
Proposed Residential Development, Glan Gors, Wrexham.

Detailed Remediation Strategy

On behalf of
Pennaf Housing Group and Wrexham County Borough Council

December 2013

Rev /

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1.0 Introduction

Bay Associates Consulting Ltd (BA) have been instructed by Pennaf Housing Group to develop the Remediation Strategy, Implementation Plan and Verification reports for the proposed redevelopment of land known as Glan Gors, off Anthony Eden drive, Wrexham. The site location is shown in Appendix A.

The development proposal comprises 23 No low rise residential units with gardens, adoptable highway and footway access and associated landscaping.

This report is part of a staged assessment of the site with the following Stage 2 Contamination Assessment Reports undertaken over land to the north of the study area which was a former landfill know as Bala Road Landfill. These reports included:

- Former Landfill Sites Stage 2 Contamination Assessment – Bala Road – commissioned by Wrexham County Borough Council. Oct 2007. Smith Grant LLP. Report R786-R27(BalaS2)(Final Rev1)
- Former Landfill Sites Stage 2 Contamination Assessment – Bala Road – commissioned by Wrexham County Borough Council. Oct 2007. Smith Grant LLP. Report R786-R54(BalaS2 Add)
- Former Landfill Sites Stage 2 Contamination Assessment – Review and Update of Previous B20(c) Investigation Works Under Part IIA Bala Road – commissioned by Wrexham County Borough Council. Oct 2012. Smith Grant LLP. Report R1661-R10(V2)

The investigations of the Bala Road landfill were undertaken as part of a Part 2A assessment into former landfills but provide useful information on the potential study site characteristics which formed part of the Bala Road Landfill and informed the site specific desk study and intrusive investigation works undertaken by E-geo Solutions Ltd

- Stage 1 Desk Study and Preliminary Ground Contamination Risk Assessment - Land at Glan Gors, Anthony Eden Drive, Wrexham, LL13 8TH – Commissioned by Bay Associates Nov 2012 E-geo Solutions Ltd Report E0500S1.P1.R1
- Intrusive Geotechnical and Geo Environmental Ground investigation - land at Glan Gors, Anthony Eden Drive. – Commissioned by Bay Associates August 2013 E-geo Solutions Ltd Report E0500.S1.P2.R1.V5

The intrusive geotechnical report forms part of the contract documentation.

2.0 Report Objective

In accordance with 'Model Procedures for the Management of land Contamination' - Contaminated Land Report 11 (CLR 11), the objective of the report is to set out and detail the strategy in which the proposed Glan Gors development site identified above will be remediated in preparation for low rise residential development. The purpose of the document is to address planning condition 17 within the GRANTED outline planning permission WRC P/2010/0216 dated 4th May 2010. In addition following discussions with Wrexham's contaminated land department it is the intention that this report will partially address the conditions expected as a response to the detailed planning application PP-02233943 submitted 29th November 2013.

Planning Condition 17 of the outline permission states

Development shall not begin on site until a scheme to deal with potential contamination at the site has been submitted to and improved in writing by the local Planning Authority as part of the reserved matters application. This scheme shall include a phased investigation approach to identify the extent of contamination and any measures required to remediate the site, including post- development monitoring. Where remediation works are required, the development shall not be occupied/used until a validation report to show that the works have been submitted to and approved in writing by the local Planning Authority.

In order for the condition to be fully discharged the following documents are to be submitted and approved through the design development and procurement stages.

1. Detailed Remediation Strategy (in accordance with CLR 11), which can justify the remediation/mitigation options chosen, indicate the scientific and technical bases of the chosen remediation type as well as indication of site management, site phasing and required licences.
2. Implementation Plan, which will translate the remediation strategy into a clear set of remediation activities for the site. The plan is to indicate all aspects of design, preparation, implementation and verification.
3. Verification Plan and Report, which is to indicate the data gathering requirements necessary to demonstrate that the remediation/mitigation undertaken meets the site remediation criteria.

This document completes the first stage of the required information and following completion and approval by the local authority stages 2 and 3 will be progressed in line with the scheme procurement strategy/programme.

3.0 Summary of 2013 Ground investigation works

A Series of extracts from the *Intrusive Geotechnical and Geo Environmental Ground investigation - land at Glan Gors, Anthony Eden Drive. – Commissioned by Bay Associates August 2013 E-geo Solutions Ltd Report E0500.S1.P2.R1.V5* are set out below.

Previous Assessments and the 2012 desk study had identified that contaminants could be present on site that present a risk to:

- Humans from contaminants within the made ground of landfilled wastes.
- Humans and structures on and off site from hazardous gasses generated by the landfilled wastes.
- Shallow groundwater from leaching of contaminants in the landfilled wastes.
- Construction materials placed within the landfilled wastes

To prove the current status of any contamination at the site and to establish the actual risks, an 'Intrusive Contamination Investigation' was undertaken to supplement previous information on the site. The objective of the intrusive investigation was to:

- Gather additional information needed to refine the site conceptual model.
- Determine the nature of ground materials below the site, the presence, nature and extent of any ground contamination, particularly in areas that have not been previously investigated, and for contaminants not previously looked for.
- Fully characterise the ground gas regime.
- Determine the potential for groundwater contamination.
- Provide data and recommendations for the design of any remediation works.

With reference to the following guidance the investigation strategy was designed for the site and proposed residential development:

- CIRIA - C665 – Assessing risks posed by hazardous ground gases to buildings.
- R&D Technical Report P5-066/TR [51].
- BS10175 (2011) Investigation of Potentially Contaminated Sites

3.1 Scope of Investigation Works

Exploratory Holes

A geotechnical and geo-environmental ground investigation was undertaken by e-geo Solutions Ltd with the field work element undertaken between 5th and 18th February 2013. The investigation was supervised and administered by e-geo Solutions Ltd and undertaken in accordance with BS5930 (1999) – code of Practice for Site Investigations (Amendment 1).

