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CONSULTING ENGINEERS

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Surface Water Drainage Report

Avanton Richmond Developments Ltd

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1.0 Introduction

This Surface Water Drainage report has been prepared by Manhire Associates Ltd on behalf of Avanton Richmond Developments Ltd, in support of a Planning Application.

The development site is located approximately 600m northeast of Richmond town centre, National Grid Reference 518890,175430. It is accessed via Manor Road, which bounds the site to the east. Railway lines form the north-western and southern boundaries.

The site is located within the boundary of the London Borough of Richmond upon Thames Local Planning Authority.

The site is approximately triangular in shape, covering an area of about 1.842Ha and is currently occupied by a retail warehouse building (Homebase) in the central third, with associated car / bus parking in the north-eastern third and storage areas in the south-western third of the site.

In this pre-redevelopment layout, the site is almost fully paved with several small areas of vegetation and trees throughout the site.

Surrounding land uses are mixed residential and commercial.

Refer to Site Location Plan in Appendix A.

1.1 Planning History - Originally Submitted Application

A Planning Application (the 'Application') for the site was originally submitted to the London Borough of Richmond upon Thames ('LBRuT') on 14.02.2019 (Application Ref. 19/0510/FUL). LBRuT resolved to refuse the Application in July 2019 and the Application was referred to the Mayor of London (the 'Mayor') for his Stage 2 review. The Mayor set out, in his Stage 2 Report, that the Proposed Development is of a nature or scale that it would have a significant impact on the implementation of the London Plan policies on housing and affordable Housing. On 29 July 2019, the Mayor issued a Direction pursuant to Article 7 of the Oder and Powers conferred by Section 2A of the Town and Country Planning Act (1990) that he would act as the Local Planning Authority for the purposes of determining the application.

Since July 2019, amendments were submitted to the Mayor in July 2020. In October 2020, the Mayor granted conditional planning permission subject to the completion of a Section 106 Agreement.

In November 2021, following the adoption of the 2021 London Plan, the scheme was revised for conformity to the new policies as discussions regarding the Section 106 Agreement with the GLA and LBRuT had not been finalised. The current amendments include the amendments considered in November 2021.

This document forms part of a suite of updated documents which have been prepared to ensure compliance with the latest guidance.

1.2 Development Proposals

The proposed development comprises the demolition of the current retail units and the development of 4 No. residential buildings. Building A is a part 3, part 4, part 7 and 8 storey building, Building B is an 11 storey building, Building C is a part 8 and 10 storey building and Building D is a part 4, part 7 and part 8 storey building. In addition, a basement plant room is proposed beneath Building A.

1.3 Purpose for Study

The purpose of this assessment is to demonstrate that the development proposal outlined above can be satisfactorily accommodated without worsening any flood risk for the area, as per National guidance provided within the National Planning Policy Framework (NPPF).

1.4 Scope of Study

The characteristics of the proposed development site and surrounding area are described in Section 2.0 of this report. We outline the proposed surface water drainage strategy for the development in Section 3.0, and our conclusions are presented in Section 4.0.

A topographical survey referenced to Ordnance Datum, provided by Survey Design Services Ltd. has been reviewed as part of this study.

Refer to Topographic Site Survey in Appendix B.

The following abbreviations are used in this report:
AOD – Above Ordnance Datum
BGL – Below Ground Level
LLFA – Lead Local Flood Authority
GIA – Gross Internal Area
NPPF – National Planning Policy Framework
SuDS – Sustainable Drainage Systems
TWU – Thames Water Utilities

2.0 The Existing Site

The Site is located at Former Homebase Manor Road, Richmond, TW9 1YB. The site is roughly triangular in shape and bounded to the north and south by merging railway lines and Manor Road (B353) to the east. In the northeast corner of the site, Manor Road crosses the railway lines on an elevated roundabout.

The total site area is 1.842ha which is almost entirely impermeable either (i) under buildings or (ii) paved parking, roads, and other hardstanding areas.

In the pre-redevelopment layout, the site is almost fully paved with several small areas of vegetation and trees throughout the site. These can be seen on the Topographical Survey drawings of which are presented in Appendix B.

The Topographical Survey indicates the site to be approximately 7.00m AOD at the east of the site, sloping to approximately 6.00m AOD at the southwest of the site. The southwest of the site is contained by a retaining wall with the railway alongside the site at approximately 7.300m AOD.

The site lies within Flood Zone 1. Sites located in flood zone 1 have a low probability of flooding. This means in any year land has a less than 0.1% chance of flooding from rivers or the sea.

Figure 1 - EA's 'Flood Map for Planning' (© Environment Agency).

A Topographical Survey was produced by Point2Surveys Ltd, Drawing No. LS2024/T/01-10 dated August 2018 included in Appendix B to this report.

2.1 Existing Ground Conditions

Following the development of the preliminary CSM and assessment of engineering considerations, Fairhurst scoped and designed a preliminary intrusive ground investigation targeted to refine the understanding of the site for geo-environmental and geotechnical purposes.

The preliminary ground investigation was carried out by LMB Geosolutions Ltd, under the management of Fairhurst, between the 21st and 27th of April 2021 with three post-fieldwork monitoring visits between the 5th and 26th of May 2021. All exploratory locations were surveyed for below ground utilities and inspection hand pits were dug to 1.2 m bgl prior to drilling.

The original scope of works comprised the following:

5 No. rotary percussive boreholes to 15 m bgl (BH101 to BH105)
3 No. trial pits to 5 m bgl (TP01 to TP03)
Geotechnical and geo-environmental soil sampling
Installation of groundwater and ground gas monitoring installations at all boreholes
3 No. return monitoring visits across a 1 month period
1 No. round of groundwater sampling

The stratigraphy is summarized in Table 1.

Geological Strata		
Geological Unit	**Description**	**Estimated thickness (m)**
Surfacing	Brick Paving and subbase (0.1m bgl) and tarmac over roadstone gravel (0.3m bgl)	0.10 – 0.30
Made Ground	Brown to dark brown clayey gravelly sand with occasional brick and concrete cobbles. Gravel sub - angular fine to course flint, brick, concrete and rare clinker	0.40 – 2.0
Kempton Park Gravel Member	Brown to orange slightly gravelly medium to coarse SAND. Gravel sub-angular to rounded medium to course flint.	1.55– 4.10
London Clay Formation	Dark grey to grey, brown CLAY. Closely fissured.	1.35 – 20.70

Table 1 - Geotechnical strata

A second round of ground investigations was undertaken to supplement the existing data in August 2022 by Manhire Associates Geo-Environmental Limited which comprised three boreholes drilled to 30m. These were supplemented by six windowless sampler holes to a maximum of 2½m depth. Representative soil and water samples were recovered from the boreholes for subsequent laboratory examination and testing; whilst Standard Penetration Tests (SPT) were carried out as appropriate. Standpipes were installed in the three percussive boreholes to allow monitoring of groundwater levels.

Details of Ground Conditions and the monitoring results are presented in Appendix C

2.2 Groundwater and Hydrology

The nearest surface water feature to the site is a pond located approximately 310m south of the site. The River Thames is positioned approximately 1.4km to the northwest and 1.3km to the southeast at its closest positions, and generally flows in an easterly or south easterly direction at these locations.

The Environment Agency classifies the Superficial Kempton Park Gravel Member as Secondary A Aquifer and the London Clay Formation as an Unproductive Stratum. The site is not within a source protection zone, nor are there any groundwater abstractions within 1km of the site.

Groundwater is considered to be present within the Kempton Park Gravel Member based on historical borehole records and likely to be perched above the low permeability London Clay Formation. Regionally groundwater is considered to flow in a north easterly direction towards and in hydraulic connectivity with the River Thames, the dominant surface water feature in the vicinity of the site.

During the ground investigations undertaken by Fairhurst, between the 21st and 27th of April 2021 with three post-fieldwork monitoring visits between the 5th and 26th of May 2021.

Groundwater monitoring was conducted in five boreholes across the site. All boreholes were installed with 50mm diameter combined ground gas and groundwater monitoring wells within the Made Ground, Kempton Park Gravel Member and London Clay Formation.

Initial groundwater strikes reported during the ground investigations are summarised in Table 2 below.

Borehole	Groundwater Level		Stratum
	m bgl	m AOD	
BH101	4.50 rising to 4.30	2.20 rising to 2.40	Kempton Park Gravel Member
BH102	4.50 rising to 3.90	1.90 rising to 2.50	Kempton Park Gravel Member
BH103	3.50 rising to 2.80	3.04 rising to 3.74	Kempton Park Gravel Member
BH104	3.20 rising to 2.60	3.05 rising to 3.65	Kempton Park Gravel Member
BH105	2.80 rising to 3.00	3.45 rising to 3.25	Kempton Park Gravel Member

Table 2 – Summary of Groundwater strikes recorded during investigation (April 2021)

In order to understand the groundwater regime more comprehensively following the completion of site investigation work, groundwater monitoring rounds were undertaken on 5th, 13th and 26th May 2021 as summarized below in Table 3.

BOREHOLE	RESPONSE ZONE		GROUNDWATER LEVEL	
	m bgl	STRATA	m bgl	m AOD
BH101	1.50 to 8.45	MG / KPGM / LC	2.46 to 2.56	4.24 to 4.14
BH102	1.00 to 7.00	MG / KPGM / LC	2.32 to 2.41	4.08 to 3.99
BH103	2.00 to 8.00	KPGM / LC	3.88 to 4.26	2.66 to 2.28
BH104	1.00 to 5.00	MG / KPGM / LC	3.66 to 4.68	2.59 to 1.57
BH105	1.00 to 6.00	MG / KPGM / LC	3.45 to 4.03	2.80 to 2.22

MG – Made Ground, KPGM – Kempton Park Gravel Member, LC – London Clay Formation

Table 3 – Summary of Groundwater levels recorded during return visit monitoring (May 2021)

The findings suggest that a shallow body of groundwater is situated within the Kempton Park Gravel Member. The Kempton Park Gravel Member was saturated at varying levels across the site with recorded groundwater levels between 4.24m to 3.99m AOD in the north of the site (BH101 and BH102) lowering to between 2.80m to 1.57m AOD in the central and southern area of the site (BH103, BH104 and BH105).

It should be noted that groundwater levels are subject to variation as a result of seasonal changes and during following periods of adverse weather conditions.
As part of the ground investigations undertaken in August 2022 by Manhire Associates Geo-Environmental Limited also found that the Kempton Park Gravel Member was saturated at varying levels across the site with recorded groundwater levels at between 3.57m to 3.67m AOD in the east of the site (BH1) lowering to between 2.17m to 2.05m AOD in the central and northern area of the site (BH2 and BH3).

Location	BH1		BH2		BH3	
Red. level						
Date	m bgl	m OD	m bgl	m OD		
19/08/2022	2.51		4.11		4.15	
23/09/2022	2.54		4.15		4.17	
11/10/2022	2.61		4.21		4.23	

Table 4 – Summary of Groundwater strikes recorded during investigation (August to October 2022)

The standpipe records were in broad agreement with that previously found by Fairhurst. Details of the ground conditions are presented in Appendix C

2.3 Infiltration Potential

As noted above due to the high water table underlying the site it is considered that infiltration will not be suitable method to discharge surface water from the site.

2.4 Existing Drainage

The existing site contains surface and foul water drainage serving the existing retail store (to be demolished as part of the proposed works).

A topographical and drainage survey (see appendices) shows the drainage network including conveyance features south of the access road into the site.

Due to the scale of the proposed development, it is not anticipated that any of the existing drainage within the site will be suitable for reuse in this area.

2.5 Existing Site Run-off

The available Thames Water record and utility surveys indicate that the closest surface sewers to the site is a 915mm dia. surface water sewer running under Manor Road in a northerly direction.

All surface water from the site currently discharges freely and directly to soakaways located under the existing carparking areas.

The current site is brownfield land with negligible soft landscaping. The total site area is approx. 18420m2 of which 18420m2 is impermeable.

In accordance with the Modified Rational Method, the peak existing run-off from the site is calculated from the formula:
$Q = 3.61 \times Cv \times A \times i$

For the following peak 1, 30 & 100-year return period storm event this gives an existing discharge rate from the site of:

Annual Exceedance Probability (AEP)	Brownfield Discharge Rate (l/s)
1 in 1 year	162
1 in 30 year	398
1 in 100 year	519

Table 5.0 – Existing Brownfield rates

2.6 Greenfield Runoff

The Greenfield runoff rate was calculated using the online UK SuDS tool developed by HR Wallingford. The IH124 method was used to determine the greenfield runoff rates. Only the proposed impermeable areas equating to 1.08 ha were used in estimating the greenfield run off rates as requested by the GLA. The full UK SuDS report can be found in Appendix E

Q Bar = 1.64 l/sec

Q1 = 1.39 l/sec
Q30 = 3.77 l/sec
Q100 = 5.32 l/sec

2.7 Previous Drainage Strategy

A Flood Risk Assessment & Drainage Strategy was previously undertaken by Fairhurst in July 2020 (Ref: 126782-RP-C-0001) following a planning application for the redevelopment of the Site which was submitted to London Borough of Richmond Upon Thames (LBRuT) in February 2019 (ref. 19/0510/FUL) (the 'Original Proposed Development') and was considered at LBRuT Planning Committee on 3 July 2019. The previous surface water drainage strategy proposed to use infiltration techniques, based on assumed ground conditions and infiltration rates, and detailed a number of soakaways positioned between the buildings to manage surface water on the site.

It also proposed that the area to the north of the site used by TFL, where there is no development, will drain as per the existing situation.

The drainage strategy noted that infiltration tests and groundwater monitoring should be undertaken to confirm this proposed strategy would be feasible for this site.

Dependent on the results of this infiltration testing/viability, the proposal considered the possibility of a connection to the public sewer network on Manor Road.

Calculations were undertaken to determine the volume of attenuation required to achieve the calculated 1:100 year greenfield run off rate of 8.9 l/sec. A volume of 1485m3 was calculated however the extent of storage required in the context of this site would be difficult to achieve and would equate to most of the central pedestrian spaces being underlain by geo-cellular storage which would not be practicable, particularly in consideration of the other space requirements required by incoming services.
A restricted discharge rate of 25.2 l/sec was therefore agreed with the Council's Drainage Officer and advised that the run-off and attenuation would be acceptable.
A pre planning enquiry was submitted to Thames water as part of the previous Drainage Strategy and confirmation of sufficient capacity was provided in January 2019.

A copy of this Thames Water response is included in Appendix D.

Due to time lapsed, a new pre-planning enquiry has been submitted with a response expected imminently. This response will be shared with the GLA upon receipt.

Given that the proposed discharge rates are a considerable reduction of the existing brownfield runoff rates, we would anticipate that flood risk to the local watercourses would not be exacerbated as a result of the development.

2.8 Surface Water Run-off

The proposed drainage strategy will seek to discharge surface water in line with the drainage hierarchy, outlined in the London Plan. The hierarchy is listed below in order of preference for surface water disposal:

- Rainwater re-use (rainwater harvesting/greywater recycling);
- An adequate soakaway or other infiltration system;
- Hybrid solution of infiltration and discharging to a surface water body;
- To a surface water body (e.g. an ordinary watercourse);
- To a surface water sewer, highway drain, or other drainage system;
- To a combined sewer.

