	-	115	589	578.80	359	369	115	501	511	366	
Nitrate as NO3	50	DWS	mg/l	4 of 5	0	0.18	12	10.080						0.78	
Nitrite as NO2	0.5	DWS	mg/l	1 of 5	0	<0.1	<0.5	0.5						0.43	
Sulphate as SO4	250	DWS	mg/l	5 of 5	0	30	150	146.0						70	
Sulphide	-	-	mg/l	No GAC	-	0.01636	0.212521	0.18934						0.02502	
Total Alkalinity as CaCO3	-	-	mg/l	No GAC	-	380	640	632.0						380	
Phenol and mineral oils															
Phenol	0.0077	EQS	mg/l	0 of 2	0	<0.0001	<0.001	0.00096							
Phenol (Monohydric)	0.0077	EQS	mg/l	0 of 13	0	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Phenols, Total	-	-	mg/l	No GAC	-	<0.002	<0.002	0.002							
Cresols	-	-	mg/l	No GAC	-	<0.0001	<0.0001	0.0001							
TPH															
Aliphatics >C10-12	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001					
Aliphatics >C12-16	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001					
Aliphatics >C16-21	-	-	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001	<0.001					
Aliphatics >C21-35	-	-	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001	<0.001					
Aliphatics >C35-44	-	-	mg/l	No GAC	-	<0.001	<0.001	0.001							
Aliphatics >C5-35	-	-	mg/l	No GAC	-	<0.01	<0.01	0.01	<0.01	<0.01					
Aliphatics >C5-6	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001					
Aliphatics >C6-8	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001					
Aliphatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001					
Aromatics >C10-12	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001					
Aromatics >C12-16	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001					

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

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Sample Ref	1	1	200	200	200	200
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Investigation			NW1604	NW1604	NW1604	NW1604
Aquifer						

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile		
Aromatics >C16-21	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001
Aromatics >C21-35	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001
Aromatics >C35-44		-	mg/l	No GAC	-	<0.001	<0.001	0.001		
Aromatics >C5-7	0.01	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Aromatics >C7-8	0.7	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Aromatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Aromatics >C10-44			mg/l	No GAC	-	<0.001	<0.001	0.001		
Total Aliphatics and Aromatics C10-C44			mg/l	No GAC	-	<0.001	<0.001	0.001		
Total Aliphatics and Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01	<0.01	<0.01
Total Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01	<0.01	<0.01
PAH										
Acenaphthene	2	USEPA	mg/l	2 of 4	0	<0.00001	0.001126	0.00111	0.000409	<0.00001
Dibenz-a-h-anthracene		-	mg/l	No GAC	-	<0.00001	0.015089	0.01301	<0.00001	<0.00001
Fluoranthene	0.000006	EQS	mg/l	3 of 4	3	<0.00001	0.019478	0.01766	0.000058	<0.00001
Fluorene		-	mg/l	No GAC	-	<0.00001	0.001201	0.00117	0.000184	<0.00001
Indeno(1,2,3-cd)pyrene		-	mg/l	No GAC	-	<0.00001	0.064903	0.05567	<0.00001	<0.00001
Phenanthrene		-	mg/l	No GAC	-	<0.00001	0.006666	0.00607	0.000167	<0.00001
Pyrene		-	mg/l	No GAC	-	<0.00001	0.021859	0.01972	0.000055	<0.00001
Napthalene	0.002	EQS	mg/l	1 of 4	0	<0.00005	<0.001	0.00097	0.000808	<0.00005
Pah,Total		-	mg/l	No GAC	-	<0.0002	0.359917	0.32411	0.001863	<0.0002
Acenaphthylene		-	mg/l	No GAC	-	<0.00001	<0.001	0.00085	0.000011	<0.00001
Anthracene	0.0001	EQS	mg/l	3 of 4	3	<0.00001	0.002814	0.00255	0.000111	<0.00001
Benzo(a)anthracene		-	mg/l	No GAC	-	<0.00001	0.012339	0.01117	0.000014	<0.00001
Benzo (g,h,i) perylene		-	mg/l	No GAC	-	<0.00001	0.073465	0.06308	<0.00001	<0.00001
Benzo(a)pyrene	0	EQS	mg/l	2 of 4	2	<0.00001	0.049364	0.04291	<0.00001	<0.00001
Benzo(b)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.054044	0.04726	<0.00001	<0.00001
Benzo(k)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.021665	0.01871	<0.00001	<0.00001
Chrysene		-	mg/l	No GAC	-	<0.00001	0.015904	0.0141	0.000047	<0.00001
BTEX										
Benzene	0.001	DWS	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001
Toluene	0.074	EQS	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001
Ethylbenzene	0.02	EQS*	mg/l	0 of 4	0	<0.001	<0.001	0.001	<0.001	<0.001
O-Xylene	0.03	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		
Xylene	0.03	EQS*	mg/l	0 of 3	0	<0.001	<0.001	0.001	<0.001	<0.001
m,p xylenes	0.03	EQS*	mg/l	0 of 1	0	<0.002	<0.002	0.002		
VOC										
1,1,1,2-Tetrachloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001		
1,1,1-Trichloroethane	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,1,2,2-Tetrachloroethane	0.14	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,1,2-Trichloroethane	0.4	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,1-Dichloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001		
1,1-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,1-Dichloropropene			mg/l	No GAC	-	<0.001	<0.001	0.001		
1,2,3 Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,2,3-Trichloropropane			mg/l	No GAC	-	<0.001	<0.001	0.001		
1,2,4-Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,2,4-Trimethylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001		
1,2-Dibromo-3-Chloropropane	0.001	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,2-Dibromoethane	0.0004	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		
1,2-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