The scope of work involved:

- The construction of 6 No. shallow boreholes to allow examination and sampling of ground strata.
- The installation of shallow gas and groundwater monitoring wells to a depth of 3.00m with gas taps and lockable covers in all shallow boreholes.
- The excavation of 4 No. trial pits for soil sampling purposes and 2 no. for undertaking CBR tests, with examination of ground strata by a geo-environmental engineer with the photographing of exposed strata and the careful description of soil types.
- The construction of 3 No. deep boreholes to depths of 16.95m to determine the geological and geotechnical properties of the ground strata to assist foundation design.
- The installation of deep groundwater monitoring wells to allow monitoring and sampling of groundwater in all deep boreholes.
- Monitoring of gas monitoring wells on 6 occasions between 15 February 2013 and 11th April 2013. (No monitoring of previously installed boreholes was undertaken as the boreholes could not be located however previous data from 2007 to 2011 is available and has been assessed in the desk study report).

3.2 Testing and Analysis

Ground samples were collected from the shallow boreholes and trial pits and submitted for chemical analysis at Jones Environmental Ltd an accredited analytical laboratory. Samples were tested for:

Suite	Chemical Determinants	No. of Samples
Suite 1	moisture content, sulphate, sulphide, phenol mono, total cyanide, arsenic, cadmium, chromium, lead, copper, nickel, zinc, mercury, PAH US EPH 16, GRO C6-C10, EPH banded C10-C40.	17
Suite 2	sulphate (total and water soluble),	6
Suite 3	TPH (C10-C40), BTEX/MTBE	7
Suite 4	TPH Aliphatic/Aromatic split	7
Suite 5	Asbestos screen	4
Suite 6	SVOC/VOC	3
Suite 7	PCBs	2

Table 1 – Ground Sample Testing Suites

Samples of perched groundwater from the shallow boreholes and groundwater from the deep boreholes were collected on two occasions (27/02/13 and 03/04/13) and submitted for chemical analysis at Jones Environmental Ltd an accredited analytical laboratory. Samples were tested for:

Suite	Chemical Determinants	No. of Samples
Suite 1	magnesium, manganese, potassium, sodium, calcium, arsenic, cadmium, chromium, lead, iron, copper, nickel, zinc, mercury, PAH US EPH 16, GRO C6-C10, EPH banded C10-C40, phenol, cyanide, sulphate, sulphide, chloride, alkalinity as CaCO ₃ , BOD, COD and pH	6 (on two occasions)

Table 2 – Groundwater testing Suite

3.3 Gas Monitoring

Gas monitoring standpipes were installed in all the shallow boreholes with the response zones within the depth of made ground where exchange of atmospheric and soil gasses occur.

Monitoring of the standpipes for methane (% volume), carbon dioxide (% volume), oxygen (% volume), and flow was undertaken with a GA2000 Serial number GA12439.

Initial gas monitoring was undertaken on six occasions over an 8 week period on 15/02/13, 27/02/13, 12/03/13, 20/03/13, 03/04/13, and 11/04/13. Additional monitoring was undertaken on a further six occasions between 01/05/13 and 31/07/13. This extended period of monitoring together with monitoring results from previous gas monitoring over a period which extended from 2007 to 2011 is considered an acceptable period of monitoring to characterize the site particularly with the consistency of the results obtained

Borehole Number	Installation (From ground level down)	Borehole Number	Installation (From ground level down)
BD1S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround	BD3S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround
BS1	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround	BS3	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround
BD2S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround		
BS2	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround		

Table 3 - Gas Monitoring

Previous gas monitoring of installations at the site and adjacent Bala Road Landfill over a period from 2007 to 2011 had indicated consistent methane concentrations less than 1% but with carbon dioxide concentrations greater than 5% but with negligible flow. Based on the previous (by others) and current assessment of risk, the historic low gas concentrations recorded and the low gas generation potential of the materials placed within the site, guidance suggests that a minimum of six gas monitoring visits should be undertaken. This is the minimum normally acceptable to regulators however if site conditions or monitoring results differ from previous findings an extended period of monitoring will be considered.

Groundwater was encountered at shallow depth within the boreholes with. The water inflows were generally at the base of the made ground or interface of made ground and underlying alluvial deposits allowing monitoring of gasses within the unsaturated zone of the made ground.

During the construction of the boreholes water inflow was either not noted or recorded as being very slow with the ground strata becoming damp or only seepages noted at depths of 1.20m to 1.90m (bgl). The absence of moderate or rapid inflows suggests that the strata are of relatively low permeability. However following completion of the monitoring installations standing water levels of 0.98m to 1.36m

below ground level were recorded causing the lower portions of the response zones to be flooded.

The water inflows were generally at the base of the made ground or interface of made ground and underlying alluvial deposits which allowed monitoring of gasses within the unsaturated zone of the made ground, however with higher standing water levels the thickness of the unsaturated zone decreased. Although the thickness of the unsaturated zone in some of the boreholes was relatively small it is considered that with the number of boreholes across that site, the type of made ground and the presence of more silty made ground at depth that the gas monitoring results provide a representative indication of the gas regime.

Additional monitoring was undertaken on a further six occasions between 01/05/13 and 31/07/13 when the standing water level reduced which increased the thickness of the unsaturated zone. BH and Trial Pit locations can be seen in Appendix B

3.4 Summary of Ground Conditions

3.4.1 Stratigraphy

The general stratigraphic sequence at the site is:

- Black topsoil.
- Made Ground – dark brown very silty fine to coarse sand and gravel with some to much plastic sheet, bags, glass bottles and gravel, cloth, metal wire, ash gravel, and cobbles of sandstone.
- Silt – dark and light grey slightly sandy clayey SILT.
- Peat – dark brown to black silty slightly clayey PEAT (in parts).
- Alluvium – brown slightly sandy clayey SILT and medium brown very silty fine SAND.
- Glacial Till – dark brown sandy silty CLAY with much fine to coarse gravel and some cobbles

The strata and depths encountered during the investigation were:

Stratum	Description	Depth to base m range (average)
Topsoil	Dark brown silty sandy topsoil	0.10
Made Ground	Loose dark brown very silty fine to coarse sand and gravel with some to much plastic sheet, bags, glass bottles and gravel, cloth, metal wire, ash gravel, and cobbles of sandstone	1.10 – 1.70 (1.50) (2.70m at BD3)
Silt	Very soft to soft dark and light grey slightly sandy clayey SILT	1.90 -2.10 (2.00)
Peat	Very soft dark brown to black silty slightly clayey PEAT (in parts)	1.70 – 3.00 (2.50) (BD1S, BS2, BH 1only)
Alluvium	Soft brown slightly sandy clayey SILT and loose to medium dense medium brown very silty fine SAND with silt partings	8.90 – 10.2 (9.40)
Glacial Till	Stiff dark brown sandy silty CLAY with some to much fine to coarse gravel and some cobbles	17m +