The items within the drainage hierarchy are now considered in turn:

- Rainwater re-use

It is not proposed to use rainwater harvesting techniques for the scheme due to the required space for an appropriately sized tank, and the additional complexity involved with the routing of dual potable and non-potable water mains within the proposed buildings. The demand on the potable water supply will be reduced as much as possible through the use of low flow appliances.

- Infiltration

As noted in Section 2.2 due to the high water table underlying the site it is considered that infiltration will not be suitable method to discharge surface water from the site.

- Surface water body

There are no watercourses in the vicinity of the Site and therefore, the discharge of surface water from the Site to a surface water body is unfeasible.

- Surface water sewer

There is a 915mm dia. surface water sewer running under Manor Road in a northernly direction. This will be the proposed method to discharge surface water from the site.

- Combined Sewer

There is no nearby combined sewer to discharge to, so this has been discounted.

The proposed development will not increase the impermeable areas on the site resulting in an increase in runoff.

The drainage strategy for the site must incorporate sustainable drainage principals and must not lead to a net increase in run-off rate above the existing rate for the site.

It is therefore proposed to restrict the surface water discharge rate of the new development to 25.21 l/sec for all events as originally agreed with the Council`s Drainage Officer as per Table 6.0 below.

As a result, there will be no net increase in run off rates from the proposed development while also ensuring improvements are achieved for the 1 in 30 and 1 in 100 year events.

Annual Exceedance Probability (AEP)	Proposed Discharge Rate (l/s)	Brownfield Discharge Rate (l/s)	% Decrease in Flow Rates
1 in 1 year	25.2	162	**84.4%**
1 in 30 year	25.2	398	**93.6%**
1 in 100 year	25.2	519	**95.1%**

Table 6.0 – Existing Brownfield rates

These improvements will therefore reduce flood risk associated with the site significantly, in line with current guidance for London Borough of Richmond upon Thames.

Calculation have also been undertaken as part of this drainage strategy to demonstrate the volume of attenuation required to restrict the discharge rate to greenfield runoff rates as per the Table 7 below.

3.0 Proposed Surface Water Drainage Strategy

Due to the latest Site Investigation works undertaken that concluded infiltration was not feasible on site the revised surface water drainage strategy proposes to discharge the surface water to the public sewer on Manor Road.

It will be restricted to a rate of 25.2 l/sec as was previously agreed with the Council's Drainage Officer as infiltration proved to be unviable.

Preliminary calculation indicates a 445m3 volume of attenuation will be required to attenuate the 1:100 year event +40% allowance for climate change to manage the surface water on the site.

Several attenuation tanks have been used to attenuate the 1:100 year event +40% allowance for climate change and have been positioned between the buildings which has been coordinated with the required underground service corridors and set at a level needed where the tanks will not be affected by floatation due to the high ground water levels.

Increasing the size and depth of these tanks will therefore not be possible due to the above constraints.

Due to the latest FRA and modelling work undertaken and the and the resultant lowered levels required onsite, a surface water gravity discharge to the public sewer will not be possible.

The lowest level within the site will be approximately 6.100m AOD. The invert level of the proposed point of connection to the existing surface water sewer is 5.170m AOD a difference of only 930mm.

As such, a surface water pumping station will be required to lift flows from the site and discharge into the shallow public surface water sewer on Manor Road.

It is proposed that runoff from each part of the development will be afforded an element of treatment and flow attenuation prior to leaving the site. This will be achieved via a series of source control features such as green roofs and rain gardens as shown on both the drainage layout and the appended landscaping masterplan in Appendix G and via underground storage tanks.

The tanks and wider drainage network have been and modelled to demonstrate the drainage systems operation and performance for the critical duration 1 in 1 year, 30 year and 100 year event plus a 40% allowance for climate change.

Table 5 (below) discusses other types of SuDS (taken from C753) and whether they could be utilised at this site.

SuDS Component	Site Suitability	Comments
Green roofs	Yes	Green roofs can be utilised
Soakaways	No	Variable ground and high-water table
Rainwater harvesting systems	No	Not suitable due to size and type of development
Filter Strips	No	Variable ground and high-water table
Filter trenches	No	Variable ground and high-water table
Infiltration trenches	No	Variable ground and high-water table
Swales	No	Not suitable due to site layout
Bio-retention	No	Not suitable due to site layout
Pervious pavements	Yes	Type C Pervious pavements can be utilised in certain areas.
Geocellular systems	Yes	Subject to architect's final design
Infiltration basins	No	Variable ground and high-water table
Detention basins	No	Not suitable due to site layout.
Ponds	No	Not suitable due to size of development and site layout
Storm water wetlands	No	Not suitable due to size of development and site layout
Rain gardens	Yes	Rain gardens can be utilised where levels permit.

3.1 Green roofs

Green roofs are proposed to be utilised throughout the development on all blocks. Any rainwater falling on such surfaces will be captured and slowed down, helping manage flood risk downstream by holding back rainwater for a longer time than conventional roofs.

3.2 Rain gardens

Rainwater from roofs and some of the access roads and footways will be directed into rain gardens and tree pits throughout the development, as shown on the layout plan. Water that is not taken up by plants or stored in the soil layers, will be collected into an underdrain and conveyed to the main site wide drain within the site.

3.3 On-site underground attenuation

It is proposed to use underground storage tanks to provide on-site attenuation to reduce the peak surface water runoff rate from the development. This will be provided in the form of underground cellular storage units located under the landscaped areas between the buildings. The cellular storage will be designed so that silt is prevented from entering the tanks via silt traps positioned immediately upstream of the tanks. Silt traps are also very effective at removing pollution from runoff.

3.4 Water Quality

Runoff from roof areas is relatively uncontaminated and does not warrant a complex treatment process prior to discharge. It is recommended that the new development employ a good housekeeping regime, external areas to be swept regularly to limit silt build up and any debris cleared away and disposed of immediately.

3.5 Overland flow exceedance routes

Consideration has been given to extreme rainfall events and a Hydrological and Hydraulic Modelling Study has been undertaken by Hydrock to identify and address overland surface water flows through a direct rainfall runoff model and have recommended mitigation where needed to ensure the proposed development would be safe across its design life. A copy of the post development model drawing for the 1 in 100 year + 40% climate change event has been provided within Appendix F.

4.0 SuDS Maintenance Schedules

It is understood that a management company will be taking ownership of the maintenance tasks listed below for the proposed SuDS components.

4.1 Underground drainage

General maintenance inspections should be carried out on a yearly basis unless noted otherwise in this report.

During any routine inspection, the condition of manhole covers, gulley gratings, channel drains etc. should be checked for damage, deformation and settlement. Settlement of paved surfaces may be an indication of a collapsed sewer / drain, check the position of the fault against known drainage runs i.e., between manholes.

Manholes - The most common problems are settlement of levelling brickwork and break up of mortar bedding / benching to the frame. Block paving is a particular problem around the manhole frame where there are often small 'cuts' of paving with insufficient bedding, resulting in the rapid displacement of the pieces. Remedial action is to re-bed the segments in mortar and dust with dry paving sand. Other problems may not be apparent unless the manhole cover is lifted to expose the chamber, benching and channels. With correctly constructed manholes there should be no need to visually inspect for at least five years. On inspection, the following should be checked:

- Infiltration, ground water entering the chamber through construction joints, seepage or squirting / gushing (proprietary sealants are available but excavation and partial reconstruction may be required).

- Damaged benching should not really occur unless by high pressure infiltration or poor construction. Check for deposition of detritus which may cause blockages of the sewer / drain. Can normally be jetted or hosed clear, larger items will need to be removed.

Deep chambers - over 1.5m in depth must not be entered unless two fully trained persons are present and only if gas monitoring equipment is available. Note, also that it may take two persons to lift the cover, using only the correct keys.

Pipelines - designed to be self-cleansing so should not require regular maintenance. Maintenance will therefore be restricted to resolving problems as they occur such as blockage or collapse.

Gully pots - Inspection and removal of leaves from gully gratings at least once a year (preferably in the spring after leaf fall in the autumn).

Channel drains - particularly gratings are susceptible to damage in heavily trafficked areas. The channels are designed to be self-cleansing but should be checked for signs of blockage and jetted as necessary.

Drainage pipes, manholes & silt traps - Inspect manholes & silt traps for build-up of silt and general debris (once a year, preferably in the spring after leaf fall in the autumn). If silt/debris is building up, then clean with jetting lorry / gully sucker & inspect pipe – same may be required. If the pipes to be jetted are plastic, then a high flow, low pressure setting should be used so that the pipes are not damaged. (NOTE: Manhole covers can be heavy and suitable lifting equipment / procedures should be used. Personnel should not enter manholes to carry out maintenance).

Unusual / unresolved problems - If the drainage system is still holding water following cleaning, or the jetting of the system removes excessive amounts of debris this may indicate greater issues within the system. A CCTV survey is likely to be required and further advice should be sought from a drainage contractor or engineer.

Remedial actions are to be carried out following identification of the problem(s). The works must only be undertaken by a reputable civil engineering contractor, carrying appropriate public liability insurance.

4.2 Attenuation storage tanks

Attenuation storage tanks are used to create a below-ground void space for the temporary storage of surface water before infiltration, controlled release or use. The storage structure is usually formed using one of the following methods:

- Geocellular storage systems
- plastic corrugated arch structures (constructed over and backfilled with an open-graded aggregate base)
- oversize concrete pipes
- oversize plastic pipes
- corrugated steel pipes
- precast or in situ concrete box culvert sections and tanks (including flat-packed concrete panels)
- glass-reinforced plastic (GRP) tanks
- hybrid structures using reinforced earth walls and concrete roof panels.

Storage tanks are used to create a below-ground void space for the temporary storage of surface water before infiltration, controlled release or reuse. The storage structure has been formed using a subbase Geocellular storage system.

Regular inspection and maintenance are required to ensure the effective long-term operation of below-ground storage system. Maintenance responsibility for systems should be placed with a responsible organisation. Table 1.0 provides guidance on the type of operational and maintenance requirements that are appropriate. The list of actions is not exhaustive, and some actions may not always be required.

Specific maintenance needs of the system should be monitored, and maintenance schedules adjusted to suit requirements.

4.3 SuDS flow control structures

SuDS flow control structures can be protected orifices, slots weirs or other controls at or near the surface to be accessible and easy to maintain. They may be in baskets, in small chambers or in the open.

4.4 Swale / Rain Garden

Swales will require regular maintenance to ensure continuing operation to design performance standards. Maintenance of swales is relatively straightforward for landscape contractors, and typically there should only be a small amount of extra work (if any) required for a swale over and above what is necessary for standard public open space.

Adequate access should be provided to all swale areas for inspection and maintenance, including for appropriate equipment and vehicles. Litter and debris removal should be undertaken as part of general landscape maintenance for the site and before any other SuDS management task.

The major maintenance requirement for dry swales is mowing. Mowing should ideally retain grass lengths of 75–150 mm across the main “treatment” surface, to assist in filtering pollutants and retaining sediments and to reduce the risk of flattening during runoff events. However, longer vegetation lengths, where appropriate, are not considered to pose a significant risk to functionality.

4.5 Maintenance Plans and schedules

Green Roof maintenance shall be as per Table 1

Green Roof: Operation & Maintenance Requirements – Table 1		
Maintenance Schedule	Required Action	Frequency
Regular Inspections	Inspect all components including soil substrate, vegetation, drains, irrigation systems (if applicable), membranes and roof structure for proper operation, integrity of waterproofing and structural stability	Annually and after severe storms
	Inspect soil substrate for evidence of erosion channels and identify any sediment sources	Annually and after severe storms
	Inspect drain inlets to ensure unrestricted runoff from the drainage layer to the conveyance or roof drain system	Annually and after severe storms
	Inspect underside of roof for evidence of leakage	Annually and after severe storms
Regular maintenance	Remove debris and litter to prevent clogging of inlet drains and interference with plant growth	Six monthly and annually or as required
	During establishment (ie year one), replace dead plants as required	Monthly (but usually responsibility of manufacturer)
	Post establishment, replace dead plants as required (where > 5% of coverage)	Annually (in autumn)
	Remove fallen leaves and debris from deciduous plant foliage	Six monthly or as required
	Remove nuisance and invasive vegetation, including weeds	Six monthly or as required
	Mow grasses, prune shrubs and manage other planting (if appropriate) as required – clippings should be removed and not allowed to accumulate	Six monthly or as required
Remedial actions	If erosion channels are evident, these should be stabilised with extra soil substrate similar to the original material, and sources of erosion damage should be identified and controlled	As required
	If drain inlet has settled, cracked or moved, investigate and repair as appropriate	As required
Source: CIRIA C753, Table 12.5		

Swale / Rain garden maintenance shall be as per Table 2

Swale / rain garden: Operation & Maintenance Requirements – Table 2		
Maintenance Schedule	Required Action	Frequency
Regular Maintenance	Remove litter and debris	Monthly or as required
	Cut grass – to retain grass height within specified design range	Monthly (during growing season), or as required
	Manage other vegetation and remove nuisance plants	Monthly at start, then as required
	Inspect inlets, outlets and overflows for blockages, and clear if required	Monthly
	Inspect infiltration surfaces for ponding, compaction, silt accumulation, record areas where water is ponding for > 48 hours	Monthly, or when required
	Inspect vegetation coverage	Monthly for 6 months, quarterly for 2 years, then half yearly
	Inspect inlets and facility surface for silt accumulation, establish appropriate silt removal frequencies	Half yearly
Occasional maintenance	Reseed areas of poor vegetation growth, alter plant types to better suit conditions, if required	As required or if bare soil is exposed over 10% or more of the swale treatment area
Remedial actions	Repair erosion or other damage by re-turfing or reseeding.	As required
	Relevel uneven surfaces and reinstate design levels	As required
	Scarify and spike topsoil layer to improve infiltration performance, break up silt deposits and prevent compaction of the soil surface	As required
	Remove build-up of sediment on upstream gravel trench, flow spreader or at top of filter strip	As required
	Remove and dispose of oils or petrol residues using safe standard practices	As required
Source: CIRIA C753, Table 21.3		

Permeable paving maintenance shall be as per Table 3

Pervious pavements : Operation & Maintenance Requirements – Table 3		
Maintenance Schedule	Required Action	Frequency
Regular Maintenance	Brushing and vacuuming (standard cosmetic sweep over whole surface)	Once a year, after autumn leaf fall, or reduced frequency as required, based on site-specific observations of clogging or manufacturer's recommendations – pay particular attention to areas where water runs onto pervious surface from adjacent impermeable areas as this area is most likely to collect the most sediment
Occasional Maintenance	Stabilise and mow contributing and adjacent areas	As required
	Removal of weeds or management using glyphospate applied directly into the weeds by an applicator rather than spraying	As required – once per year on less frequently used pavements
Remedial Actions	Remediate any landscaping which, through vegetation maintenance or soil slip, has been raised to within 50 mm of the level of the paving	As required
	Remedial work to any depressions, rutting and cracked or broken blocks considered detrimental to the structural performance or a hazard to users, and replace lost jointing material	As required
	Rehabilitation of surface and upper substructure by remedial sweeping	Every 10 to 15 years or as required (if infiltration performance is reduced due to significant clogging)
Monitoring	Initial inspection	Monthly for three months after installation
	Inspect for evidence of poor operation and/or weed growth – if required, take remedial action	Three-monthly, 48 h after large storms in first six months
	Inspect silt accumulation rates and establish appropriate brushing frequencies	Annually
	Monitor inspection chambers	Annually
Source: CIRIA C753, Table 20.15		