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Investigation			NW1604	NW1604	NW1604	NW1604
Aquifer						

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile
1,2-Dichloroethane	0.003	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,2-Dichloropropane	0.04	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,3,5-Trimethylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
1,3-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.002	<0.002	0.002
1,3-Dichloropropane			mg/l	No GAC	-	<0.001	<0.001	0.001
1,4-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
2,2-Dichloropropane			mg/l	No GAC	-	<0.002	<0.002	0.002
2-Chlorotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001
4-Chlorotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001
4-Isopropyltoluene			mg/l	No GAC	-	<0.001	<0.001	0.001
Bromobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Bromochloromethane			mg/l	No GAC	-	<0.004	<0.004	0.004
Bromodichloromethane	0.06	WHO	mg/l	0 of 1	0	<0.004	<0.004	0.004
Bromomethane			mg/l	No GAC	-	<0.001	<0.001	0.001
Chlorobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Chloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001
Chloroethene	0.0005	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Chloroform	0.0025	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Chloromethane			mg/l	No GAC	-	<0.001	<0.001	0.001
Dibromochloromethane	0.1	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
Dibromomethane	0.02	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Dichlorodifluoromethane			mg/l	No GAC	-	<0.001	<0.001	0.001
Dichloromethane	0.02	EQS	mg/l	0 of 1	0	<0.027	<0.027	0.027
Hexachlorobutadiene (HCBD)	0.0006	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
Isopropylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Methyl tert-butyl ether (MTBE)	0.015	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
Sec-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Styrene	0.05	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Tert-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Tetrachloroethene	0.01	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Tetrachloromethane (Carbon Tetra Chloride)	0.003	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Tribromomethane	0.1	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
Trichloroethene	0.01	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Trichlorofluoromethane			mg/l	No GAC	-	<0.001	<0.001	0.001
cis-1,2-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
n-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
n-propylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
trans-1,2-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
trans-1,3-Dichloropropene	0.02	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
SVOC								
2,4,5-Trichlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001
2,4,6-Trichlorophenol	0.2	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
2,4-Dichlorophenol	0.0042	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
2,4-Dimethylphenol	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
2,4-Dinitrotoluene	0.1	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001
2,6-Dinitrotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001
2-Chloronaphthalene			mg/l	No GAC	-	<0.001	<0.001	0.001
2-Chlorophenol	0.05	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
2-Methylnaphthalene			mg/l	No GAC	-	<0.001	<0.001	0.001
2-Methylphenol	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	01_BH103	01_BH105	GEO_BH201	GEO_BH202	GEO_BH204	GEO_BH205
Sample Ref	1	1	200	200	200	200
Easting	384689.014	384463.735	384762.04	384723.888	384815.474	384689.078
Northing	399695.588	399571.588	399820.851	399716.141	399703.59	399735.153
Hole Elevation (mOD)	42.57	40.666	43.4	42.663	43.276	42.578
Sample Depth (mbgl)	0.9	4.52	4.95	4.19	2.36	5.68
Piezometer top (mbgl)	1	3	3	4	1.5	4.8
Piezometer base (mbgl)	3.5	9.5	5	9	10	10.8
Sample Date	24/01/19	24/01/19	11/08/21	11/08/21	11/08/21	11/08/21
Investigation			NW1604	NW1604	NW1604	NW1604
Aquifer						