Table 4 – Ground Strata

3.4.2 Groundwater

Groundwater was encountered in the trial pits and boreholes at the depths shown on the table below:

TP/BH No.	Water encountered	Comment	TP/BH No.	Water encountered	Comment
TP1	0.80	Rapid inflow	BD3S	1.70	Damp
TP2	1.00	Rapid inflow	BH 1	3.00	Medium inflow rising to 1.60 (20 min)
TP3	1.10	Rapid inflow	BH 2	5.50	Slow inflow rising to 3.60 (20 min)
TP4	0.90	Moderate inflow	BH 3	4.00	Slow inflow rising to 3.80 (20 min)
BD1S	1.20	Slight seepage			
BD2S	1.90	Slight seepage			
BS2	2.00	Damp			

Perched groundwater was encountered in the made ground in trial pits at depths of 0.80m to 1.10m, and in the shallow boreholes at depths of 1.20m to 1.90m. Subsequent monitoring in the shallow boreholes indicated the perched water standing at depths of 0.98m to 1.36m.

Shallow groundwater in the alluvial deposits was encountered at depths of 3.00m in BH 1 (rising to 1.60m in 20 minutes), 5.50m in BH 2 (rising to 3.60m in 20 minutes) and 4.00m in BH 3 (rising to 3.80m in 20 minutes)

Monitoring of the installations was undertaken during gas monitoring and water sampling with water levels shown in table 5 below:

TP/BH No.	Water encountered	Comment	TP/BH No.	Water encountered	Comment
TP1	0.80	Rapid inflow	BD3S	1.70	Damp
TP2	1.00	Rapid inflow	BH 1	3.00	Medium inflow rising to 1.60 (20 min)
TP3	1.10	Rapid inflow	BH 2	5.50	Slow inflow rising to 3.60 (20 min)
TP4	0.90	Moderate inflow	BH 3	4.00	Slow inflow rising to 3.80 (20 min)
BD1S	1.20	Slight seepage			
BD2S	1.90	Slight seepage			
BS2	2.00	Damp			

Table 5 – Borehole Water Levels

3.4.3 Contamination Observations

During the examination of the ground strata no obvious olfactory indications of contamination were noted. There was no indication of hydrocarbons or unusual odours. The perched water that flowed into the trial pits was relatively clear with no obvious discolouration.

A previous ground investigation undertaken by Terra Firma in September 2012 reported a 'hydrocarbon' odour within the wastes. However the descriptions of the ground strata in the three trial pits are identical indicating crisp packet, boot, oil can, wheel found in each pit. The likelihood of the same items being found in each pit is remote and casts significant doubt on the validity and accuracy of the trial pit logs. No hydrocarbon odours were noted in any of the trial pits or boreholes during the recent investigation.

3.5 Summary of Risk Assessment and Mitigation

3.5.1 Contamination Source

The results of the investigations, analysis of ground samples and waters and monitoring for ground gasses have identified the following:

- Very isolated occurrence of very slightly elevated concentrations of arsenic and lead in the made ground (BD2S – 0.70m).
- Isolated occurrence of elevated concentrations of petroleum hydrocarbons within the made ground (BS1 – 0.4m, BS3 – 1.70m, BD3S, BD3S – 0.90m)
- Very isolated occurrence of asbestos fibres (amosite) but with no detectable mass (TPSS2 and TPSS4)
- Slightly elevated concentrations of benzo (a)pyrene across the site
- Elevated concentrations of calcium, manganese and PAH in the perched water in the made ground
- Elevated concentrations of arsenic, calcium, manganese, potassium, ammoniacal nitrogen and PAH in the shallow groundwater in the alluvial deposits below the site
- Occasional elevated concentrations of methane across the site
- Elevated concentrations of carbon dioxide in the majority of locations across the site with depleted oxygen concentrations

The investigation involved sampling at discrete locations although the type of made ground encountered across the site was similar at all sampling locations. The screening analysis was based on a typical suite of tests, based on the initial conceptual model and to fall within an available budget. However it is possible that other substances may be present or that elevated concentrations of chemical parameters and gasses may be encountered between sampling locations.

3.5.2 Potential Receptors

The principal receptors to the identified contaminants during and following site redevelopment for residential use are:

- Humans – Future residents – site to be developed with residential properties
- Humans – Site construction personnel – personnel involved in site construction activities
- Humans – Adjacent property occupiers – site surrounded by residential properties on three sides
- Buildings and Construction materials - site to be developed with residential properties with associated services and infrastructure

- Shallow Groundwater - groundwater at shallow depth within alluvial deposits - Secondary 'A' aquifer
- Deep Groundwater - groundwater at depth within Coal Measures - Secondary 'A' aquifer
- Surface water course – River Gwenfro

3.5.3 Potential Pathways

The following potential pathways may exist at the site during and following development.

- Human health exposure via Ingestion, inhalation and dermal contact with identified solid contaminants in near surface made ground
- Human health exposure from inhalation of hazardous gasses
- Migration via permeable ground and services, and emissions of hazardous gasses from the ground
- Direct contact with contaminants in the made ground by construction materials
- Direct movement of leached contaminants within the perched groundwater into shallow ground water
- Migration of leached contaminants into the River Gwenfro via permeable ground strata and drainage

3.5.4 Preliminary Risk Assessment

In order for any risk to exist, a "Source - Pathway - Receptor" linkage must be established. This linkage requires:

- A source of contamination in the ground which has the potential to cause harm or to cause pollution of controlled waters.
- A pathway by or through which a receptor is being exposed to or affected by a contaminant or, could be so exposed or affected by a contaminant.
- A receptor that could be harmed by exposure to a contaminant.

The identification of each of these three elements is linked to the identification of the others. A pathway can only be present if it is capable of exposing an identified receptor to an identified contaminant. That particular contaminant should likewise be capable of harming or, in the case of controlled waters, be capable of polluting that particular receptor. If a pollutant source, pathway and receptor are found to be present then there could be a risk to the identified receptor. If there is an absence of any part of the source, pathway or receptor process, there is no risk.