Below Ground Control Chambers maintenance shall be as per Table 4

Below Ground Control Chamber Maintenance Requirements – Table 4		
Maintenance Schedule	Required Action	Frequency
Regular Maintenance	Remove cover and inspect ensuring water is flowing freely and that the exit route for water is unobstructed. Remove debris and silt.	Annually
	Undertake inspection after leaf fall in autumn	Annually
	Check topsoil levels are 20mm above edges of baskets and chambers to avoid mower damage	As necessary
Remedial Actions	Repair inlets, outlets, overflows and vents or any physical damage.	As required
Monitoring	Inspect / Check all inlets, outlets, vents and overflows to ensure that they are in good condition and operating as designed.	Annually

Storage Tank maintenance shall be as per Table 5

Storage Tanks: Operation & Maintenance Requirements – Table 5		
Maintenance Schedule	Required Action	Frequency
Regular Maintenance	Inspect and identify any areas that are not operating correctly. If required, take remedial action.	Monthly for 3 months, then annually
	Remove debris from the catchment surface (Where it may cause risks to performance)	Monthly
	For systems where rainfall infiltrates into the tanks from above, check surface of filter for blockage by sediment, algae or other matter; Remove and replace surface infiltration medium as necessary	Annually
	Remove sediment from pre-treatment structures such as catch pits and/or internal fore bays	Annually, or as required.
Remedial Actions	Repair inlets, outlets, overflows and vents	As required
Monitoring	Inspect / Check all inlets, outlets, vents and overflows to ensure that they are in good condition and operating as designed.	Annually
	Survey inside of tank for sediment build-up and remove if necessary	Every 5 years or as required
Source: CIRIA C753, Table 21.3		

5.0 Discussions & Conclusions

- The existing site is considered to be brownfield land. The site is 1.842Ha and is currently occupied by a retail warehouse building (Homebase) in the central third, with associated car / bus parking in the north-eastern third and storage areas in the south-western third of the site. In this pre-redevelopment layout, the site is almost fully paved with several small areas of vegetation and trees throughout the site.

- Existing Greenfield run off rates have been calculated using only the proposed impermeable areas as requested by the GLA to be Q Bar = 1.64 l/sec, Q1 = 1.39 l/sec, Q30 = 3.77 l/sec, Q100 = 5.23 l/sec

- Existing Brownfield run off rates have been calculated to be Q1= 162 l/sec, Q30= 398 l/sec, Q100= 519 l/sec.

- The proposed development comprises the demolition of the current retail units and the development of 4 No. residential buildings. Building A is a part 3, part 4, part 7 and 8 storey building, Building B is an 11 storey building, Building C is a part 8 and 10 storey building and Building D is a part 4, part 7 and part 8 storey building. In addition, a basement plant room is proposed beneath Building A.

- The previous surface water drainage strategy proposed to use infiltration techniques, based on assumed ground conditions and infiltration rates, and detailed several soakaways positioned between the buildings to manage surface water on the site. The drainage strategy noted that infiltration tests and groundwater monitoring should be undertaken to confirm this proposed strategy would be feasible for this site and considered an alternative strategy by connecting to the public surface water sewer network on Manor Road.

- An assessment was undertaken to determine the volume of attenuation required to achieve the 1:100 year greenfield run off rate of 8.9 l/sec. A volume of 1485m3 was calculated however it was acknowledged that the extent of storage required in the context of this site would be difficult to achieve and would equate to most of the central pedestrian spaces being underlain by geo-cellular storage which would not be practicable, particularly in consideration of the other space requirements.

- A discharge rate of 25.2 l/sec was agreed with the Council's Drainage Officer as part of the original strategy if infiltration proved to be unviable and advised that this run-off rate and associated attenuation would be acceptable. This reduction in run of rates equates to an 84% reduction of the existing sites 1 in 1 year discharge rate and a 95% reduction of the existing 1 in 100 year discharge rate.

- Groundwater monitoring was conducted in April 2021 and August 2022.The findings suggested that a shallow body of groundwater is situated within the Kempton Park Gravel Member and due to this high water table underlying the site it is considered that infiltration will not be suitable method to discharge surface water from the site.

- As infiltration is not feasible this revised drainage strategy proposes to discharge the surface water to the public sewer on Manor Road. It will be restricted to a rate of 25.2 l/sec as was previously agreed with the Council's Drainage Officer.

- Due to the latest FRA and modelling work undertaken and the resultant lowered levels required onsite, a surface water gravity discharge to the public sewer will not be possible. As such, a surface water pumping station will be required to lift flows from the site and discharge into the shallow public surface water sewer on Manor Road.

- Several attenuation tanks have been used to attenuate the 1:100 year event +40% allowance for climate change and have been positioned between the buildings which has been coordinated with the required underground service corridors and set at a level needed where the tanks will not be affected by floatation due to the high ground water levels. Increasing the size and depth of these tanks will therefore not be possible due to the above constraints.

- Given that the proposed discharge rates are a considerable reduction of the existing brownfield runoff rates, we would anticipate that flood risk to the local watercourses would not be exacerbated as a result of the development.

- It is proposed to incorporate green roofs, rain gardens and Type C permeable paving where possible into the scheme as well as increasing the overall permeability of the site through the introduction of soft landscaping indicated on the Landscape General Arrangement Plan by Gillespie's Drawing number P11559-00-001-100 Rev16 provided as part of this report.

- Measures taken to prevent pollution of the receiving surface waters including silt trap chambers as discussed within this report.

- Full details of the maintenance plans for the surface water drainage system have been provided as part of this report.

- A management company will be appointed to undertake inspections and maintenance activities for the surface water drainage system. Specific details are not known at this time.

- A copy of the post development model drawing for the 1 in 100 year + 40% climate change event has been provided within Appendix F indicating the overland flow exceedance routes.

APPENDIX A – Site Location Plan

APPENDIX B – Topographical Site Survey

APPENDIX C – Ground Investigations

APPENDIX D – Thames Water Sewer Records

APPENDIX E – Hydraulic Calculations

APPENDIX F – Drainage Strategy

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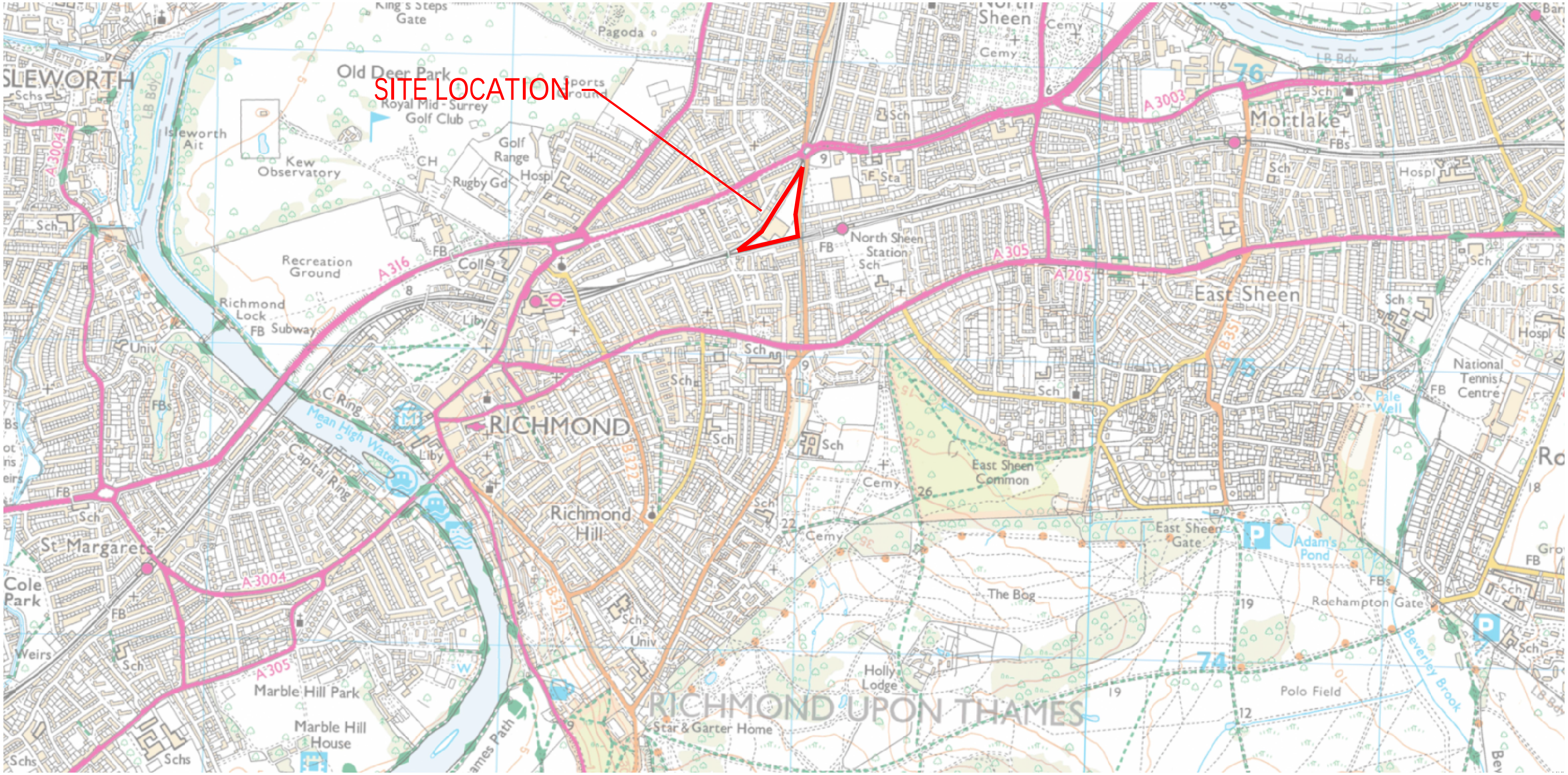
Norbiton, Kingston Upon Thames, KT2 7AZ
Tel: 020 8390 9097
Fax: 020 8390 7888

APPENDIX G – Proposed Architectural Layouts for Information

APPENDIX A – Site Location Plan



Manhire Associates
CONSULTING ENGINEERS

Manhire Associates Limited
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Kingston Upon Thames, KT2 7AZ

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NOTES

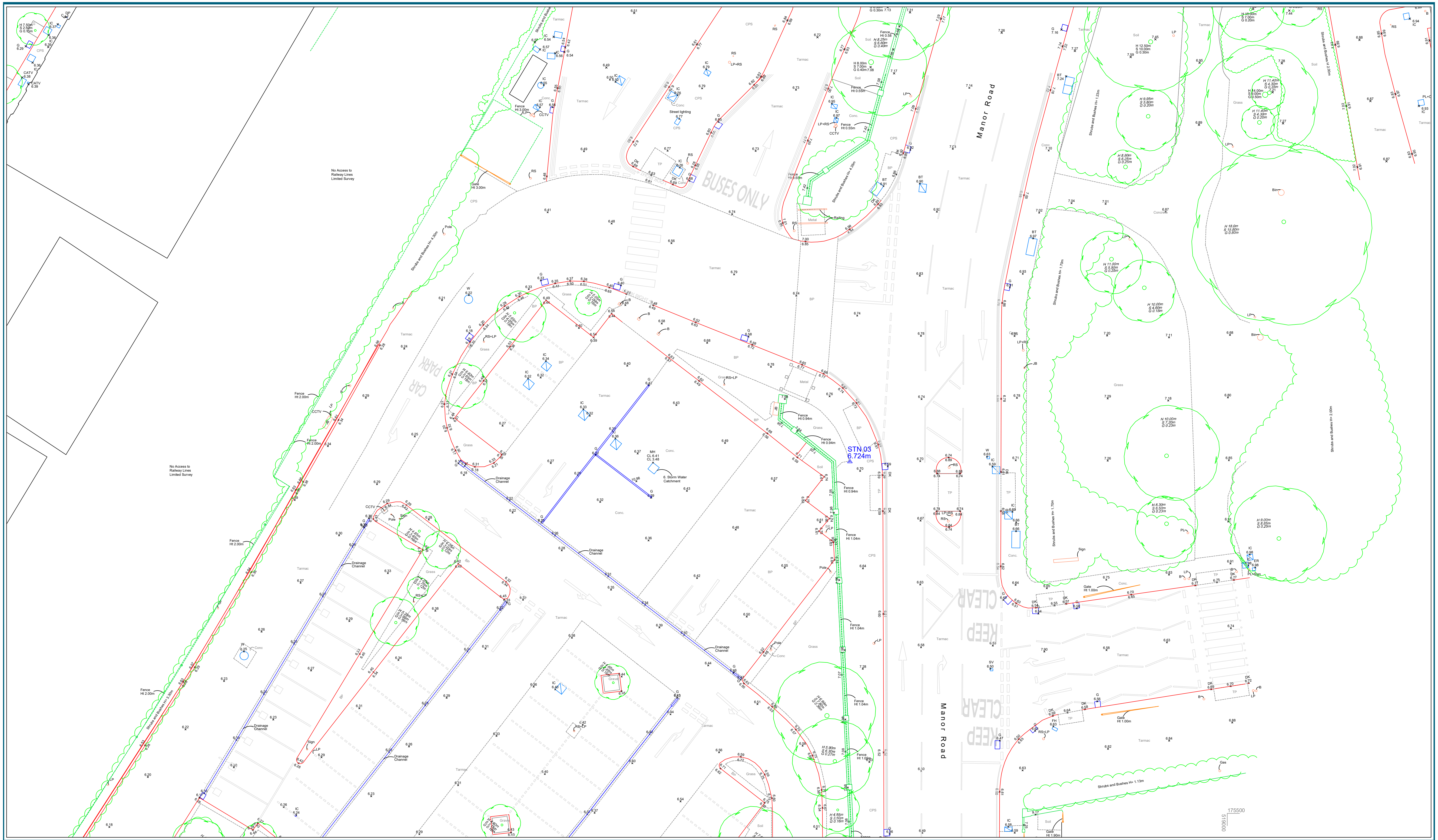
REV	DATE	DESCRIPTION	BY
–	–	–	–

PROJECT MANOR ROAD RICHMOND

TITLE SITE LOCATION PLAN

PROJECT NO	21031		
DRG NO	PSK860		
DATE	MAR 23	REV	Rev00
BY	GMC	CHK	–

APPENDIX B – Topographical Site Survey



Sources:

Levels are related to Ordnance Survey Datum via GPS Observations

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All information contained in this drawing (including digital data) should be checked and verified prior to any fabrication or construction.