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile
4-Bromophenyl Phenyl Ether			mg/l	No GAC	-	<0.001	<0.001	0.001
4-Chloro-3-Methylphenol	0.04	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
4-Nitrophenol			mg/l	No GAC	-	<0.001	<0.001	0.001
Bis(2-chloroethoxy)methane			mg/l	No GAC	-	<0.001	<0.001	0.001
Bis(2-ethylhexyl)phthalate	0.0013	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Butylbenzylphthalate	0.0075	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Carbazole			mg/l	No GAC	-	<0.001	<0.001	0.001
Di-N-Butyl Phthalate	0.008	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Di-N-Octyl Phthalate	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Dibenzofuran			mg/l	No GAC	-	<0.001	<0.001	0.001
Diethylphthalate	0.2	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Dimethylphthalate	0.8	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Hexachlorobenzene (HCB)	0.001	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001
Hexachlorocyclopentadiene	0.05	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001
Pentachlorophenol (PCP)	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
Other								
2,3,4,6-Tetrachlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001
2,3,5,6-Tetrachlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001
2-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001
3-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001
3/4 Methylphenol			mg/l	No GAC	-	<0.001	<0.001	0.001
4-Chlorophenyl Phenyl Ether			mg/l	No GAC	-	<0.001	<0.001	0.001
4-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001
Aliphatics >C10-44			mg/l	No GAC	-	<0.001	<0.001	0.001
Aniline			mg/l	No GAC	-	<0.001	<0.001	0.001
Azobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Benzyl Alcohol			mg/l	No GAC	-	<0.001	<0.001	0.001
Bis(2-chloroisopropyl)ether			mg/l	No GAC	-	<0.001	<0.001	0.001
Bis(2-ethylhexyl) adipate			mg/l	No GAC	-	<0.001	<0.001	0.001
Diphenylamine			mg/l	No GAC	-	<0.001	<0.001	0.001
Iron (Soluble)			mg/l	No GAC	-	0.0066	3	2.448
M-Dinitrobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Naphthalene1-methyl-			mg/l	No GAC	-	<0.001	<0.001	0.001
Naphthols (2-Naphthalenesulfonic acid, 1-hydroxy-)			mg/l	No GAC	-	<0.0001	<0.0001	0.0001
P-Dinitrobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
Resorcinol			mg/l	No GAC	-	<0.0001	<0.0001	0.0001
Trimethylphenol			mg/l	No GAC	-	<0.0001	<0.0001	0.0001
Xylenols & Ethylphenols			mg/l	No GAC	-	<0.0001	<0.0001	0.0001
cis1,3-Dichloropropene			mg/l	No GAC	-	<0.001	<0.001	0.001

0.0066

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_BH206	GEO_BH208	GEO_BH209	GEO_BH210	GEO_BH211A	GEO_TP202B	GEO_TP202C
Sample Ref	200	200	200	200	200	3	8
Easting	384729.233	384562.98	384548.843	384479.67	384441.79	384722.997	384712.277
Northing	399690.75	399592.56	399628.33	399554.7	399513.96	399751.007	399739.124
Hole Elevation (mOD)	42.692	40.66	41.214	40.45	40.44	42.736	42.618
Sample Depth (mbgl)	2.77	12	12.47	10.8	7.73	0.45	1
Piezometer top (mbgl)	2	3	11	14	5		
Piezometer base (mbgl)	6	13	17	19.6	10.5		
Sample Date	10/08/21	10/08/21	10/08/21	10/08/21	10/08/21	30/03/21	30/03/21
Investigation	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604
Aquifer							