The results of sampling and analysis have identified contamination sources at the site which based on the Source-Pathway-Target model the assessment of risks is as follows:

HUMANS - (Future site users)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Arsenic/Lead in near surface made ground	Ingestion/ Dermal contact/ Inhalation	Possible	Minor	Low to Medium. Very isolated occurrences of very slightly elevated concentrations of arsenic and lead with concentrations are only marginally above the SGVs, but present in near surface strata.
Petroleum hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	Possible	Minor	Low to Medium. Occasional elevated concentrations of petroleum hydrocarbons present in the near surface strata of made ground across the site. Concentrations of aliphatic/ aromatic fractions not at values which present a health risk from contact with or ingestion.
Poly aromatic hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	Possible	Minor	Low to Medium. Very slightly elevated concentrations of benzo (a)pyrene present in the near surface made ground across the majority of the site but at concentrations not considered to present a significant risk.
Asbestos fibres of amosite in near surface made ground	Inhalation	Unlikely	Major	Medium. Isolated occurrence of asbestos fibres (amosite) detected but quantification analysis indicates the quantity of asbestos in the samples would not be deemed to present a risk.
Methane	Migration through permeable strata, emissions through ground surface and accumulation in spaces with ignition source	Possible	Catastrophic	High. Occasional elevated concentrations of methane to a maximum of 3.1% and GSV of 0.065 l/hr giving site characterisation of 'amber 1'
Carbon dioxide	Migration through permeable strata, emissions through ground surface and accumulation in poorly vented spaces	Possible	Catastrophic	High. Elevated concentrations of carbon dioxide detected across the site with maximum concentration greater than 10% a GSV of 0.15 l/hr giving site characterisation of 'amber 2'

Table 6 – Human Health Risk Assessment (End User)

HUMANS - (Construction Personnel)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Arsenic/Lead in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Petroleum hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Poly aromatic hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Asbestos fibres of amosite in near surface made ground	Inhalation	None	Major	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Methane	Migration through permeable strata, emissions through ground surface and accumulation in spaces with ignition source	Possible	Catastrophic	High. Occasional elevated concentrations of methane to a maximum of 3.1% and GSV of 0.065 l/hr giving site characterisation of 'amber 1'
Carbon dioxide	Migration through permeable strata, emissions through ground surface and accumulation in poorly vented spaces	Possible	Catastrophic	High. Elevated concentrations of carbon dioxide detected across the site with maximum concentration greater than 10% a GSV of 0.15 l/hr giving site characterisation of 'amber 2'

Table 7 – Human Health Risk Assessment (Construction Personnel)

HUMANS - (Adjacent Property Occupiers)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Methane	Migration through permeable strata and accumulation in spaces off site with ignition source	Unlikely to none	Catastrophic	Low. Occasional elevated concentrations of methane to a maximum of 3.1% on site but no plausible migration pathway due to topography and perched water level in the made ground.
Carbon dioxide	Migration through permeable strata and accumulation in poorly vented spaces off site	Unlikely to none	Catastrophic	Low. Elevated concentrations of carbon dioxide detected across the site with maximum concentration greater than 10% but no plausible migration pathway due to topography and perched water level in the made ground.

Table 8– Human Health Risk Assessment (Adjacent Property Occupiers)

CONTROLLED WATERS – (Shallow and Deep Groundwater)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Calcium, manganese, potassium and PAH in perched water made ground	Vertical migration	Unlikely to shallow groundwater	Minor to None	Low. Vertical migration of leached parameters in perched groundwater in made ground unlikely to migrate vertically due to low permeability strata and shallow groundwater under sub artesian pressure. Quality of shallow ground water poorer than perched water.
		None to deep groundwater	None	None. Vertical migration of shallow groundwater into deep groundwater extremely unlikely due to very low permeability glacial till and likely poor quality of deep groundwater.

Table 9– Controlled Waters (Shallow and Deep Groundwater's)

CONTROLLED WATERS – (Surface water – River Gwenfro)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Arsenic, calcium, manganese, potassium and PAH in shallow groundwater	Lateral migration in groundwater	Unlikely to none	Minor to None	Very Low. Lateral migration of shallow groundwater in alluvium towards River Gwenfro unlikely due to low permeability strata and shallow hydraulic gradient. Previous studies found no significant elevated concentrations of determinants along River Gwenfro
Arsenic, calcium, manganese, potassium and PAH in shallow groundwater	Migration along drain and pipe bedding	Unlikely	Minor to None	Low. Leakage into drain unlikely. Migration along pipe bedding and discharge into River Gwenfro at outfall unlikely

Table 9– Controlled Waters (Shallow and Deep Groundwater's)

Descriptor	Description	Descriptor	Description
Almost certain	Likely to occur on many occasions	Catastrophic	Death
Likely	Will probably recur but not persistent	Major	Permanent harm
Possible	May recur occasionally	Moderate	Semi-permanent injury/damage
Unlikely	Not expected to happen but is possible	Minor	Short term harm/damage
None	Will not happen	None	No injury or adverse outcome

3.6 Summary of Mitigation

The investigation findings and the evaluation of risk for the site and its proposed redevelopment with residential properties has identified sources of contamination which present some degree of risk. The risks are primarily associated with the presence of elevated concentrations of chemical parameters and the presence of hazardous ground gasses.

3.6.1 Ground Contamination

To remove potential risk from the sources of solid contamination and potential exposure to asbestos and waste materials that present a physical risk the options for risk control include:

- Provision of a barrier layer to prevent direct contact with the lead in the ground.
- Provision of service corridors with imported clean backfill and use of metal or other proprietary material for water service pipes in the ground.
- Adopting appropriate and stringent health and safety measures during ground related construction activities

For the barrier layer the overall objective is to break the exposure pathway with different methods to be used in different areas of the development depending on the final construction. Normal site construction activities will provide the majority of the barrier layers where buildings and sealed surfaces are present. The thickness and material specification within a particular area will be dependent on the final construction at that location

3.6.2 Ground Gas

Due to the elevated concentrations of methane and carbon dioxide the site has been classed as 'amber 2 in accordance with NHBC Guidance on Methane and Carbon Dioxide Report Edition No.04 (March 2007) and CIRIA Publication C659 Assessing Risks Posed by Hazardous Ground Gases to Buildings. All structures and buildings will have to incorporate gas control and protection measures appropriate for the site characterisation category which requires high level gas protection measures, comprising a membrane and ventilated sub-floor void with a minimum of one complete volume change per 24 hours. Provision of venting should be in accordance with current accepted guidance and standards.