Stations:

STN01 - 518899.719, 175472.891, 6.147
STN02 - 518970.579, 175484.687, 6.586
STN03 - 518969.606, 175528.346, 6.724

Key:

A/C	Air Conditioning Unit	PO	Post
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BP	Brick Paving	SRFC	Surface Change
BT	BT Inspection Cover	S/O	Smoke Outlet
CATV	Cable Television Inspection Cover	SV	Stop Valve
CPS	Concrete Paving Slab	TCB	Telephone Call Box
DK	Dropped Kerb	TP	TacCPS Paving
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IRS	Illuminated Road Sign		
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PB	Post Box		
PL	Pavement Light		

Indicative

	S1	S2
	S3	S4
S5	S6	S7
S8	S9	S10

Project: Homebase, Richmond

Title: Topographic Survey
Sheet 2

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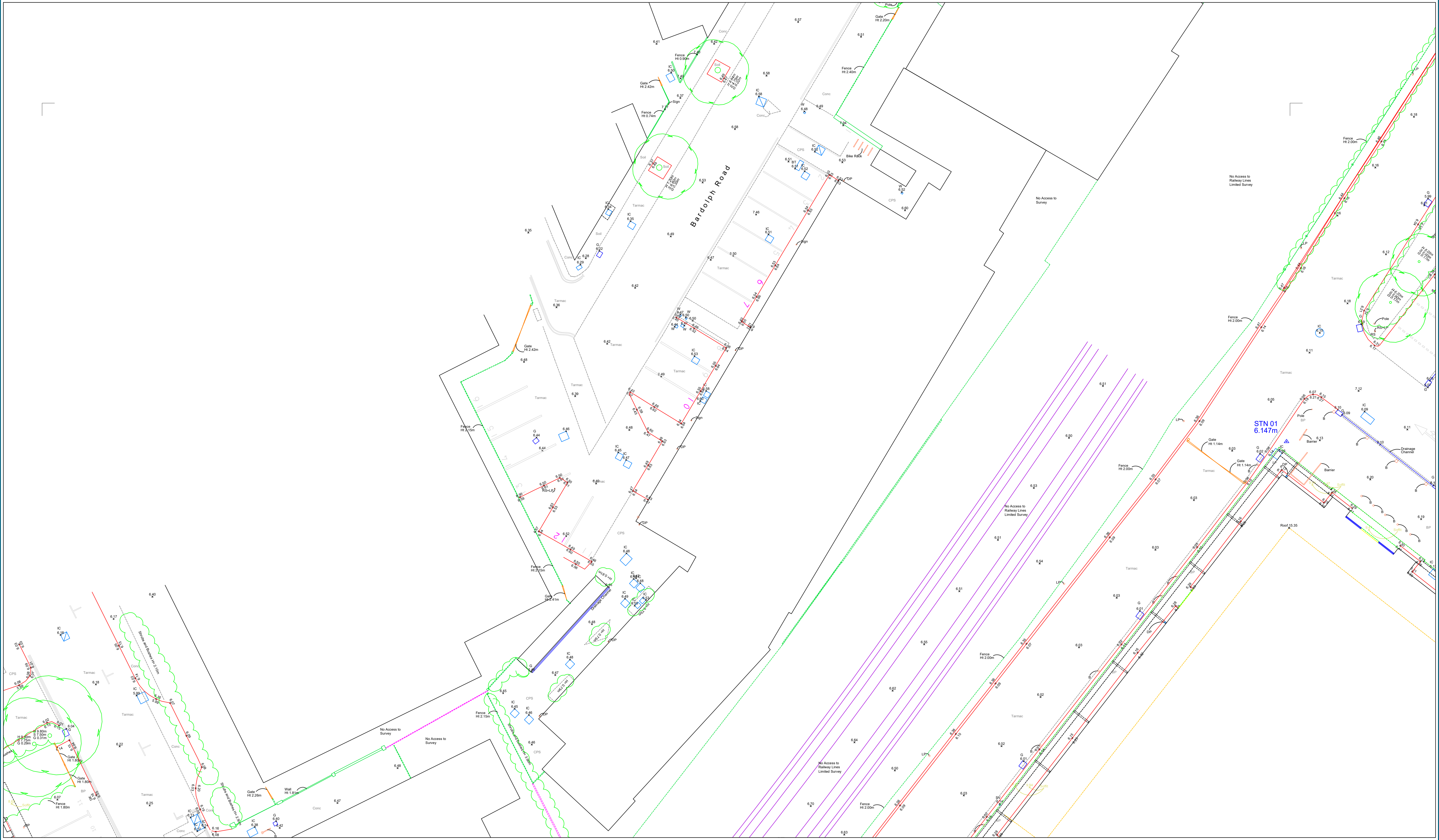

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W	Water Inspection Cover
WM	Water Meter

	S1	S2
	S3	S4
S5	S6	S7
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Project: Homebase, Richmond

Title: Topographic Survey
Sheet 3

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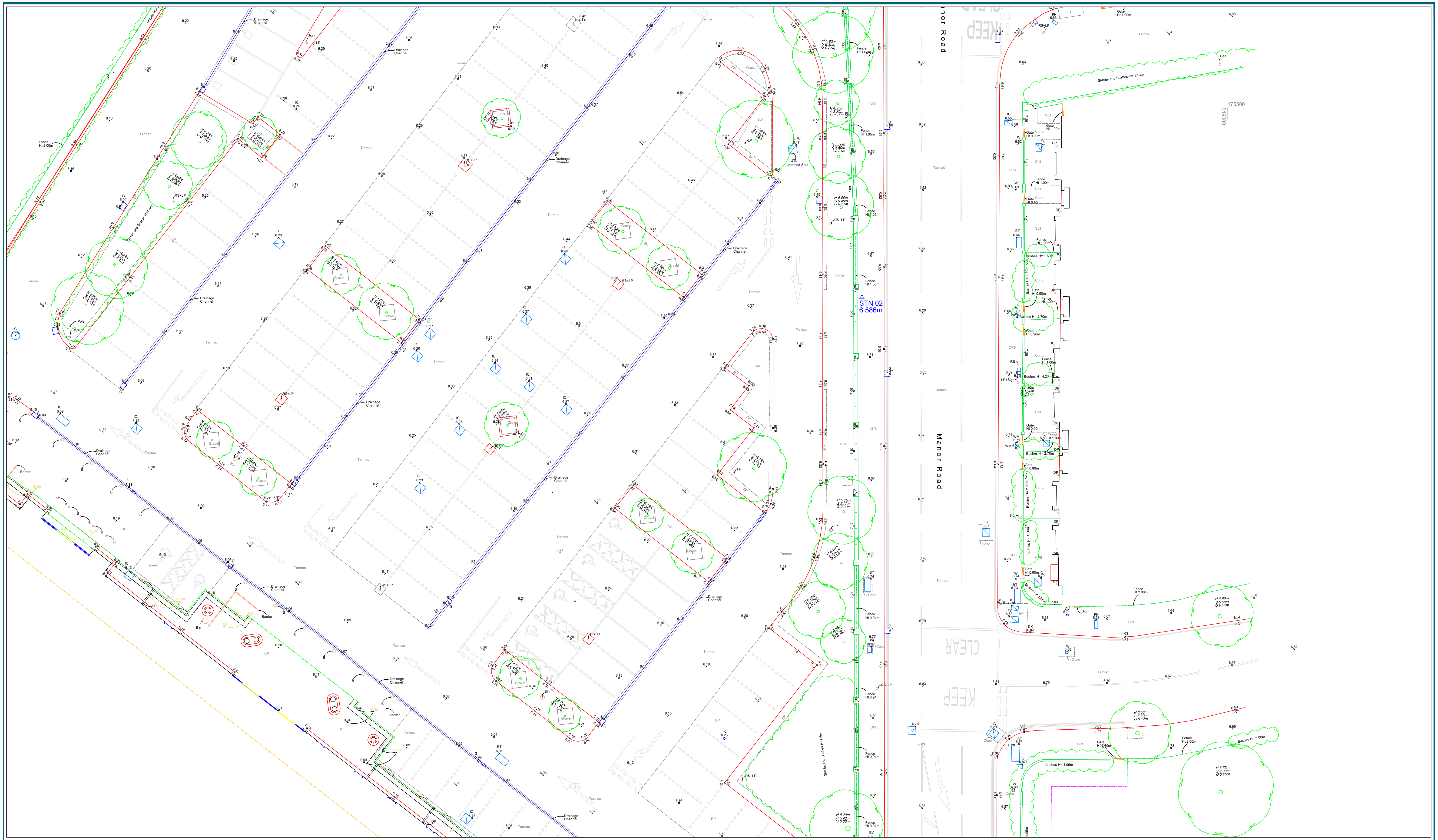

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WM	Water Meter

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Indicative

Project: Homebase, Richmond

Title: Topographic Survey Sheet 4

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Indicative

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	S3	S4
S5	S6	S7
S8	S9	S10

Project: Homebase, Richmond

Title: Topographic Survey Sheet 5

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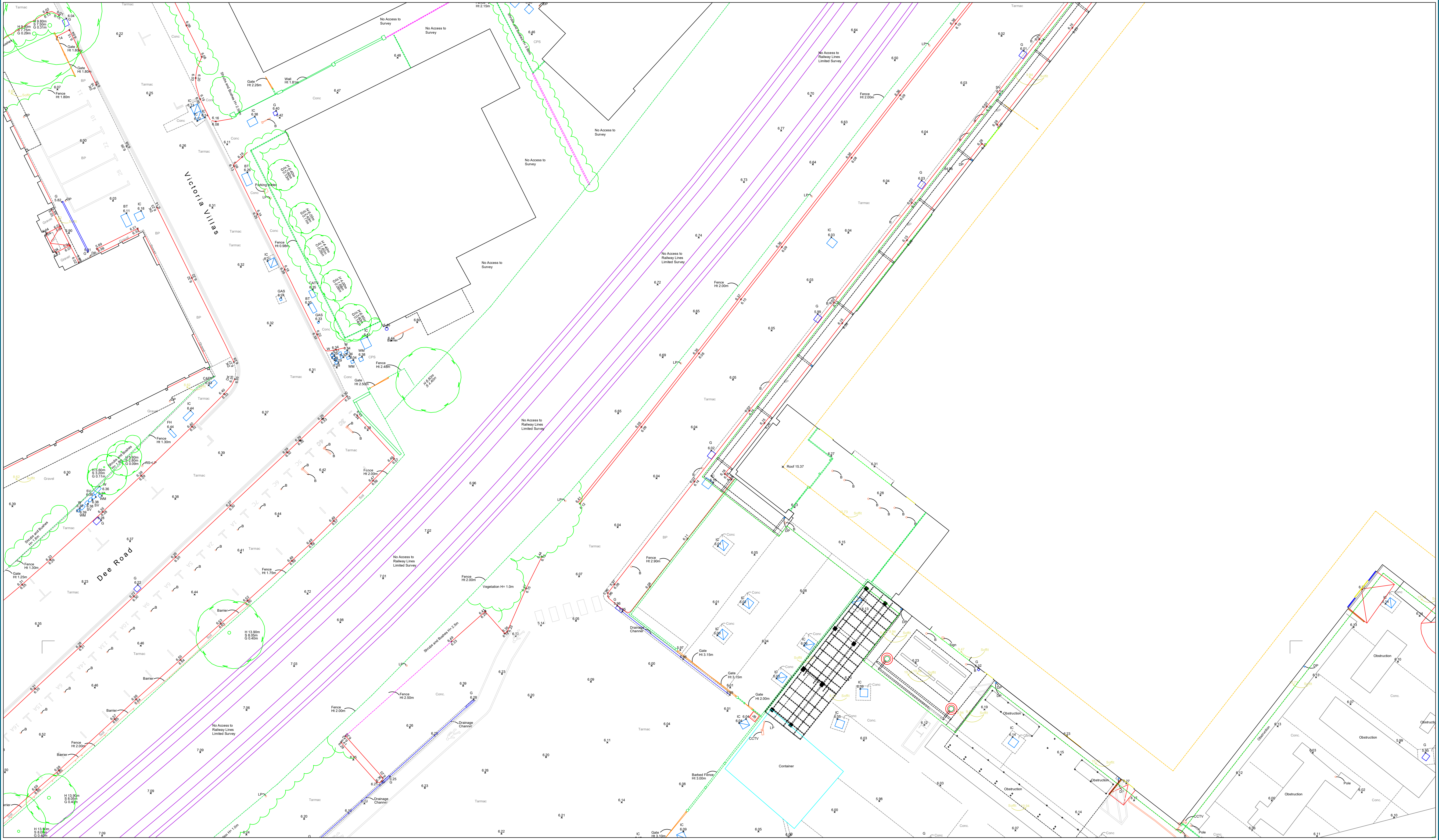

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WM	Water Meter

	S1	S2
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S5	S6	S7
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Project: Homebase, Richmond

Title: Topographic Survey Sheet 6

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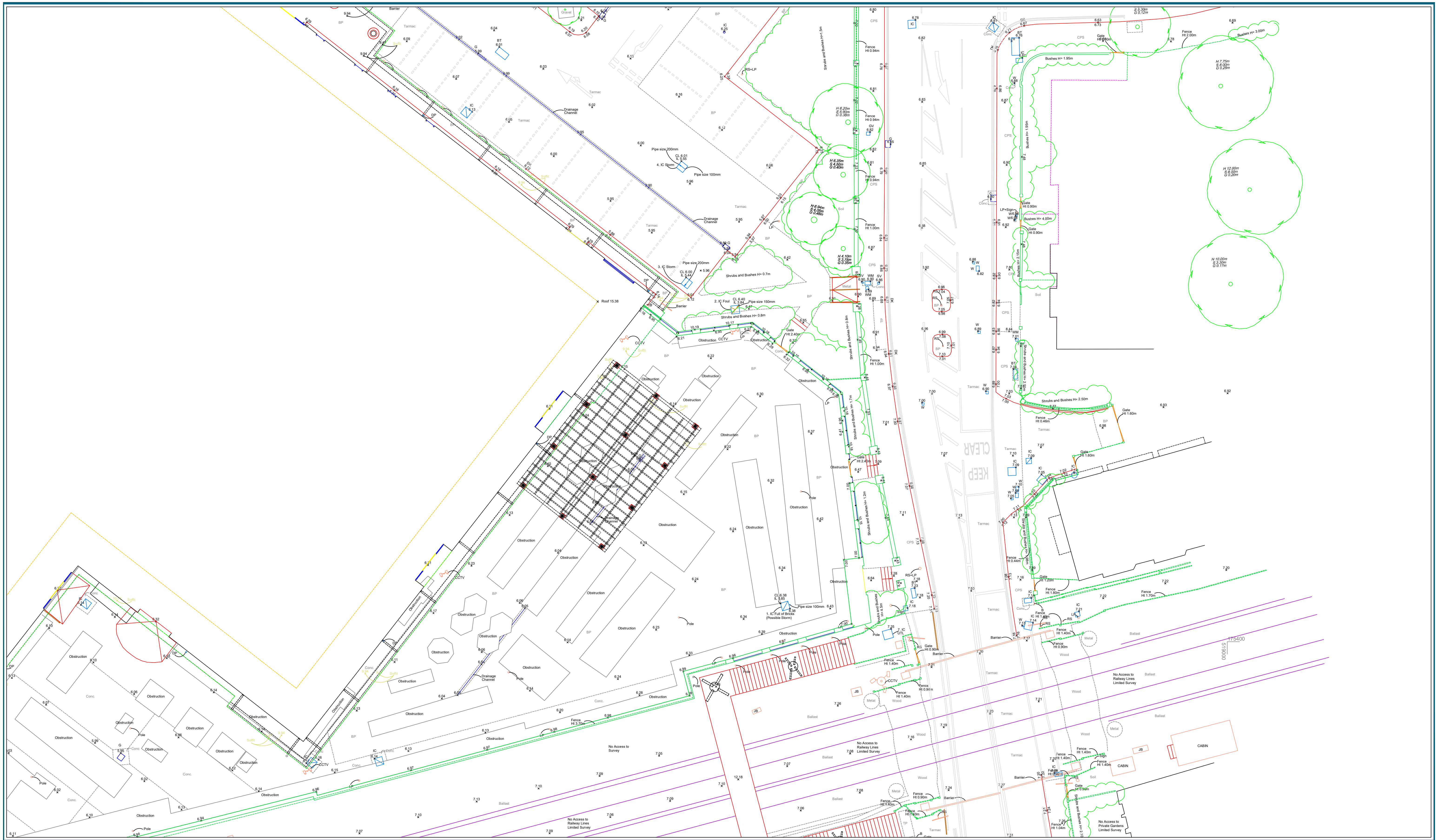