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile										
Metal																		
Antimony	0.005	DWS	mg/l	11 of 13	2	<0.00017	0.010497	0.00921	0.000601	0.000867	0.00061	0.002005	0.000411					
Arsenic	0.01	DWS	mg/l	13 of 13	1	0.000551	0.019811	0.01217	0.000897	0.00481	0.001961	0.001124	0.019811					
Beryllium	0.004	USEPA	mg/l	1 of 13	0	<0.0001	0.000142	0.00012	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001					
Cadmium	0.00008	EQS	mg/l	8 of 13	8	<0.00003	0.000968	0.0009	0.000631	0.000232	0.000968	<0.00003	<0.00003					
Calcium		-	mg/l	No GAC	-	37	190	184.0	110	99	140	120	180					
Chromium	0.0047	EQS	mg/l	8 of 13	1	<0.00025	0.007823	0.00372	0.000351	0.000603	0.00041	0.000643	0.000993					
Copper	0.001	EQS	mg/l	8 of 13	7	<0.0004	0.007768	0.00744	<0.0004	0.002559	0.000525	0.003132	<0.0004					
Lead	0.0012	EQS	mg/l	9 of 13	1	<0.00009	0.001893	0.0013	0.000347	0.000128	0.000356	<0.00009	0.000903					
Magnesium		-	mg/l	No GAC	-	9.9	29	28.60				27	26					
Manganese		-	mg/l	No GAC	-	0.004903	2.7502	2.270	0.854463	0.390387	0.753782	0.746742	0.421533					
Mercury	0.001	DWS	mg/l	3 of 13	0	<0.00001	0.000023	0.00002	<0.00001	0.000014	0.000013	<0.00001	<0.00001					
Nickel	0.004	EQS	mg/l	10 of 13	4	<0.0005	0.014998	0.00987	0.001963	0.00484	0.014998	0.001259	0.001076					
Potassium		-	mg/l	No GAC	-	7.1	21	19.40				7.1	13					
Selenium	0.01	DWS	mg/l	9 of 13	1	<0.00025	0.032081	0.01696	0.000346	0.006872	0.002252	0.000387	<0.00025					
Sodium	200	EUDWS	mg/l	5 of 5	0	8.2	120	103.60				38	14					
Vanadium	0.02	EQS*	mg/l	5 of 13	0	<0.0006	0.003487	0.00309	<0.0006	0.002819	<0.0006	<0.0006	<0.0006					
Zinc	0.0123	EQS	mg/l	10 of 13	8	<0.0013	0.101119	0.10065	0.032346	0.014094	0.100339	0.003744	0.002366					
Inorganic																		
pH	<6 - >9	EQS*	pH Units	No GAC	-	6.9	8.1	7.740	6.9	7	6.9	7	7.1					
Cyanide	0.001	EQS	mg/l	0 of 13	0	<0.04	<0.04	0.04	<0.04	<0.04	<0.04	<0.04	<0.04					
Complex Cyanide	0.001	EQS	mg/l	3 of 3	1	0.00061	0.008794	0.00798					0.008794	0.00061	0.00065			
Cyanide Free	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02					<0.02	<0.02	<0.02			
Thiocyanate	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02					<0.02	<0.02	<0.02			
Chloride	250	EQS*/DWS	mg/l	13 of 13	1	4.4	320	158.60	5.1	31	51	22	34					
Ammoniacal Nitrogen as N	0.3	EQS	mg/l	13 of 13	8	0.05	16	9.760	0.05	1.3	0.13	2.5	5.6					
Dissolved Organic Carbon		-	mg/l	No GAC	-	<2	24	19.80	<2	6.5	<2	3.5	3.4					
Total hardness		-	mg/l	No GAC	-	115	589	578.80	355	327	589	410	543					
Nitrate as NO3	50	DWS	mg/l	4 of 5	0	0.18	12	10.080				<0.5	2.4					
Nitrite as NO2	0.5	DWS	mg/l	1 of 5	0	<0.1	<0.5	0.5				<0.5	<0.5					
Sulphate as SO4	250	DWS	mg/l	5 of 5	0	30	150	146.0				98	130					
Sulphide		-	mg/l	No GAC	-	0.01636	0.212521	0.18934				0.018106	0.096618					
Total Alkalinity as CaCO3		-	mg/l	No GAC	-	380	640	632.0				390	600					
Phenol and mineral oils																		
Phenol	0.0077	EQS	mg/l	0 of 2	0	<0.0001	<0.001	0.00096						<0.0001	<0.001			
Phenol (Monohydric)	0.0077	EQS	mg/l	0 of 13	0	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1					
Phenols, Total		-	mg/l	No GAC	-	<0.002	<0.002	0.002						<0.002				
Cresols		-	mg/l	No GAC	-	<0.0001	<0.0001	0.0001						<0.0001				
TPH																		
Aliphatics >C10-12	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001						<0.001	<0.001			
Aliphatics >C12-16	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001						<0.001	<0.001			
Aliphatics >C16-21		-	mg/l	No GAC	-	<0.001	<0.001	0.001						<0.001	<0.001			
Aliphatics >C21-35		-	mg/l	No GAC	-	<0.001	<0.001	0.001						<0.001	<0.001			
Aliphatics >C35-44		-	mg/l	No GAC	-	<0.001	<0.001	0.001						<0.001	<0.001			
Aliphatics >C5-35		-	mg/l	No GAC	-	<0.01	<0.01	0.01										
Aliphatics >C5-6	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001						<0.0001	<0.0001			
Aliphatics >C6-8	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001						<0.0001	<0.0001			
Aliphatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001						<0.0001	<0.0001			
Aromatics >C10-12	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001						<0.001	<0.001			
Aromatics >C12-16	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001						<0.001	<0.001			

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_BH206	GEO_BH208	GEO_BH209	GEO_BH210	GEO_BH211A	GEO_TP202B	GEO_TP202C
Sample Ref	200	200	200	200	200	3	8
Easting	384729.233	384562.98	384548.843	384479.67	384441.79	384722.997	384712.277
Northing	399690.75	399592.56	399628.33	399554.7	399513.96	399751.007	399739.124
Hole Elevation (mOD)	42.692	40.66	41.214	40.45	40.44	42.736	42.618
Sample Depth (mbgl)	2.77	12	12.47	10.8	7.73	0.45	1
Piezometer top (mbgl)	2	3	11	14	5		
Piezometer base (mbgl)	6	13	17	19.6	10.5		
Sample Date	10/08/21	10/08/21	10/08/21	10/08/21	10/08/21	30/03/21	30/03/21
Investigation	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604
Aquifer							