All risk control and mitigation measures undertaken at the site should be carefully controlled and checked in accordance with best quality control procedures. Gas protection and control measures in particular should be checked at each stage of installation in accordance with current guidance. The method and frequency of validation and certification should be detailed in the Remediation Strategy and implementation plan

4.0 Ground Contamination.

4.1 Remediation Options Appraisal.

The Site investigation has recommended that for ground contamination the pathway be broken by the installation of a Barrier (form and type to suit location) however in accordance with CLR 11 it is necessary to review available remediation options to ensure that the most appropriate option is developed and implemented. Options available to manage the risks include

- manage (remove, modify) the source;
- interrupt the pathway or;
- Modify the receptor or the behaviour of the receptor.

In order to determine an appropriate remediation method for dealing with identified risk for the site it is necessary to define the boundaries within which remediation options are to be considered this can be achieved by setting a number of objectives that have to be met for each remediation option which are considered acceptable to all parties.

The objectives that are to be considered for this site are

- **Technical effectiveness of strategy in reducing risk**
Solutions need to be proven method in dealing with reducing/eliminating risks
- **Practicality of implementing and maintaining**
The solutions need to be able to be implemented without causing significant disruption to the surrounding residential area and need to be maintenance free
- **Durability of strategy**
Solutions need to be seen to not fail during the lifetime of the development
- **Sustainability i.e. use of energy or environmental impact.**
Solutions need to consider impact on site and surrounding residential environment as well as consider the required energy usage
- **Cost of strategy in terms of scale of development**
Solutions need to be considered appropriate for the economic climate and be in line with current commercial costs associated with the scale of the development
- **Development Programme.**
Solutions need to be deliverable within the proposed timeframe.

There are a number of treatment methods typically available when considering contaminated land remediation for example:

- Physical (soil vapour extraction, dual phase extraction, soil washing, permeable reactive barriers; diaphragm walls);
- Biological (bioremediation, bioventing, monitored natural attenuation);
- Chemical (transformation by chemical treatment);
- Thermal (thermal desorption, (six phase heating), vitrification);
- Civil Engineering Methods (excavation & disposal, capping layers inc. geo-textiles);

- Stabilisation (concrete, lime slurry);

Due to the composition of the made ground within the site comprising old landfill waste including plastic sheet, bags, glass bottles and gravel, cloth, metal wire, ash gravel, and cobbles of sandstone, along with the relatively low and isolated exceedences of contaminants noted within the made ground, the treatment methods that are suitable based on the scale of proposed development site are limited

For example the low levels of hydrocarbons and metals within the made ground would not justify soil washing or onsite bioremediation likewise the levels and extent of contamination over the a relatively small area means the site is not really suitable for chemical or thermal processes of remediation.

Stabilization techniques could be employed to encapsulate the contaminants within the host medium however it is generally not considered viable for shallow treatments in residential areas.

It is considered that due the nature of material in the made ground Civil engineering methods of remediation would be the most appropriate.

Civil engineering techniques remain the most widely used remedial method of brownfield re-development although they are often not the most cost effective. The pressures of the development programme are often the drivers for employing a civil engineering remedial technique as the treatment timescales are significantly reduced.

Typically these methods are:

- Full excavation and disposal: This would result in full depth removal of contaminated ground across the site with disposal to suitable land fill. The resulting level change would require the import of suitable clean material to achieve accessible development levels.
- Capping Layers: Provision of suitable capping layers to remove the pathway with the contaminants with the soil. Capping layers can consist of hard forms such as building footprints, roads, footpaths and hard landscaping or soft landscaping of suitable composition and thickness.

These two methods are scored against the remediation objectives in Table 10 below

4.2 Selected Ground Remediation Options

In terms of meeting the remediation objects both Civil engineering options meet the requirements. In overall terms however it is considered that the capping strategy provides the most appropriate recognised, sustainable, cost effective solution for reducing risk identified within the site investigation report.

OBJECTIVE	STRATEGY		
	FULL EXCAVATION AND DISPOSAL/IMPORTATION OF CLEAN		APPROPRIATE CAPPING LAYERS
Technical effectiveness of strategy in reducing risk	Completely removes risk to end users		Breaks pathway to end user reducing risk to negligible
Score		10	9
Practicality of implementing and maintaining	Significant disruption due to major earthworks operations removal from site and import of new materials – Maintenance Free		Reduced earthworks operations, less removal from site and less importation of materials. Maintenance needs to be considered if capping layers excavated through in future
Score		8	8
Durability of strategy in reducing risk	Total removal of made ground contamination and replacement with clean materials is considered not to fail in terms of lifetime of development		Capping of Site is a recognised strategy to break pathway and reduce risk. However there are minor risks associated with excavations through capping layer by other parties for example services repairs/renewals.
Score		10	8
Sustainability i.e. use of energy or environmental impact*	Complete excavation and disposal of made ground and import of clean materials is not considered a sustainable solution and impact on surrounding and far removed environment is considerable. Significant lorry movements will be required resulting in disruption and nuisance to surrounding residential areas and local highway network.		Considerable less vehicle movements and excavation/import of materials. Recycled materials can be used to create capping within the construction layers. Less disruption and nuisance to local residential environment
Score		3	5
Cost of strategy in terms of scale of development Development**	Significant costs associated with site wide excavation and disposal along with import of materials to achieve development levels		Reduced excavation disposal and import costs. Capping layer provided by Construction materials already required
Score		3	5
Development Programme***	Longer contract duration		Shorter contract duration
Score		4	6
Total Score		38	41

*Low Score = Poor sustainability /high environmental impact

**Low Score = High Cost

*** Low score = Poor Programme implications

Table 10 – Remediation Options Scoring Matrix

Whilst capping of the site is considered as the most suitable solution it is recognized that in reality due to the layout and finished levels of the of the proposed development a combination of techniques will provide the final solution. Based on existing ground levels, proposed levels and varying depths and form of capping it is recognised that in some locations excavation and disposal of the existing ground will be required particularly in soft locations where depth of capping is increased to that of hard landscaping. An example of this provided in Appendix C drawing No 6503-008.