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Project: Homebase, Richmond

Title: Topographic Survey Sheet 7

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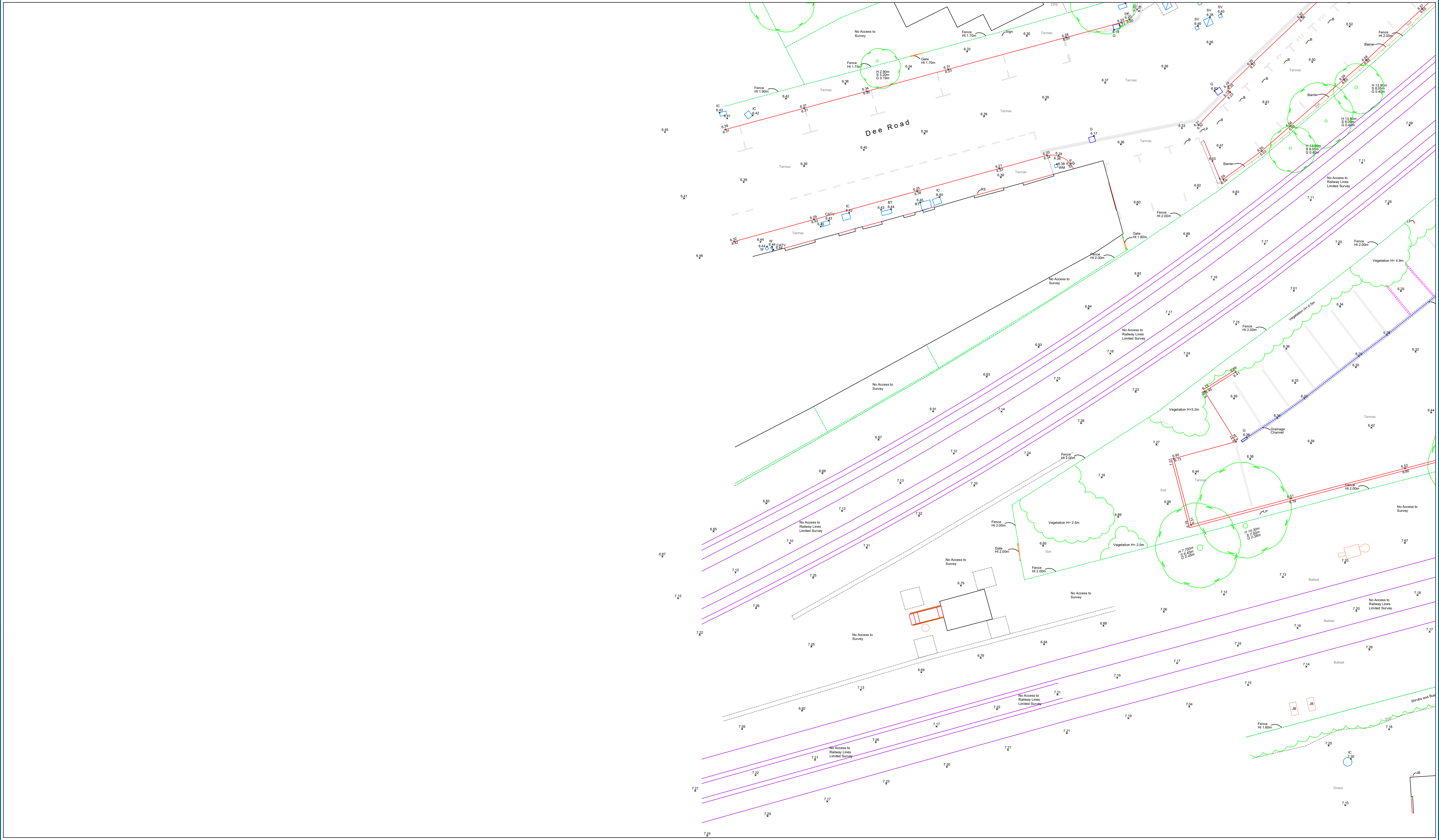

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- PO Post
- RL Ridge Level
- SRFC Surface Change
- S/O Smoke Outlet
- SV Stop Valve
- TCB Telephone Call Box
- TP TacCPS Paving
- W Water Inspection Cover
- WM Water Meter

Indicative

	S1	S2
	S3	S4
S5	S6	S7
S8	S9	S10

Project: Homebase, Richmond

Title: Topographic Survey Sheet 8

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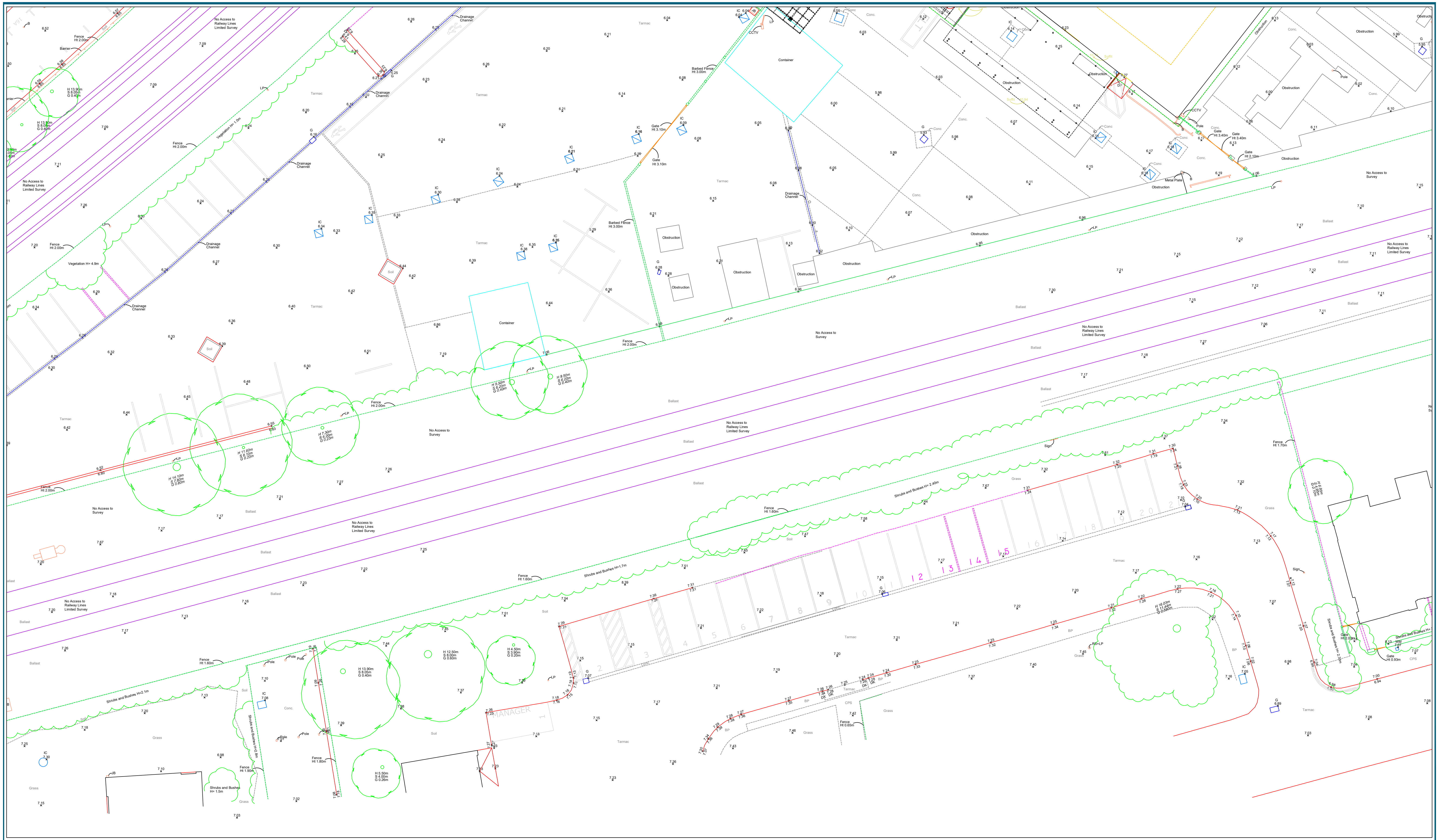

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	S1	S2
	S3	S4
S5	S6	S7
S8	S9	S10

Indicative

Project: Homebase, Richmond

Title: Topographic Survey Sheet 9

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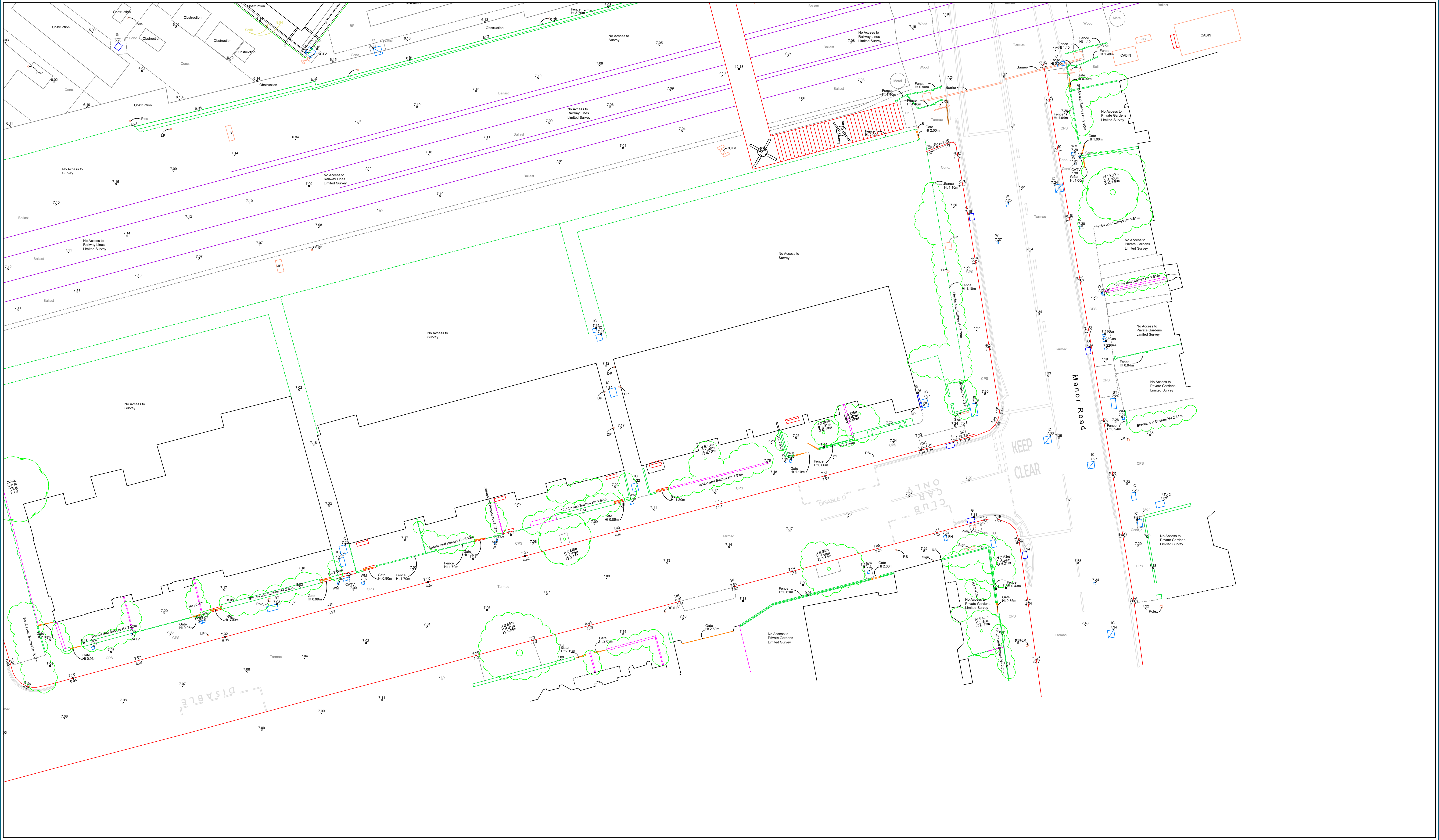

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	S1	S2
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S8	S9	S10

Project: Homebase, Richmond

Title: Topographic Survey
Sheet 10

Drawn By: SB

Scale: 1:100 @ A0

Date: August 2018

Dwg No: **LS2024/T/10RevA**

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WM	Water Meter

Indicative

			S13
		S11	S12
		S1	S2
		S3	S4
S5	S6	S7	
S8	S9	S10	

Project: Homebase, Richmond

Title: Topographic Survey
Sheet 11

RevB: Additional Area Added to Plan

Point 2 Surveyors Ltd,
3rd Floor,
17 Slingsby Place,
London WC2E 9AB,
0207 836 5828
www.point2surveyors.com