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile		
Aromatics >C16-21	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		<0.001
Aromatics >C21-35	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		<0.001
Aromatics >C35-44		-	mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
Aromatics >C5-7	0.01	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		<0.0001
Aromatics >C7-8	0.7	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		<0.0001
Aromatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		<0.0001
Aromatics >C10-44			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
Total Aliphatics and Aromatics C10-C44			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
Total Aliphatics and Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01		<0.001
Total Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01		<0.001
PAH										
Acenaphthene	2	USEPA	mg/l	2 of 4	0	<0.00001	0.001126	0.00111		0.001126
Dibenz-a-h-anthracene		-	mg/l	No GAC	-	<0.00001	0.015089	0.01301		0.015089
Fluoranthene	0.000006	EQS	mg/l	3 of 4	3	<0.00001	0.019478	0.01766		0.019478
Fluorene		-	mg/l	No GAC	-	<0.00001	0.001201	0.00117		0.001201
Indeno(1,2,3-cd)pyrene		-	mg/l	No GAC	-	<0.00001	0.064903	0.05567		0.064903
Phenanthrene		-	mg/l	No GAC	-	<0.00001	0.006666	0.00607		0.006666
Pyrene		-	mg/l	No GAC	-	<0.00001	0.021859	0.01972		0.021859
Napthalene	0.002	EQS	mg/l	1 of 4	0	<0.00005	<0.001	0.00097		<0.00005
Pah, Total		-	mg/l	No GAC	-	<0.0002	0.359917	0.32411		0.359917
Acenaphthylene		-	mg/l	No GAC	-	<0.00001	<0.001	0.00085		<0.00001
Anthracene	0.0001	EQS	mg/l	3 of 4	3	<0.00001	0.002814	0.00255		0.002814
Benzo(a)anthracene		-	mg/l	No GAC	-	<0.00001	0.012339	0.01117		0.012339
Benzo (g,h,i) perylene		-	mg/l	No GAC	-	<0.00001	0.073465	0.06308		0.073465
Benzo(a)pyrene	0	EQS	mg/l	2 of 4	2	<0.00001	0.049364	0.04291		0.049364
Benzo(b)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.054044	0.04726		0.054044
Benzo(k)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.021665	0.01871		0.021665
Chrysene		-	mg/l	No GAC	-	<0.00001	0.015904	0.0141		0.015904
BTEX										
Benzene	0.001	DWS	mg/l	0 of 4	0	<0.001	<0.001	0.001		<0.001
Toluene	0.074	EQS	mg/l	0 of 4	0	<0.001	<0.001	0.001		<0.001
Ethylbenzene	0.02	EQS*	mg/l	0 of 4	0	<0.001	<0.001	0.001		<0.001
O-Xylene	0.03	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
Xylene	0.03	EQS*	mg/l	0 of 3	0	<0.001	<0.001	0.001		<0.001
m,p xylenes	0.03	EQS*	mg/l	0 of 1	0	<0.002	<0.002	0.002		<0.002
VOC										
1,1,1,2-Tetrachloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
1,1,1-Trichloroethane	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,1,2,2-Tetrachloroethane	0.14	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,1,2-Trichloroethane	0.4	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,1-Dichloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
1,1-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,1-Dichloropropene			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
1,2,3 Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,2,3-Trichloropropane			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
1,2,4-Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,2,4-Trimethylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001		<0.001
1,2-Dibromo-3-Chloropropane	0.001	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,2-Dibromoethane	0.0004	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001
1,2-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001		<0.001

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_BH206	GEO_BH208	GEO_BH209	GEO_BH210	GEO_BH211A	GEO_TP202B	GEO_TP202C
Sample Ref	200	200	200	200	200	3	8
Easting	384729.233	384562.98	384548.843	384479.67	384441.79	384722.997	384712.277
Northing	399690.75	399592.56	399628.33	399554.7	399513.96	399751.007	399739.124
Hole Elevation (mOD)	42.692	40.66	41.214	40.45	40.44	42.736	42.618
Sample Depth (mbgl)	2.77	12	12.47	10.8	7.73	0.45	1
Piezometer top (mbgl)	2	3	11	14	5		
Piezometer base (mbgl)	6	13	17	19.6	10.5		
Sample Date	10/08/21	10/08/21	10/08/21	10/08/21	10/08/21	30/03/21	30/03/21
Investigation	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604
Aquifer							