4.3 Capping Strategy

The overall objective of the capping strategy is to break the exposure pathway between contaminants of concern and receptor in this case humans. Normal construction hard standings and building footprints will provide the majority of the barrier layers. with garden areas receiving a minimum of 1000mm of validated clean inert material with perimeter landscaping receiving 600mm of validated clean inert material Minimum 200mm of validated topsoil to be included within the capping depth

Drawing 6503-122 in Appendix C sets out the proposed capping strategy for the site with capping form/type and make up identified in Table 11 below

Residential Garden Capping will comprise

- 800mm of clean inert general fill, it is proposed to utilise a general fill material in accordance with Specification for highway works series 600 class 2C or 2D stony or silty cohesive. This general fill material closely represents the existing ground it will be replacing thus placement of new capping should not impact significantly on existing gas pathways and will not create addition horizontal migration.
- 200mm of clean inert Multi-purpose Topsoil to BS 3882:2007.

Under hard landscaping areas a suitable layers of geotextile will be provide to suit CBR results (Contractor to confirm results).

Within soft landscaping areas an orange geotextile separation/identification layer will be proved to identify to future activities a demarcation zone between the existing made ground and clean capping

Within Residential garden areas the contractor will be required to validate formation and finished levels to ensure correct depth of capping. Refer to table 12 below.

Site Location	Capping strategy
Buildings and Footprint	Screed, insulation, Gas protection (See section 5.2) for details Beam and Block Flooring minimum 200mm Clear void.
Driveways and Parking Bays	40mm Thin Surface Course 60mm Dense Binder AC 225 Type 1 Sub base Tensar TX 160 Geogrid - OSA
Carriageway	40mm Thin Surface Course 60mm Dense Binder DBM50 100mm Dense Base DBM50 150 Type 1 Sub base 2 layers of Tensar TX 160 Geogrid - OSA
Footpaths	20mm Dense AC 6 Surface course 40mm Dense Binder AC 20 200 type 1 Sub base 2 Layers of Tensar TX 160 Geogrid - OSA
Garden Paths	40mm Flagstones 40mm sand 100mm Type 1 sub base Tensar TX 160 Geogrid - OSA
Gardens	18 Number Residential Gardens 200mm Validated* Clean inert imported topsoil in accordance with BS 3882:2007

	800mm validated clean inert imported Fill – Class 2C and 2D in accordance with the specification for highway works Series 600 table 6/1 Total depth to be validated* PAGeotechnical Bioliner Orange - OSA * Refer to section 4.4 below
Landscaping	200mm Validated* Clean inert imported topsoil in accordance with BS 3882:2007 400mm validated clean inert imported Fill – Class 2C or 2D in accordance with the specification for highway works Series 600 table 6/1 Total Depth to be validated* *Refer to section 4.4 below

Table 11 – Capping Strategy

4.4 Capping Validation.

The Implementation plan will set out the detail design for capping, each plot will have formation and finished garden levels defined similarly to Drawing 6503-122 in Appendix C Table 12 sets out the validation/testing strategy for the capping layers

	Capping Material	
	Topsoil	Subsoil
Type	Multi-purpose Topsoil to BS 3882:2007	Class 2C and 2D in accordance with the specification for highway works
Certification	BS 3882:2007 Declaration of analysis Analysis Certificate Sampling protocol	Series 600 table 6/1
Testing Regime	1 No per 100m3 per source	1 No per 200m3 per source
Chemical Composition	Suite 1 - pH, arsenic, cadmium, chromium (hexavalent and total), lead, copper, nickel, zinc, boron, mercury, selenium, sulphide, sulphur, sulphate, PAH, cyanide (total, free, complex), thiocyanate, phenol, and total petroleum hydrocarbons as a screen (FCC) and TPHCWG (Wrexham) Note where source is unknown samples to analysed for PCB;s and Asbestos screen	Suite 1 - pH, arsenic, cadmium, chromium (hexavalent and total), lead, copper, nickel, zinc, boron, mercury, selenium, sulphide, sulphur, sulphate, PAH, cyanide (total, free, complex), thiocyanate, phenol, and total petroleum hydrocarbons as a screen (FCC) and TPHCWG (Wrexham) Note where source is unknown samples to analysed for PCB;s and Asbestos screen
Thickness	200mm	800mm
Depth Validation	5 No spot levels to be taken on top of subsoil. Locations to be garden corners and centre 1 No Finished Garden level to be taken in centre.	5 No spot levels to be taken at formation following placement of marking layer. Locations to be garden corners and centre

Table 12 - Validation and testing strategy for capping

4.5 Effectiveness of Combined Remedial Option

It is considered that combined option of part dig and dump and full site capping reduces the risks associated with the made ground contamination to negligible levels.

The advantages of capping the site are

- Capping prevents the need for intrusive remediation
- Capping is cheaper than other remedial techniques

- Can be applied to all contaminants
- No long term maintenance or monitoring

The disadvantages are

- Does not remove contaminants
- May affect future use of the site

It is considered that the durability of the capping would be expected to last the full life span of the development. It is anticipated that remedial works will be required however this should be limited to the upper layers of the capping i.e. resurfacing of the highway or services reinstatements (Services will be installed in clean trenches)

5.0 Ground Gas Contamination –

5.1 Options Appraisal.

Similarly to ground contamination, in accordance with CLR 11 remediation options need to be identified for each pollutant linkage identified, remedial options available for ground gas remediation at the site include.

- manage (remove, modify) the source;
- interrupt the pathway or;
- modify the receptor or the behaviour of the receptor.

The site investigation has identified elevated concentrations of methane in one borehole with detectable but not elevated concentrations recorded in one other. Concentrations of Carbon Dioxide were detected in all BH's across the site, it is considered that the low flow volumes and low concentrations of gases are being generated by aerobic degradation of the very small quantities of degradable material in the made ground.

Remediation techniques for dealing with ground gas are more limited than options available for ground contamination and include in-situ methods such as total removal of gas generating material, reduction/prevention of infiltrating or ground water reaching waste to slow down methane production or ex situ methods such as recovering the ground gas followed by capture or destruction.

Due to the composition of the made ground and the potential for further low level gas generation neither of these source management techniques are considered suitable for the site and are not considered further

With ground gas it is recognised that breaking the pathway between the source and receptor provides a robust remediation strategy for the life of the development subject to appropriate selection of materials coupled with correct installation and testing.