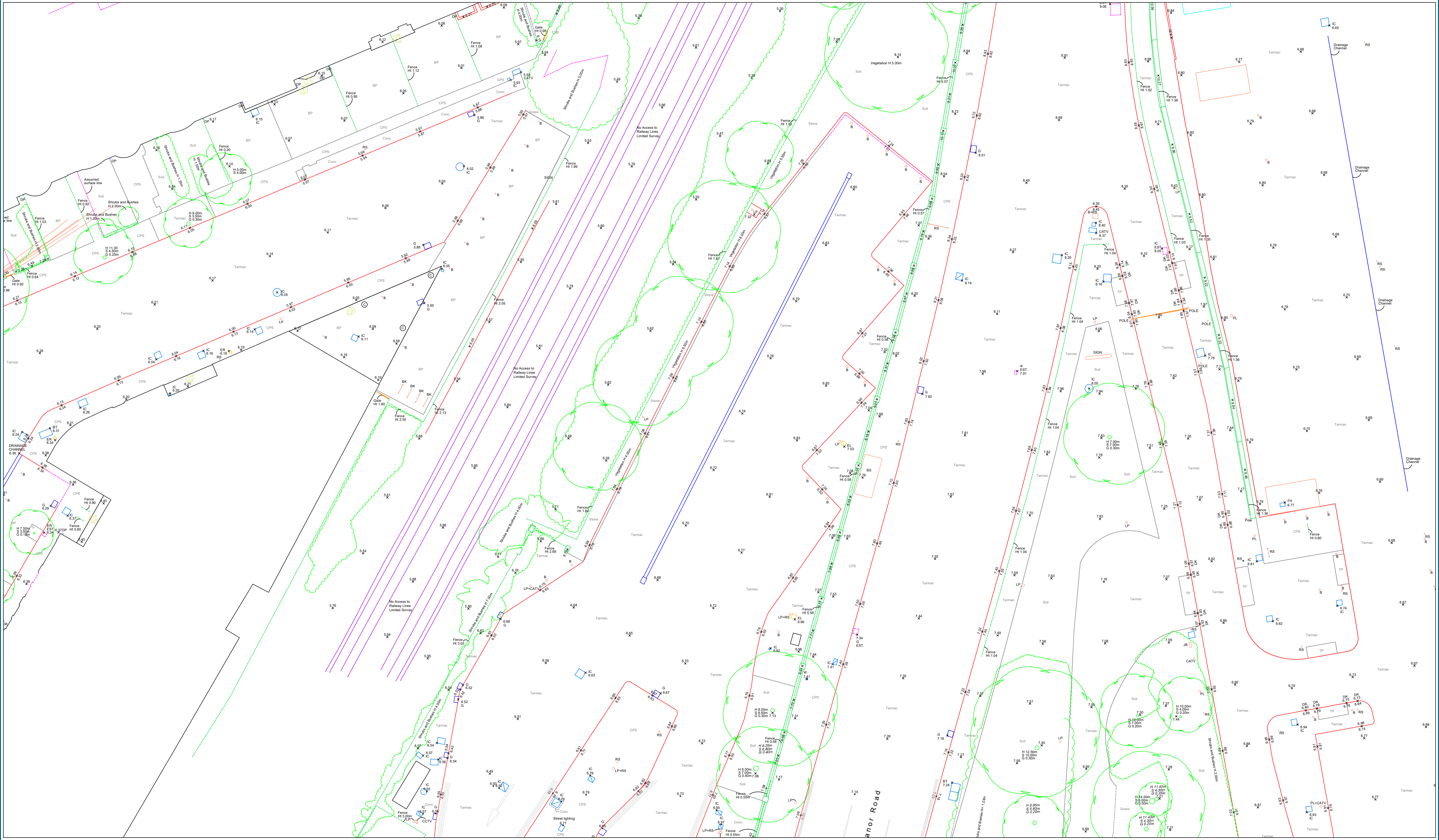
POINT 2 surveyors

Drawn By: SB

Scale: 1:100 @ A0

Date: August 2018

Dwg No: LS2024/T/11RevA



Sources:

Levels are related to Ordnance Survey Datum via GPS Observations

Survey location is related to Ordnance Survey Grid via GPS Observations.

All information contained in this drawing (including digital data) should be checked and verified prior to any fabrication or construction.

Stations:

STN01 - 518899.719, 175472.891, 6.147
STN02 - 518970.579, 175484.687, 6.586
STN03 - 518969.606, 175528.346, 6.724

Key:

A/C	Air Conditioning Unit
B	Bollard
BP	Brick Paving
BT	BT Inspection Cover
CATV	Cable Television Inspection Cover
CPS	Concrete Paving Slab
DK	Dropped Kerb
DP	Down Pipe
EL	Eaves Level
FH	Fire Hydrant
G	Gully
GP	Gate Post
IC	Inspection Cover
ILB	Illuminated Bollard
IRS	Illuminated Road Sign
JB	Junction Box
LP	Lamp Post
MH	Man Hole Cover
PB	Post Box
PL	Pavement Light
PO	Post
RL	Ridge Level
SRFC	Surface Change
S/O	Smoke Outlet
SV	Stop Valve
TCB	Telephone Call Box
TP	TacCPS Paving
W	Water Inspection Cover
WM	Water Meter

		S13
	S11	S12
	S1	S2
	S3	S4
S5	S6	S7
S8	S9	S10

Indicative

Project: Homebase, Richmond

Title: Topographic Survey
Sheet 12

RevB: Additional Area Added to Plan

Drawn By: SB

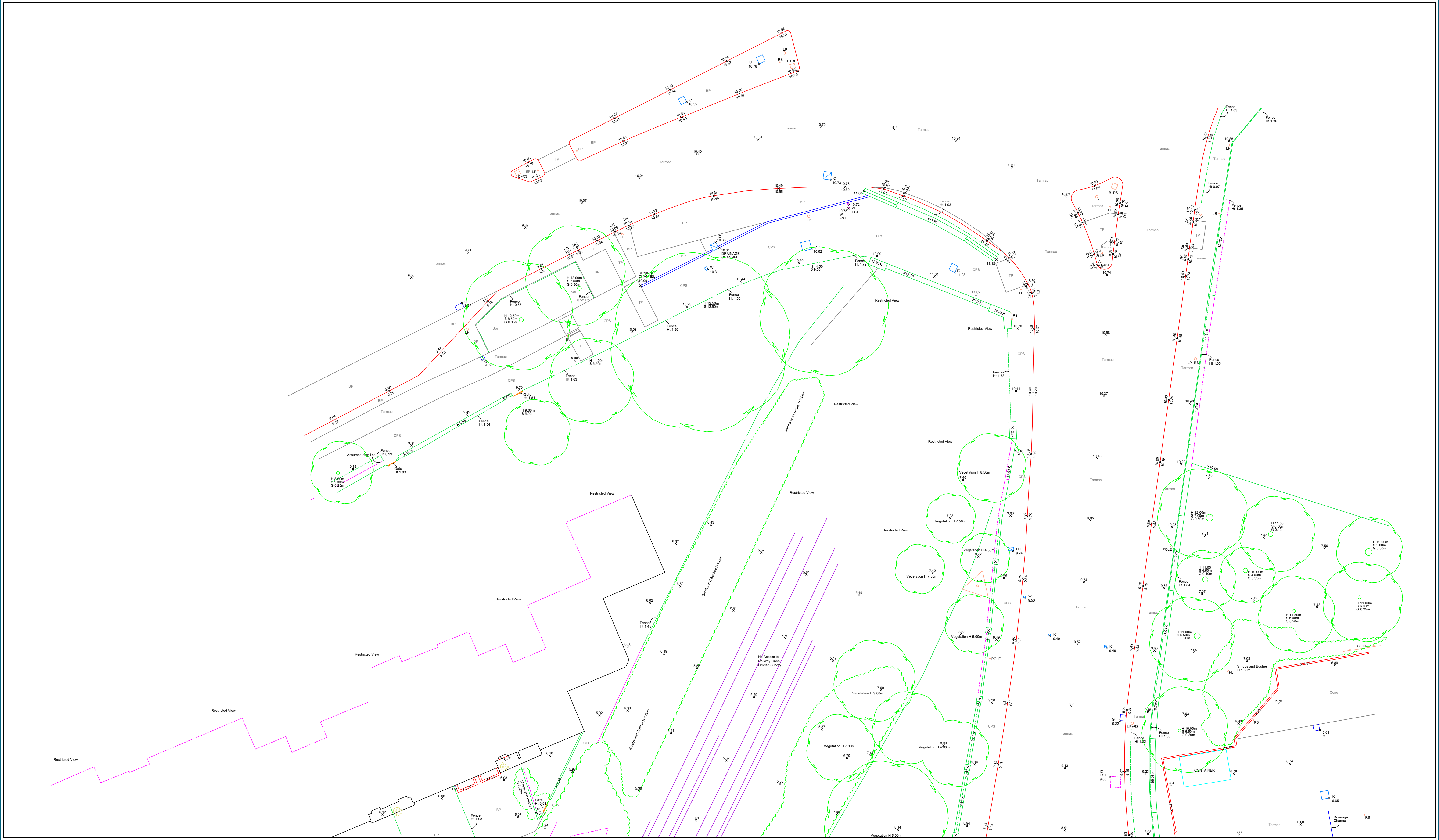
Scale: 1:100 @ A0

Date: August 2018

Dwg No: LS2024/T/12RevA

Point 2 Surveyors Ltd,
3rd Floor,
17 Slingsby Place,
London WC2E 9AB,
0207 836 5828
www.point2surveyors.com

POINT 2 surveyors



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		S13
	S11	S12
	S1	S2
	S3	S4
S5	S6	S7
S8	S9	S10

Indicative

Project: Homebase, Richmond

Title: Topographic Survey Sheet 13

RevB: Additional Area Added to Plan

Point 2 Surveyors Ltd,
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0207 836 5828
www.point2surveyors.com

POINT 2 surveyors

Drawn By: SB

Scale: 1:100 @ A0

Date: August 2018

Dwg No: LS2024/T/13RevA

APPENDIX C – Ground Investigations

Manhire Associates
CONSULTING ENGINEERS

Manor Road, Richmond

Geo-Environmental Site Investigation Report

Taylor Wimpey West London Limited

DATE OF ISSUE:
07/11/2022

Status:	**Information**	**Project No.:**	**21031**
Revision:	**0**	**Date:**	**November 2022**

Manhire Associates
Geo-Environmental Limited
Hanover House, 76 Coombe Road
Norbiton, Kingston Upon Thames, KT2 7AZ
Tel: 020 8390 9097
Fax: 020 8390 7888

Contents

Appendices

1.0 Introduction

a. This report has been prepared by Manhire Associates Geo-Environmental Ltd to assess the environmental risks and factors associated with the soils and groundwater encountered on the site following a programme of sampling and contaminant testing undertaken (Phase 2) at the Homebase site, located to the west of Manor Road, Richmond Upon Thames. This report supplements a previous investigation by Fairhurst [1] and should be read in conjunction with it.

b. **Planning condition 25** requires that "*Development shall not commence until a strategy to deal with the potential risks associated with any contamination of the site has been submitted to, and approved in writing by, the Local Planning Authority*"

c. A Phase 1 Geo-Environmental and Geotechnical Preliminary Risk Assessment and a Phase 2 Ground Investigation Report has previously been prepared by Fairhurst as part of the Amended Application. Their Phase I Report identified potential sources of contamination on-site and a moderate risk was identified typically. It recommended that a ground investigations be undertaken to further quantify potential risks. The Phase 2 investigation undertaken by Fairhurst in July 2021 found low levels of contamination in 2 trial pits and detected asbestos in 2 samples. The report recommended that in areas of proposed soft landscaping, the placement of an engineered capping layer formed from imported, chemically 'clean' soils be installed and noted that on completion of these remedial works it would be considered that the risks to future site users would be considered **Low.** Ground water samples analysed were largely compliant with UKDWS with limited exceedances in 4 boreholes but were considered **Low Risk** to the shallow groundwater within the Kempton Park Gravel Member. Assessment of the ground gas indicated **Very Low Risk** for the site. The report recommended a second round of ground investigations to include boreholes, window sampling groundwater monitoring and geo-environmental and geo-technical sampling and testing to supplement the existing data.

d. The purpose of this additional Phase 2 investigation and sampling was to determine the following:

- Provision of sufficient geotechnical data to provide design parameters for the economic design of the foundations, earthworks and temporary works.
- Assessment of problems and constraints associated with the construction of the works arising from the soil or ground water conditions, including temporary works, excavation, extraction and drainage.
- Consideration of changes in the stability, drainage or other geotechnical aspects of the site and the surrounding ground and buildings which may arise from the works.
- Assessment of the ground water regime.
- Sampling and testing for an environmental risk assessment in accordance with CLEA guidelines, and the Environmental Protection Act 1990.

- Pile design – assessment of pile design parameters and assessment of various capacities for various pile diameters and recommendations for factors of safety.

e. The intrusive site investigation consisted of three boreholes to a depth of 30m and a series of six continuous dynamic windowless sampler holes were carried out, supported by a programme of laboratory testing.

- The ground conditions revealed by the investigation comprised Made Ground overlying Kempton Park Gravel with London Clay at depth.

- Contamination testing found low levels of contamination, which were below the relevant trigger concentrations, however chemical analysis found some contamination above trigger levels in 3 isolated locations which will require limited remediation.

- Standpipe readings found groundwater varied across the site with readings indicating groundwater at some 2.5m depth below ground level in BH1 and some 4.2m below ground level in BH2 & BH3.

- The groundwater in BH3 was recorded at 2.36m AOD which is below the proposed basement excavation level and thus groundwater control will not be required.

f. With regards to potential remediation of soil contaminated with PAH. metals or asbestos, it is considered that where in areas of hardstanding or below building footprints, contaminants can remain in situ, as the pathway in a source-pathway-receptor model will be blocked. Where they coincide with areas of soft landscaping, remediation will be necessary. A 450mm thick cap should be utilised, comprising imported clean soils with a capillary break layer at the base underlain by a geotextile barrier. This is to block the pathway in a source-pathway-receptor model and to discourage excavation below that level.

g. **Planning Condition 26** requires that *“Prior to occupation, a verification report demonstrating the completion of works set out in the approved remediation strategy and the effectiveness of the remediation shall be submitted to, and approved in writing, by the Local Planning Authority”.*

h. **Planning Condition 27** requires that “If, during development, contamination not *previously identified is found to be present at the site then no further development (unless otherwise agreed in writing with the Local Planning Authority) shall be carried out until a remediation strategy detailing how this contamination will be dealt with has been submitted to and approved in writing by the Local Planning Authority”.*

i. This Report also describes measures being adopted on site so that any unexpected contamination identified on site is reported and details of what the post remediation verification report needs to include.

j. This Report is prepared for the use of Taylor Wimpy West London in connection with the development. The report is not intended for, and should not be relied upon by any third party, and no responsibility is undertaken to any third party, without the express written agreement of Manhire Associates Geo-Environmental Ltd.

2.0 Site description

The site is a triangular plot of land currently occupied by Homebase and Pets at Home retail outlets with associated car parking and yard area in Richmond upon Thames. Manor Road forms the southern boundary in the northern and western are marked by railway lines. To the east of the building is car parking whilst the yard is to the north. An Autoglass repair centre and "We Buy Any Car" franchises are located within the main car park area.

Figure 1 of Appendix E illustrates the general layout of the site and its immediate environs as they presently stand.