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile	
1,2-Dichloroethane	0.003	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
1,2-Dichloropropane	0.04	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
1,3,5-Trimethylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
1,3-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.002	<0.002	0.002	<0.002
1,3-Dichloropropane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
1,4-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2,2-Dichloropropane			mg/l	No GAC	-	<0.002	<0.002	0.002	<0.002
2-Chlorotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
4-Chlorotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
4-Isopropyltoluene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bromobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bromochloromethane			mg/l	No GAC	-	<0.004	<0.004	0.004	<0.004
Bromodichloromethane	0.06	WHO	mg/l	0 of 1	0	<0.004	<0.004	0.004	<0.004
Bromomethane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Chlorobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Chloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Chloroethene	0.0005	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Chloroform	0.0025	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Chloromethane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Dibromochloromethane	0.1	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Dibromomethane	0.02	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Dichlorodifluoromethane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Dichloromethane	0.02	EQS	mg/l	0 of 1	0	<0.027	<0.027	0.027	<0.027
Hexachlorobutadiene (HCBd)	0.0006	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Isopropylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Methyl tert-butyl ether (MTBE)	0.015	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Sec-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Styrene	0.05	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Tert-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Tetrachloroethene	0.01	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Tetrachloromethane (Carbon Tetra Chloride)	0.003	DWS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Tribromomethane	0.1	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Trichloroethene	0.01	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Trichlorofluoromethane			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
cis-1,2-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
n-Butylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
n-propylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
trans-1,2-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
trans-1,3-Dichloropropene	0.02	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
SVOC									
2,4,5-Trichlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2,4,6-Trichlorophenol	0.2	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2,4-Dichlorophenol	0.0042	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2,4-Dimethylphenol	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2,4-Dinitrotoluene	0.1	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2,6-Dinitrotoluene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2-Chloronaphthalene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2-Chlorophenol	0.05	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
2-Methylnaphthalene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2-Methylphenol	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_BH206	GEO_BH208	GEO_BH209	GEO_BH210	GEO_BH211A	GEO_TP202B	GEO_TP202C
Sample Ref	200	200	200	200	200	3	8
Easting	384729.233	384562.98	384548.843	384479.67	384441.79	384722.997	384712.277
Northing	399690.75	399592.56	399628.33	399554.7	399513.96	399751.007	399739.124
Hole Elevation (mOD)	42.692	40.66	41.214	40.45	40.44	42.736	42.618
Sample Depth (mbgl)	2.77	12	12.47	10.8	7.73	0.45	1
Piezometer top (mbgl)	2	3	11	14	5		
Piezometer base (mbgl)	6	13	17	19.6	10.5		
Sample Date	10/08/21	10/08/21	10/08/21	10/08/21	10/08/21	30/03/21	30/03/21
Investigation	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604	NW1604
Aquifer							

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile	
4-Bromophenyl Phenyl Ether	0.04	EQS*	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
4-Chloro-3-Methylphenol			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
4-Nitrophenol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bis(2-chloroethoxy)methane	0.0013	EQS	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bis(2-ethylhexyl)phthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Butylbenzylphthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Carbazole	0.0075	EQS	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Di-N-Butyl Phthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Di-N-Octyl Phthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Dibenzofuran	0.008	EQS*	mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Diethylphthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Dimethylphthalate			mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Hexachlorobenzene (HCB)	0.001	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Hexachlorocyclopentadiene	0.05	USEPA	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Pentachlorophenol (PCP)	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001	<0.001
Other									
2,3,4,6-Tetrachlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2,3,5,6-Tetrachlorophenol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
2-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
3-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
3/4 Methylphenol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
4-Chlorophenyl Phenyl Ether			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
4-Nitroaniline			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Aliphatics >C10-44			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Aniline			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Azobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Benzyl Alcohol			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bis(2-chloroisopropyl)ether			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Bis(2-ethylhexyl) adipate			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Diphenylamine			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Iron (Soluble)			mg/l	No GAC	-	0.0066	3	2.448	<0.001
M-Dinitrobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Naphthalene 1-methyl-			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Naphthols (2-Naphthalenesulfonic acid, 1-hydroxy-)			mg/l	No GAC	-	<0.0001	<0.0001	0.0001	<0.001
P-Dinitrobenzene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001
Resorcinol			mg/l	No GAC	-	<0.0001	<0.0001	0.0001	<0.001
Trimethylphenol			mg/l	No GAC	-	<0.0001	<0.0001	0.0001	<0.001
Xylenols & Ethylphenols			mg/l	No GAC	-	<0.0001	<0.0001	0.0001	<0.001
cis1,3-Dichloropropene			mg/l	No GAC	-	<0.001	<0.001	0.001	<0.001

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_WS201B	GEO_WS207
Sample Ref	200	200
Easting	384735.29	384628.92
Northing	399787.2	399674.79
Hole Elevation (mOD)	43.55	41.91
Sample Depth (mbgl)	0.79	0.27
Piezometer top (mbgl)	0.5	0.9
Piezometer base (mbgl)	1.3	4.9
Sample Date	11/08/21	10/08/21
Investigation	NW1604	NW1604
Aquifer		