5.2 Design parameters

The maximum results obtained from the monitoring regime classify the site as Amber 2 in accordance with NHBC guidelines or gas characteristic 3 in accordance with CIRIA C665 These guidelines can be used to inform the design strategy for the form and occupancy type of building.

5.3 Selected Gas mitigation Option

In determining the gas mitigation methods based on the guidelines provided by NHBC and CIRIA C665 reference is made to the following British standard

BS 8485:2007 'code of practice for the characterization and remediation from ground gas in affected developments.'

Following determination of the site specific gas situation Section 7 of BS8485:2007 sets out the recommended gas protection appropriate for the buildings. As there are a number existing designs and component elements available in the market this provides a guide as to the relative performance of types of designs and systems available.

The factors that should be considered in making this decision include:

- Characteristic gas situation;
- type of construction, foundations and ground slab detail;
- size (particularly width) of building footprint;
- end use of building (domestic or commercial, controlled or uncontrolled, occupancy, room size, etc.);
- the nature of the management of maintenance of gas control facilities and service provision of the buildings; and
- views of client/building owner.

The proposed development at this site is one of managed housing however it is recognised that there may be fluidity in ownership during the development lifetime and for that reason the mitigation requirement will be based on that of non-managed private housing.

BS8485:2007 Table 2 extract shown in Table 13 below advises that the required gas protection will need to achieve a score of 4.

Table 2 Required gas protection by characteristic gas situation and type of building

Characteristic gas situation, CS	NHBC traffic light	Required gas protection			
		Non-managed property, e.g. private housing	Public building ^{A)}	Commercial buildings	Industrial buildings ^{B)}
1	Green	0	0	0	0
2	Amber 1	3	3	2	1 ^{C)}
3	Amber 2	4	3	2	2
4	Red	6 ^{D)}	5 ^{D)}	4	3
5			6 ^{E)}	5	4
6				7	6

NOTE Traffic light indications are taken from NHBC Report no.: 10627-R01 (04) [3] and are mainly applicable to low-rise residential housing. These are for comparative purposes but the boundaries between the traffic light indications and CS values do not coincide.

^{A)} Public buildings include, for example, managed apartments, schools and hospitals.

^{B)} Industrial buildings are generally open and well ventilated. However, areas such as office pods might require a separate assessment and may be classified as commercial buildings and require a different scope of gas protection to the main building.

^{C)} Maximum methane concentration 20% otherwise consider an increase to CS3.

^{D)} Residential building on higher traffic light/CS sites is not recommended unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations.

^{E)} Consideration of issues such as ease of evacuation and how false alarms will be handled are needed when completing the design specification of any protection scheme.

Table 13 – Table 2 Extract from BS 8485:2007

From BS8485:2007 Table 3 extract shown in Table 14 below the levels of protection required to achieve that score based on the proposed foundation solution are highlighted in red.

Construction make up for ALL plots will comprise the following (Selected Gas Protection measures to achieve a score of 4.5 marked in red, required score 4)

- Beam and Block flooring comprising
- 65mmscreed on
Isolation layer on
125mm kingspan TF70 Urethane insulation on
PAGEotechnical Monarflex Reflex Super Proprietary gas protection system
(All joints and penetrations lapped taped and sealed in accordance with manufacturers recommendations (refer drawing 6503-0011 Appendix 3)
Cavity wall tray Lapped taped and sealed to gas membrane (refer to architects details)
- 200mm clear void from underside of beam to ground.
- 225x75mm grilled airbricks and proprietary Periscope vents around perimeter at 2m centres, cross vents to internal load bearing walls to be set at 2m centres. Note Minimum cross sectional area to be 3000mm² per opening in accordance with building regulations Part C 2004 edition (incorporating 2010 amendments) Section 4: walls cl 4.19.

Table 3 Solutions scores

PROTECTION ELEMENT/SYSTEM		SCORE	COMMENTS
a) Venting/dilution (see Annex A)			
Passive sub floor ventilation (venting layer can be a clear void or formed using gravel, geocomposites, polystyrene void formers, etc.) ^{A)}	Very good performance	2.5	Ventilation performance in accordance with Annex A.
	Good performance	1	If passive ventilation is poor this is generally unacceptable and some form of active system will be required.
Subfloor ventilation with active abstraction/pressurization (venting layer can be a clear void or formed using gravel, geocomposites, polystyrene void formers, etc.) ^{A)}		2.5	There have to be robust management systems in place to ensure the continued maintenance of any ventilation system. Active ventilation can always be designed to meet good performance. Mechanically assisted systems come in two main forms: extraction and positive pressurization.
Ventilated car park (basement or undercroft)		4	Assumes car park is vented to deal with car exhaust fumes, designed to Building Regulations Document F [5] and IStructE guidance [6].
b) Barriers			
Floor slabs			
Block and beam floor slab		0	It is good practice to install ventilation in all foundation systems to effect pressure relief as a minimum. Breaches in floor slabs such as joints have to be effectively sealed against gas ingress in order to maintain these performances.
Reinforced concrete ground bearing floor slab		0.5	
Reinforced concrete ground bearing foundation raft with limited service penetrations that are cast into slab		1.5	
Reinforced concrete cast in situ suspended slab with minimal service penetrations and water bars around all slab penetrations and at joints		1.5	
Fully tanked basement		2	
c) Membranes			
Taped and sealed membrane to reasonable levels of workmanship/in line with current good practice with validation ^{B), C)}		0.5	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation, and the integrity of joints.
Proprietary gas resistant membrane to reasonable levels of workmanship/in line with current good practice under independent inspection (CQA) ^{B), C)}		1	
Proprietary gas resistant membrane installed to reasonable levels of workmanship/in line with current good practice under CQA with integrity testing and independent validation		2	
d) Monitoring and detection (not applicable to non-managed property, or in isolation)			
Intermittent monitoring using hand held equipment		0.5	Where fitted, permanent monitoring systems ought to be installed in the underfloor venting/dilution system in the first instance but can also be provided within the occupied space as a fail safe.
Permanent monitoring and alarm system ^{A)}	Installed in the underfloor venting/dilution system	2	
	Installed in the building	1	
e) Pathway intervention			
Pathway intervention		—	This can consist of site protection measures for off-site or on-site sources (see Annex A).