3.0 Development proposals

It is intended to construct a series of multi-storey blocks on the site with a small basement located under Block A measuring 31m x 6m extending approximately 3m below the existing ground level.

The proposed ground floor layouts are provided at Figure 2 of Appendix E.

4.0 Geology

Published records of the British Geological Survey indicate the site to lie Kempton Park Gravel overlying London Clay at depth.

5.0 Field work

The extent of the field work was specified by the client and comprised three boreholes drilled by light percussive techniques to 30m. These were supplemented by six windowless sampler holes to a maximum of 2½m depth. The location of the exploratory points is shown on Figure 1 at Appendix E.

Representative soil and water samples were recovered from the boreholes for subsequent laboratory examination and testing; whilst Standard Penetration Tests (SPT) were carried out as appropriate. Details of the strata encountered are provided on the Borehole and Trial Pit Records at Appendix A; together with particulars of the samples recovered, groundwater observations and SPT results. The profile of SPT verses depth is provided at Figure 3 of Appendix E.

Standpipes were installed in the three percussive boreholes to allow monitoring of groundwater levels. Three sets of monitoring of the standpipes have been undertaken and the results of this are presented at Appendix B.

6.0 Laboratory testing

The following laboratory tests were conducted on samples recovered during the field work: -

- Natural moisture content: to assess the in situ condition of the soil.
- Liquid and Plastic Limits: to classify cohesive soil into behavioural groups.
- Particle size distribution: by sieve analysis to classify granular material.

- Unconsolidated undrained triaxial compression: to determine the shear strength of cohesive material and thus to assess its load bearing capacity.
- One-dimensional consolidation: to determine the deformation characteristics of clay under applied loading and unloading.
- Soluble sulphate concentration and pH value: for the specification of buried concrete.
- Soluble sulphate concentration and pH value: for the specification of buried concrete.
- Contamination: chemical analyses to detect the presence of contaminants as detailed in the Fairhurst report, viz: -

Metals & metalloids:	Total arsenic, cadmium, chromium, copper, lead, mercury, nickel
Inorganics:	Water soluble boron.
Organic:	Petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAH), volatile organic compounds (VOC), semi volatile organic compounds (SVOC) and phenols.
Others:	Asbestos screen and Waste Acceptance Criteria (WAC) for off site disposal of construction arisings.

Results of these tests are presented at Appendix C, whilst original testing house sheets are at Appendix D.

7.0 Ground conditions

7.1 Stratigraphy

The stratigraphy of the site as revealed by the boreholes is consistent with that previously found by Fairhurst and are described in detail at Appendix A.

7.2 Groundwater

Groundwater was encountered at some 3 – 3½m depth. However, the speed of drilling, the requirement to add water in granular material and the use of casing to support the bore will have masked some inflows. Groundwater monitoring standpipes were installed in the three boreholes.

Details of all groundwater observations from the standpipes are provided on the standpipe monitoring records and Appendix B; but it should be noted that this work was undertaken at the end of a very long dry summer and water levels may be depressed below normal levels.

8.0 Discussion

8.1 General

The site has evidently already carried development and the investigation has revealed a some Made Ground to be present. It is possible that other pockets of Made Ground may also be present; perhaps deeper, of different character or associated with the remains of underground construction; even though not detected by this investigation.

All remnants of previous construction should be removed prior to redevelopment to enable the proposals to be constructed without hindrance and to perform satisfactorily.

The magnitude of the expected loading is such that piled foundations are recommended.

8.2 Piled foundations

Either driven or bored piles would be suitable in the ground conditions found at this site. However, compared with bored piling, construction of driven piles generates greater noise and vibration which is unlikely to be acceptable in this environment. In particular, high levels of ground - borne vibrations could damage nearby structures. Consideration of the various advantages and disadvantages of the different pile types suggests CFA piles to be preferred.

They avoid many of the installation difficulties that would otherwise be experienced, particularly the need for casing and the control of groundwater inflows. Parameters for their preliminary design are provided in Tables 1 and 2.

Table 1: Design parameters for CFA piles - Shaft friction

Stratum	Typical depth, m	Ultimate unit shaft friction
All material	0.0 – 3.0	Ignore
Kempton Park Gravel	3.0 - 6.0	Increases linearly from 30 to 50 kPa
London Clay	6.0 - 30.0	Increases linearly from 40 to 145* kPa

* the average unit shaft friction on the pile must not exceed 100kPa

Table 1 has been derived in conjunction with an adhesion factor of 0.6 in the cohesive London Clay. For the Kempton Park Gravel a value of 1.0 is assumed for the coefficient of earth pressure at rest (K_0) as the gravel is assumed to be over-consolidated. The ratio between the lateral earth pressure (K_S) and K_0 is taken as 0.90 for CFA piles. For these piles the angle of friction between pile shaft and soil is assumed to be equal to the angle of internal friction of the soil itself (ø').

Table 2: Design parameters for CFA piles - End bearing capacity

Stratum	Typical depth, m	Ultimate unit end bearing capacity
London Clay	6.0 - 30.0	Increases linearly from 630 to 2205 kPa

A factor of safety must be applied to derive the allowable working load from the ultimate values obtained from Tables 1 and 2. An overall value of 2.5 is commonly employed in compression.

Working pile load tests could be carried out to verify the chosen FoS on a development of this scale. This could result in a lower factor of safety than 2.5 which could result in significant cost savings. The actual factor of safety will be dependent upon the knowledge and experience of the chosen pilling contractor and agreement with relevant parties but is generally in the order of 2.25.

Tables 1 and 2 predict that a CFA pile of 600 mm diameter, bored 24 m depth, will have an allowable load capacity 1400kPa under an overall factor of safety of 2.5.

Settlement of a single pile is not expected to exceed some 1 to 1½% of the pile diameter as the working load assuming it will be carried entirely on skin friction.

Table 3 provides preliminary load capacity for bored piles in compression under a factor of safety (FoS) of 2.5 for various pile diameters.

Table 3: Pile diameters and capacities for bored piles

Depth below g.l.	Cohesion	Ultimate Unit Capacity			Pile dia. 0.45					Pile dia. 0.60				
		Shaft friction kPa		End Bearing	Ultimate Load Capacity				Allowable Load Capacity	Ultimate Load Capacity				Allowable Load Capacity
					Shaft friction kN		End Bearing	Total		Shaft friction kN		End Bearing	Total	
m	kPa	Gravel	L. Clay	kPa	Gravel	L. Clay	kN	kN	kN	Gravel	L. Clay	kN	kN	kN
3.0		30			0			0		0			0	
3.5		33			22			22		30			30	
4.0		37			47			47		63			63	
4.5		40			74			74		99			99	
5.0		43			104			104		138			138	
5.5		47			135			135		181			181	
6.0	70	50	42	630	170	170	100	270		226	226	178	404	
6.5	74		44	663		200	105	306			267	187	454	
7.0	77		46	696		232	111	343			309	197	506	
7.5	81		49	728		266	116	382	153		354	206	560	224
8.0	85		51	761		301	121	422	169		401	215	616	247
8.5	88		53	794		337	126	464	185		450	225	674	270
9.0	92		55	827		376	132	507	203		501	234	735	294
9.5	96		57	860		415	137	552	221		554	243	797	319
10.0	99		60	893		457	142	599	239		609	252	861	344
10.5	103		62	925		499	147	647	259		666	262	928	371
11.0	106		64	958		544	152	696	278		725	271	996	398
11.5	110		66	991		590	158	747	299		786	280	1067	427
12.0	114		68	1024		637	163	800	320		850	289	1139	456
12.5	117		70	1057		686	168	854	342		915	299	1214	485
13.0	121		73	1089		737	173	910	364		982	308	1290	516
13.5	125		75	1122		789	178	967	387		1052	317	1369	548
14.0	128		77	1155		843	184	1026	411		1123	327	1450	580
14.5	132		79	1188		898	189	1087	435		1197	336	1533	613
15.0	136		81	1221		955	194	1149	459		1273	345	1618	647
15.5	139		84	1253		1013	199	1212	485		1350	354	1705	682
16.0	143		86	1286		1073	205	1277	511		1430	364	1794	718
16.5	147		88	1319		1134	210	1344	538		1512	373	1885	754
17.0	150		90	1352		1197	215	1412	565		1596	382	1978	791
17.5	154		92	1385		1261	220	1482	593		1682	392	2073	829
18.0	158		95	1418		1327	225	1553	621		1770	401	2171	868
18.5	161		97	1450		1395	231	1626	650		1860	410	2270	908
19.0	165		99	1483		1464	236	1700	680		1952	419	2372	949
19.5	168		101	1516		1535	241	1776	710		2046	429	2475	990
20.0	172		103	1549		1607	246	1853	741		2143	438	2581	1032
20.5	176		105	1582		1681	252	1932	773		2241	447	2688	1075
21.0	179		108	1614		1756	257	2013	805		2341	456	2798	1119
21.5	183		110	1647		1833	262	2095	838		2444	466	2910	1164
22.0	187		112	1680		1911	267	2179	871		2548	475	3023	1209
22.5	190		114	1713		1991	272	2264	905		2655	484	3139	1256
23.0	194		116	1746		2073	278	2350	940		2764	494	3257	1303
23.5	198		119	1778		2156	283	2439	975		2874	503	3377	1351
24.0	201		121	1811		2240	288	2528	1011		2987	512	3499	1400
24.5	205		123	1844		2327	293	2620	1048		3102	521	3623	1449
25.0	209		125	1877		2414	299	2713	1085		3219	531	3750	1500
25.5	212		127	1910		2503	304	2807	1123		3338	540	3878	1551
26.0	216		130	1943		2594	309	2903	1161		3459	549	4008	1603
26.5	219		132	1975		2686	314	3001	1200		3582	559	4140	1656
27.0	223		134	2008		2780	319	3100	1240		3707	568	4275	1710
27.5	227		136	2041		2876	325	3200	1280		3834	577	4411	1765
28.0	230		138	2074		2973	330	3303	1321		3964	586	4550	1820
28.5	234		140	2107		3071	335	3406	1362		4095	596	4691	1876
29.0	238		143	2139		3171	340	3511	1405		4228	605	4833	1933
29.5	241		145	2172		3273	345	3618	1447		4364	614	4978	1991
30.0	245		147	2205		3376	351	3727	1491		4501	623	5125	2050

Single piles stress soil in excess of depth of investigation; prove ground conditions throughout zone of stress before using.
Pile groups should be considered separately.

The actual load capacity achieved in practice depends upon the precise installation procedures. Advice should therefore be sought from specialist contractors to verify the load capacity and settlement characteristics of their particular piles in the ground conditions revealed by this investigation. In any event, it is recommended that the chosen pile configuration be confirmed by preliminary load tests conducted before installation of the contract piles in order to take advantage of minimum FoS and thus minimum cost.

8.3 Excavations

All material should be regarded as unstable. Some apparent stability may be present immediately on excavation, especially where there is a high clay content, but this must not be relied upon. All excavations should therefore be supported at all times unless battered to a safe angle of repose.

Provision of adequate support is especially important for the safety of personnel when required to work in or close to excavations. Particular care should be exercised where excavations are close to existing structures to ensure they do not experience any loss of support. Temporary and permanent works should be designed to resist the additional lateral earth pressures arising from any superimposed loads in addition to those generated by the soil itself, without significant deformation.

Groundwater was encountered at some 2½m depth in BH1 and over 4m in the other boreholes and thus is expected to be below the depth of general construction activities.

8.4 Contaminant analysis

8.4.1 Solid phase

Contaminant testing was undertaken on selected soil samples and the results compared with the limited number of CLEA[2] Soil Guideline Values (SGVs) that have been published to date. Where not available from that source, reference has also been made to the LQM CIEH Generic Assessment Criteria[3]. Appropriate trigger levels are given with the results at Appendix C.

Analysis for metals/metalloids revealed all determinands to be below the triggers for Residential land use without plant uptake.

There is no trigger presently available for lead, but the results are below the previous trigger of 450mg/kg. However, two results from BH1 & 3 are above the value of 276mg/kg provided in the AtRiskSoil database produced by Atkins and the more modern Category 4 Screening Levels of 310/kg produced by DEFRA for residential use without plant uptake.

The results for TPH analysis found very low levels that are below triggers or of little environmental interest. The PAH analysis also found the majority of determinands to be below the residential trigger levels apart from BH2,3 & WSA in which some individual determinands are above trigger levels.

Analysis for asbestos was carried out on ten selected samples. Two samples recorded some fibres being from WSB & E.

The results of this analysis are in broad agreement with that previously found by Fairhurst.

With regards to potential remediation of soil contaminated with PAH. metals or asbestos, it is considered that where in areas of hardstanding or below building footprints, contaminants can remain in situ, as the pathway in a source-pathway-receptor model will be blocked. Where they coincide with areas of soft landscaping, remediation will be necessary.

A 450mm thick cap should be utilised, comprising imported clean soils with a capillary break layer at the base underlain by a geotextile barrier. This is to block the pathway in a source-pathway-receptor model and to discourage excavation below that level.

Nevertheless, in view of the foregoing, it is recommended that appropriate health and safety precautions, such as detailed in HS(G)66[4] and elsewhere, should be followed by the construction workforce and others who may come into contact with potentially contaminated soil. They should be agreed with the Health and Safety Executive and are likely to include, but not be restricted to, the following: -.

- maintenance of good standards of personal hygiene.
- wearing personal protective clothing that is changed and cleaned frequently to eliminate skin contact.
- prevention of ingestion by using washing and changing facilities at all break times.
- prohibition of eating, drinking or smoking between break times.
- controlling the spread of dust and airborne mists to prevent inhalation.

8.4.2 Waste Acceptance Criteria (WAC) analysis

Four samples were subject to the WAC full solid waste and leachate suite. The results are presented at Appendix D. The results have been compared to the criteria contained in the Landfill Regulations 2002 as amended and are presented at Appendix D.

Within the compliance leachate waste suite, all determinands were within the Inert Waste Landfill criteria limits. Similarly, all parameters determined on the solid test were also within the Inert Waste Landfill criteria.

The contamination test results, and the WAC results should be forwarded to the contractor appointed to undertake any spoil removal. Transfer notes and chain of custody sheets should be retained for all arising removed from site.

8.5 Buried concrete

Laboratory tests for this work found soil samples yielding a characteristic soluble sulphate concentration of 0.46g/l which results in a Design Sulphate Class[5] of DS-1. Although the previous works should also be assessed to see if this level needs to be ungraded.

Ground conditions are such that groundwater must be considered to be mobile, and all pH determinations were in excess of 6.5. Therefore, the Aggressive Chemical Environment for Concrete, ACEC, is classed as AC-1.

9.0 Remedial Action Plan

9.1 General

Contaminant testing was undertaken on selected soil samples and the results compared with the limited number of CLEA[1] Soil Guideline Values (SGVs) for residential land use that have been published to date. Where not available from that source, reference has also been made to the LQM CIEH Generic Assessment Criteria[2]. Appropriate trigger levels are given with the results at Appendix C and individual values exceeding the triggers have been highlighted.

Further WAC tests will be undertaken by the Ground Works Contractor as necessary during the works to categorize the soil arisings prior to disposal off site.