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile		
Metal										
Antimony	0.005	DWS	mg/l	11 of 13	2	<0.00017	0.010497	0.00921	0.002071	0.000637
Arsenic	0.01	DWS	mg/l	13 of 13	1	0.000551	0.019811	0.01217	0.00179	0.000716
Beryllium	0.004	USEPA	mg/l	1 of 13	0	<0.0001	0.000142	0.00012	<0.0001	<0.0001
Cadmium	0.00008	EQS	mg/l	8 of 13	8	<0.00003	0.000968	0.0009	0.000853	0.000627
Calcium		-	mg/l	No GAC	-	37	190	184.0	110	190
Chromium	0.0047	EQS	mg/l	8 of 13	1	<0.00025	0.007823	0.00372	<0.00025	0.000346
Copper	0.001	EQS	mg/l	8 of 13	7	<0.0004	0.007768	0.00744	0.007221	0.007768
Lead	0.0012	EQS	mg/l	9 of 13	1	<0.00009	0.001893	0.0013	0.000124	0.000322
Magnesium		-	mg/l	No GAC	-	9.9	29	28.60	9.9	24
Manganese		-	mg/l	No GAC	-	0.004903	2.7502	2.270	0.631057	0.167887
Mercury	0.001	DWS	mg/l	3 of 13	0	<0.00001	0.000023	0.00002	<0.00001	<0.00001
Nickel	0.004	EQS	mg/l	10 of 13	4	<0.0005	0.014998	0.00987	0.002177	0.004524
Potassium		-	mg/l	No GAC	-	7.1	21	19.40	9.2	21
Selenium	0.01	DWS	mg/l	9 of 13	1	<0.00025	0.032081	0.01696	0.032081	<0.00025
Sodium	200	EUDWS	mg/l	5 of 5	0	8.2	120	103.60	120	28
Vanadium	0.02	EQS*	mg/l	5 of 13	0	<0.0006	0.003487	0.00309	0.002288	<0.0006
Zinc	0.0123	EQS	mg/l	10 of 13	8	<0.0013	0.101119	0.10065	0.056632	0.101119
Inorganic										
pH	<6 - >9	EQS*	pH Units	No GAC	-	6.9	8.1	7.740	7.5	7.1
Cyanide	0.001	EQS	mg/l	0 of 13	0	<0.04	<0.04	0.04	<0.04	<0.04
Complex Cyanide	0.001	EQS	mg/l	3 of 3	1	0.00061	0.008794	0.00798		
Cyanide Free	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02		
Thiocyanate	0.001	EQS	mg/l	0 of 3	0	<0.02	<0.02	0.02		
Chloride	250	EQS*/DWS	mg/l	13 of 13	1	4.4	320	158.60	5.6	27
Ammoniacal Nitrogen as N	0.3	EQS	mg/l	13 of 13	8	0.05	16	9.760	0.088	16
Dissolved Organic Carbon		-	mg/l	No GAC	-	<2	24	19.80	4.7	3.9
Total hardness		-	mg/l	No GAC	-	115	589	578.80	312	572
Nitrate as NO3	50	DWS	mg/l	4 of 5	0	0.18	12	10.080	0.18	12
Nitrite as NO2	0.5	DWS	mg/l	1 of 5	0	<0.1	<0.5	0.5	<0.1	<0.5
Sulphate as SO4	250	DWS	mg/l	5 of 5	0	30	150	146.0	150	30
Sulphide		-	mg/l	No GAC	-	0.01636	0.212521	0.18934	0.01636	0.212521
Total Alkalinity as CaCO3		-	mg/l	No GAC	-	380	640	632.0	380	640
Phenol and mineral oils										
Phenol	0.0077	EQS	mg/l	0 of 2	0	<0.0001	<0.001	0.00096		
Phenol (Monohydric)	0.0077	EQS	mg/l	0 of 13	0	<0.1	<0.1	0.1	<0.1	<0.1
Phenols, Total		-	mg/l	No GAC	-	<0.002	<0.002	0.002		
Cresols		-	mg/l	No GAC	-	<0.0001	<0.0001	0.0001		
TPH										
Aliphatics >C10-12	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		
Aliphatics >C12-16	0.3	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		
Aliphatics >C16-21		-	mg/l	No GAC	-	<0.001	<0.001	0.001		
Aliphatics >C21-35		-	mg/l	No GAC	-	<0.001	<0.001	0.001		
Aliphatics >C35-44		-	mg/l	No GAC	-	<0.001	<0.001	0.001		
Aliphatics >C5-35		-	mg/l	No GAC	-	<0.01	<0.01	0.01		
Aliphatics >C5-6	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		
Aliphatics >C6-8	15	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		
Aliphatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001		
Aromatics >C10-12	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		
Aromatics >C12-16	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001		