A Discovery Strategy and Watching Brief is also being adopted on site so that any unexpected contamination identified on site is reported.

9.2 Prevention of Pollution

Care should be taken in order to minimize the production of dust generated on the site, especially in dry climatic conditions.

All vehicles leaving the site should be clear of any potential contaminated debris other than that to be specifically removed. Vehicles transporting wastes for disposal should be appropriate for the required means in order to prevent release during transit.
Specific materials removed from site for subsequent disposal should be transported to a suitably approved and licensed facility. The contractor shall maintain a full documentary record in accordance with Duty of Care including copies of all Waste Transfer Notes for verification.

The programme of works and any subsequent modification should be maintained in such a manner as to avoid potential cross-contamination. A watching brief should be maintained and Manhire Geo-Environmental Ltd contacted in the event that evidence of any additional ‘contamination’ is encountered. The contractor should allow for any delays resulting from the presence of possible contamination and the necessary measures thereof.

It is the responsibility of all personnel on site to report any evidence of possible contamination to the suitably qualified and experienced Site Agent who will contact Manhire Geo-Environmental Ltd where there is any doubt about this contamination.

9.3 Remediation

Based on the previous investigations, it is considered that where contamination coincides with areas of soft landscaping, remediation will be necessary. A 450mm thick cap should be utilised, comprising imported clean soils with a capillary break layer at the base underlain by a geotextile barrier. This is to block the pathway in a source-pathway-receptor model and to discourage excavation below that level.

9.4 Validation of Imported/ Site Sourced Materials - Demolition Materials & Waste

Imported / site sourced materials can generally be split into two categories imported or site sourced demolition materials and imported soils validation of both types of materials will be required.

It should be noted that should material come from more than one source then the minimum following specified samples per source will be required.

9.4.1 Site Sourced / Imported Demolition Materials

All material should be visually assessed to check for any contamination, including asbestos presence. Any suspected materials should be removed from site. For all material the following amount of validation testing is required as a minimum number of samples per source should be 4 and samples should be analysed at a rate of 1 sample per 100m3 of material, but allowing for the above minimum. Assuming no other contamination is suspected all samples should be analysed for asbestos, CLEA metals, phenols, speciated PAH and TPH.

9.4.2 Imported Soils

All imported soils should be certified clean by the supplying facility, with tests certificates supplied.

In addition, on site sampling of the soils will be required, this should ideally be done when it has been placed, but as a minimum be undertaken on site. The following amount of validation testing is required. A minimum number of samples per source should be 4 and samples should be analysed at a rate of 1 samples per 50m3 of material but allowing for the above minimum.

All samples should be analysed for asbestos, CLEA metals, phenols, speciated PAH and TPH

9.5 Discovery Strategy and Watching Brief

During the course of the development, it will be the responsibility of the on-site manager to ensure watching briefs are undertaken and documented.
The watching brief will consist of a record of:

a. Observations of contamination made during the course of the development by any member of site staff, contractor or visitor; and

b. The key stages of the development and occurrences including contamination found during the course of the development, the formation levels of excavations, any reduced level dig/mass excavation, formation of landscaped or garden areas, etc. with supporting photographs.

9.6 Watching Brief Written Statement

Upon completion of the development, a written and signed statement will be prepared by the following parties:

a. Ground Works Contractor(s) - upon completion of foundations and ground works;

b. On-site manager - upon completion of groundworks and landscaping work; and

The written statement will clearly state whether or not evidence of contamination was identified during the course of the development along with any remedial action that was taken.

9.7 Staff Training

All site staff, contractors and visitors, will be briefed on the potential presence of land, groundwater or airborne contamination before commencing work on the site.

This will include the following information:

a. Relevant health & safety considerations;

b. The type of land, water or airborne contamination present and potentially present at the site;

c. Any particular areas of the site which are likely to be affected; and

d. Staff responsibilities under the discovery strategy.

The on-site manager will provide written confirmation that site staff were briefed about contaminated land in line with these recommendations.

9.8 Construction Workers Risk Assessments

A detailed health and safety risk assessment will be carried out, in accordance with current guidance, before works commence on-site and appropriate personal protective equipment will be worn by all construction workers.

10.0 Discovery Strategy & Watching Brief

If unexpected contamination is found at any time, then this will be reported to Environmental Health, The Royal Borough of Richmond Upon Thames (RBRUT) within seven days and 2 weeks notice given prior to undertaking any remediation if considered necessary.

The discovery strategy sets out the actions that will be taken if contamination is encountered during the course of a development. Examples of the types of observations that will be considered are detailed in Table 1 below, following which examples of the general actions that will be taken are set out in Table 2, and examples of any emergency actions are detailed in Table 3.

Evidence	Description
Visual	• Fuel or oil-like substances mixed in with or smeared on the soil or floating on perched, groundwater or surface waters. • Waste materials (refuse, barrels, industrial wastes, ash, tar, etc.) Buried at specific location across the site. • Marked variation in colour, e.g., red, orange, yellow, green, light or dark blue, etc. may indicate contamination from a variety of contaminants. • Soils including large amounts of ash and clinker where such contamination of soils wasn't expected. • Evidence of suspected asbestos.
Odours	• Fuel, oil and chemical-type odours. • Unusual odours such as sweet or fishy odours.
Well-being	• Lightheadedness and/or nausea when in excavations, at the working face of an excavation, when visual or olfactory evidence of contamination exists, etc. • Burning of nasal passages, throat, lungs or skin. • Blistering or reddening of skin due to contact with soil.

Table 1 - Potentially significant observations (not exhaustive)

▫ Person observing contamination	▫ To be reported to	▫ Action to be taken
▫ Site visitor	▫ Must report observations to the site manager.	▫ Stop work and where possible, make area safe and secure area before reporting to site manager.
▫ Contractor	▫ Must report observations to the site manager.	▫ Stop work and where possible, make area safe and secure area before reporting to site manager.
▫ On site manager	▫ Must report observations to their direct manager, the appointed Environmental Consultant, the Planning Authority and Contaminated Land Officer at LBS.	▫ Stop work and, where possible, make area safe and secure area before reporting to others.
▫ Environmental Consultant	▫ Must report observations to the site manager, the planning Authority and Contaminated Land Officer LBS.	▫ Advise that work stops and where possible, make sure the area is made safe before reporting to others.

Table 2 - General actions to be performed

▫ Occurrence	▫ Description	▫ Contact
▫ Risk to the public	▫ If at any point residents, the public or other may be at risk as a result of contamination found during the course of investigation, remediation or development works.	• Contact the emergency services if there is a risk to life. • Contaminated Land Officer at LBS. • Health & Safety Executive.
▫ Nuisance to residents/the public	▫ If a nuisance has been or is likely to be caused to nearby residents, the public and others - for example, odours, dust, noise, vibration, etc.	• Environmental Health at LBS.
▫ Pollution of controlled waters	▫ If any surface, culverted or groundwater has been polluted, e.g., slurry, contaminated soil/water or a chemical spillage entering a river or canal.	• Environmental Agency. • Planning Authority and Contaminated Land Officer at LBS.
▫ Pollution of adjoining land	▫ If land outside the boundary of the development site is polluted from site activities, e.g., slurry, contaminated soil/water or a chemical spillage.	• The owner of the land. • Planning Authority and contaminated Land Officer at LBS.

Table 3 - Emergency actions to be performed

In addition to the above, the following should also be noted:

a. Should gross contamination be encountered during groundworks, then the advice of an environmental consultant will be sought;

b. Any soil arising from areas where visual or olfactory evidence of contamination has been observed will be handled as potentially hazardous waste and temporarily stockpiled appropriately;

c. Stockpiled soils may undergo validation testing to determine whether they can be used elsewhere on the site at or close to the ground; and

d. The Contaminated Land Officer at RBKUT will be contacted to agree any further remedial works that become necessary during the course of the development.

11.0 Verification Report

Following the completion of any remedial action and the development of the site, a post -remediation verification report will be produced and submitted to the planning authority.

The report will detail fully any actions undertaken, including any report from the discovery strategy and watching brief.

All work undertaken will be supported by photographic evidence, along with any other documented items such as waste transfer noted, asbestos removal reports, soil invoices etc.

All imported soil will undergo confirmatory analysis in order to satisfy their suitability for use. Laboratory certificated results will be included within the report.

Finally the report will include the aforementioned declaration from the site manager, groundworks contractor and appointed environmental consultant stating that wither no suspected additional contamination was detected, or, that all additional detected contamination has been addressed appropriately.

References

[1] The Contaminated Land Exposure Assessment Model Department for Environment, Food and Rural Affairs The Environment Agency
R & D Publications SGV 1 *et al*., March 2002

[2] Protection of workers and the general public during the development of contaminated land HS(G)66
Health and Safety Executive, 1991

[3] Waste Management Paper 27 : Landfill gas
Department of the Environment
HMSO, Fourth impression 1996

[4] Concrete in aggressive ground
BRE Special Digest 1, 3rd Edition
Building Research Establishment, 2005

PROCEDURAL NOTES for GROUND INVESTIGATIONS

General

This report is based upon data obtained from field descriptions of the strata and examination of the samples by an engineer, together with the results of in situ and laboratory tests as appropriate. Responsibility cannot be accepted for variations in ground conditions between and around any of the exploratory points that is not revealed by the data. Whilst the report may offer an opinion on the ground conditions between exploratory points and below the depth of investigation, this is for guidance only and no liability is accepted for its accuracy.

Drilling procedure

Boring by light cable percussion drilling allows the ground conditions to be reasonably well established. However, a certain amount of disturbance is inevitable, and some mixing of soils can occur.

Sampling procedure

"Undisturbed" samples of predominantly cohesive soils are taken with a 100mm diameter open tube sampler, generally in accordance with BS 5930: 1999.

Where appropriate, or where an undisturbed sample is unsuccessful, disturbed samples are recovered and sealed into polythene bags.

Groundwater samples are taken when water is encountered in sufficient quantity.

Standard penetration tests

The test is conducted generally in accordance with BS 1377: Part 9: 1990. The sampler tube is subject to a seating drive of 150mm into the soil at the base of the borehole. Results are given on the Borehole Records as the number of blows required to drive the sampler tube a further 300mm and this is known as the “N” value. Where the driving resistance is such that full penetration is not achieved, the test is generally terminated after 50 blows and the actual distance penetrated is recorded.

Groundwater

Groundwater observations necessarily reflect the conditions encountered at the time of the exploratory work. Long term monitoring of standpipes is usually required to establish an equilibrium water level since the normal rate of boring is too fast to permit steady state conditions to be achieved.

Groundwater levels are subject to variations caused by changes in drainage conditions and seasonal climatic changes.

Water may necessarily be added to advance the bore whilst casing may be required to maintain an open hole. These can both mask subsequent groundwater observations and are therefore noted on the individual Borehole Record.

APPENDIX A

BOREHOLE AND TRIAL PIT RECORDS

SYMBOLS and ABBREVIATIONS

Samples

Undisturbed

U	Standard open drive "undisturbed" 102mm dia. in boreholes 38mm dia. in trial pits, window sampler and hand auger
T	Thin wall open drive
P	Piston
CBR	CBR mould
L	Windowless sampler liner

Disturbed

D	Small
B	Bulk
W	Water
C	Contaminants: plastic tub
J	Contaminants: brown glass jar

In situ tests

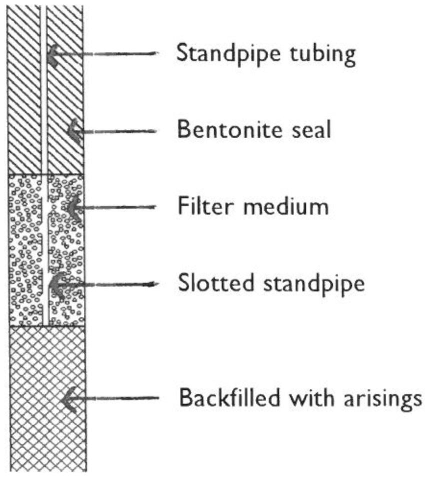
SPT	Standard Penetration Test, open shoe
CPT	solid cone N value is number of blows for 300mm penetration. Blow count also given as seating drive followed by four increments of 75mm.
V ( )	Vane test (c_u kPa)
P ( )	Hand penetrometer (c_u kg/cm^2)
M ( )	Mexe probe (CBR %)

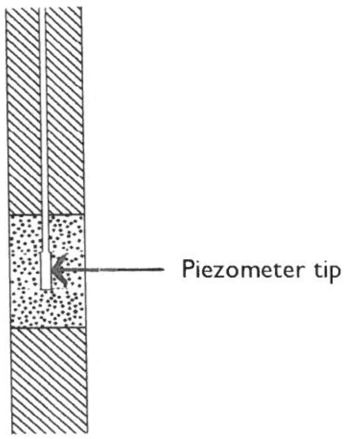
Water records

$\blacktriangledown_2$	Standing level
$\triangledown_2$	Depth encountered

suffix identifies separate strikes

Standpipes





MANHIRE ASSOCIATES GEO-ENVIRONMENTAL LIMITED	Site: Manor Road, Richmond	Borehole Number: BH1

Boring Method	Casing Diameter	Ground Level (mOD)	Client	Job Number
Cable Percussion	150mm cased to 7.00m		Taylor Wimpey West London	21031
	Location: See site plan	**Dates**: 08/08/2022-09/08/2022	**Engineer**	**Sheet**: 1/4

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description
						(0.10) 0.10	BLOCK PAVING
						(0.10) 0.20	MADE GROUND: Sand
						(0.80) 1.00	MADE GROUND: Reddy brown angular gravel
1.00-1.50	B1						
1.20-1.65	SPT(C) N=29	1.20	WET	2,4/6,6,8,9		(0.50) 1.50	MADE GROUND: Brick rubble with some orange brown sand and gravel
2.00-2.45	SPT(C) N=44	2.00	1.50	3,7/9,11,11,13			Medium dense to dense brown and orange brown sandy GRAVEL
2.00-2.50	B2						
3.00-3.45	SPT(C) N=41	3.00	2.00	3,7/9,11,13,8			
3.00-3.50	B3						
4.00-4.45	SPT(C) N=25	4.00	3.00	3,5/5,6,7,7		(5.20)	
4.00-4.50	B4						
5.00-5.45	SPT(C) N=16	5.00	4.00	2,3/3,4,4,5			
5.00-5.50	B5						
6.50-6.95	SPT(C) N=15	6.50	4.00	2,2/3,3,4,5		6.70	
6.50-7.00	B6						Stiff becoming very stiff fissured dark grey silty CLAY with some sandy laminations
8.00-8.45	U1	7.00	DRY	100 blows			
8.50	D1						
9.50-9.95	SPT N=24	7.00	DRY	2,4/5,6,6,7			

Remarks
UXO survey taken at 1.2m, 2.0m, 4.0m, 6.0, 8.0, 10.m
Chiselling from 0.00m to 1.20m for 1.0 hour. Water added from 0.70m to 6.50m.

Scale (approx)	Logged By
1:50	ljs

Figure No. 5567.BH1