Concentration exceeds GAC	100.00
Limit of Detection value exceeds GAC	<0.1

Hole Ref	GEO_WS201B	GEO_WS207
Sample Ref	200	200
Easting	384735.29	384628.92
Northing	399787.2	399674.79
Hole Elevation (mOD)	43.55	41.91
Sample Depth (mbgl)	0.79	0.27
Piezometer top (mbgl)	0.5	0.9
Piezometer base (mbgl)	1.3	4.9
Sample Date	11/08/21	10/08/21
Investigation	NW1604	NW1604
Aquifer		

Contaminant Name	GAC	GAC Source	Units	Total > LOD	Total > GAC	Min	Max	95th %ile
Aromatics >C16-21	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001
Aromatics >C21-35	0.09	WHO	mg/l	0 of 4	0	<0.001	<0.001	0.001
Aromatics >C35-44		-	mg/l	No GAC	-	<0.001	<0.001	0.001
Aromatics >C5-7	0.01	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001
Aromatics >C7-8	0.7	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001
Aromatics >C8-10	0.3	WHO	mg/l	0 of 4	0	<0.0001	<0.0001	0.0001
Aromatics >C10-44			mg/l	No GAC	-	<0.001	<0.001	0.001
Total Aliphatics and Aromatics C10-C44			mg/l	No GAC	-	<0.001	<0.001	0.001
Total Aliphatics and Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01
Total Aromatics C5-C35			mg/l	No GAC	-	<0.01	<0.01	0.01
PAH								
Acenaphthene	2	USEPA	mg/l	2 of 4	0	<0.00001	0.001126	0.00111
Dibenz-a-h-anthracene		-	mg/l	No GAC	-	<0.00001	0.015089	0.01301
Fluoranthene	0.000006	EQS	mg/l	3 of 4	3	<0.00001	0.019478	0.01766
Fluorene		-	mg/l	No GAC	-	<0.00001	0.001201	0.00117
Indeno(1,2,3-cd)pyrene		-	mg/l	No GAC	-	<0.00001	0.064903	0.05567
Phenanthrene		-	mg/l	No GAC	-	<0.00001	0.006666	0.00607
Pyrene		-	mg/l	No GAC	-	<0.00001	0.021859	0.01972
Napthalene	0.002	EQS	mg/l	1 of 4	0	<0.00005	<0.001	0.00097
Pah, Total		-	mg/l	No GAC	-	<0.0002	0.359917	0.32411
Acenaphthylene		-	mg/l	No GAC	-	<0.00001	<0.001	0.00085
Anthracene	0.0001	EQS	mg/l	3 of 4	3	<0.00001	0.002814	0.00255
Benzo(a)anthracene		-	mg/l	No GAC	-	<0.00001	0.012339	0.01117
Benzo (g,h,i) perylene		-	mg/l	No GAC	-	<0.00001	0.073465	0.06308
Benzo(a)pyrene	0	EQS	mg/l	2 of 4	2	<0.00001	0.049364	0.04291
Benzo(b)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.054044	0.04726
Benzo(k)fluoranthene		-	mg/l	No GAC	-	<0.00001	0.021665	0.01871
Chrysene		-	mg/l	No GAC	-	<0.00001	0.015904	0.0141
BTEX								
Benzene	0.001	DWS	mg/l	0 of 4	0	<0.001	<0.001	0.001
Toluene	0.074	EQS	mg/l	0 of 4	0	<0.001	<0.001	0.001
Ethylbenzene	0.02	EQS*	mg/l	0 of 4	0	<0.001	<0.001	0.001
O-Xylene	0.03	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
Xylene	0.03	EQS*	mg/l	0 of 3	0	<0.001	<0.001	0.001
m,p xylenes	0.03	EQS*	mg/l	0 of 1	0	<0.002	<0.002	0.002
VOC								
1,1,1,2-Tetrachloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001
1,1,1-Trichloroethane	0.1	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,1,2,2-Tetrachloroethane	0.14	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,1,2-Trichloroethane	0.4	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,1-Dichloroethane			mg/l	No GAC	-	<0.001	<0.001	0.001
1,1-Dichloroethene	0.05	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,1-Dichloropropene			mg/l	No GAC	-	<0.001	<0.001	0.001
1,2,3 Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,2,3-Trichloropropane			mg/l	No GAC	-	<0.001	<0.001	0.001
1,2,4-Trichlorobenzene	0.0004	EQS	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,2,4-Trimethylbenzene			mg/l	No GAC	-	<0.001	<0.001	0.001
1,2-Dibromo-3-Chloropropane	0.001	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,2-Dibromoethane	0.0004	WHO	mg/l	0 of 1	0	<0.001	<0.001	0.001
1,2-Dichlorobenzene	0.02	EQS*	mg/l	0 of 1	0	<0.001	<0.001	0.001