NOTE In practice the choice of materials might well rely on factors such as construction method and the risk of damage after installation. It is important to ensure that the chosen combination gives an appropriate level of protection

^{A)} It is possible to test ventilation systems by installing monitoring probes for post installation validation.

^{B)} If a 1 200 g DFM material is to function as a gas barrier it should be installed according to BRE 212 [8]/BRE 414 [9], being taped and sealed to all penetrations.

^{C)} Polymeric Materials >1 200 g can be used to improve confidence in the barrier. Remember that their gas resistance is little more than the standard 1 200 g (proportional to thickness) but their physical properties mean that they are more robust and resistant to site damage.

Table 14 – Table 3 Extract from BS 8485:2007

5.4 Workmanship testing and independent validation of proprietary gas membrane.

The strategy below sets out the minimum requirements regarding workmanship, testing and validation and is further covered under outline validation plan. The successful contractor is to ensure and allow for the following workmanship testing and independent validation.

Workmanship.

Contractor is to ensure that the installer of the gas proprietary system is suitable qualified and experienced, installation technicians to be trained to and hold appropriate certification to NVQ level 2 qualification in gas protection installation. Prior to commencing work on site appropriate qualification certification is to be provided to the client team.

Independent Testing and Validation.

The contractor is to employ an independent environmental consultant to carry out integrity testing and certification. Consultant to carry out thorough visual inspection of the first 5 plots including vented void and sub grade and membrane before placement of insulation and screeds. All joints and penetrations corners etc to be air lanced to ASTM D 4437. On successful completion of the first 5 plots independent verification inspections should be carried out at a rate of 1 in 5. Resulting in testing and verification of 35% of the total of 23 plots.

The contractor is to supply plot sign off sheets (verification evidence) including photographs to independent consultant for all other plots.

The contractor is to provide a detailed installation plan, method statements and QA procedures for inclusion within the implementation and subsequent verification plan.

Upon completion of all gas protection works the contractor is to provide all verification and testing reports completed by the independent consultant to the client team for inclusion within the final site wide verification plan.

5.5 Ground Gas Monitoring

Ground gas monitoring will be undertaken during the construction phase and continued for 12 months following completion by definition a number of the BH's will need to be removed to facilitate construction, however 1 No shallow and 1 No deep BH will be maintained It is currently proposed to maintain the BH's displaying the highest readings however exact locations and adjacency to foundations will need to be confirmed by the contractor at the commencement of the works to ensure that the BH's can be maintained.

A BH Constraints Drawing No 6503-131 can be seen in Appendix C

The following BH's will be maintained

- Shallow BH BS 1 which displayed elevated methane and Carbon Dioxide
- Deep BH BD2S which displayed elevated methane

Sampling regime

- Every 2 months during construction phase of 12 months = 6 Visits
- Every 2 months post construction for 6 Months = 3 visits

6.0 Ground Water Contamination

The Intrusive site investigation identified the presence of occasional elevated concentrations of arsenic, calcium manganese, potassium, ammoniacal nitrogen and PAH in the shallow groundwater in the alluvial deposits directly below the made ground, and very occasional elevated concentrations of calcium, manganese and PAH in the perched water in the made ground and concluded that there was low, very low or no risk to controlled waters. This assessment has been copied to Natural Resources Wales who have commented on one or two minor points that were subsequently addressed in the final site investigation report.

Notwithstanding the low risk to the controlled waters consideration needs to be given to the presence and potential for contaminated perched water in the made ground uncovered during construction and the potential for pollution of the ground water by construction activities. The reader is referred to section 8.4 and 8.5

7.0 Consents, Licences & Certification

The remediation strategy does not set out any procedures that require specific treatment licences or requirements for permits/exemptions as set out by Natural Resources Wales. However Waste management regulations require appropriate disposal of 'Waste' excavated as arisings from the site. The contractor is to ensure that Waste Acceptance Criteria (WAC) tests are carried out in sufficient number to satisfy the receiving registered land fill test criteria. The contractor will provide documented evidence to the client team in the form of WAC test certificates and vehicle movement documentation along with evidence of disposal at a licensed tipping facility.

8.0 Site Management Measures

Due to the nature of the existing ground and the resulting proposed development there are a number of site management measure and potential risks that need to be fully addressed by the contractor it is not intended that this section is prescriptive rather it is intended to highlight the potential risks that will need to be fully addressed in the implementation plan with appropriate input from the contraction.

In order to set out how these site management issues will be dealt with the contractor will need to provide a Materials Management Plan which sets out the methodology of how excavated materials are to be dealt with and include if/how they are to be stored on site. Intended final destination, tracking and any contingencies arrangements as well as conformation of disposal. This document will form part of the verification plan.

8.1 Risk to construction personnel

The intrusive ground investigation report risk assessment identifies a number of risks to site operatives associated during the construction phase. It is not intended to define how the contractor mitigates these risks however to ensure that the contractor is aware of identified risk and takes the appropriate mitigation measures in accordance with current guidelines and best practice, these risks these have been extracted from the Site Investigation and shown in Table 15 below.

HUMANS - (Construction Personnel)				
Contaminant Source	Pathway	Linkage Probability	Consequence	RISK/Comment
Arsenic/Lead in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Petroleum hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Poly aromatic hydrocarbons in near surface made ground	Ingestion/ Dermal contact/ Inhalation	None	Minor	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Asbestos fibres of amosite in near surface made ground	Inhalation	None	Major	Low. Risk can be removed by adopting strict health and safety procedures and requirements.
Methane	Migration through permeable strata, emissions through ground surface and accumulation in spaces with ignition source	Possible	Catastrophic	High. Occasional elevated concentrations of methane to a maximum of 3.1% and GSV of 0.065 l/hr giving site characterisation of 'amber 1'
Carbon dioxide	Migration through permeable strata, emissions through ground surface and accumulation in poorly vented spaces	Possible	Catastrophic	High. Elevated concentrations of carbon dioxide detected across the site with maximum concentration greater than 10% a GSV of 0.15 l/hr giving site characterisation of 'amber 2'

Table 15 – Risk Assessment Construction Personnel

From Table 15 it can be seen that the made ground contains some elevated contaminants presented as low risk however whilst the materials detected in the made ground contain contaminants of low risk traces of asbestos fibres of amosite were detected in TPS S2 and TPS S4 between 0.4-0.5m from existing ground the levels detected were considered low and not deemed to present a risk, however as this material was noted within the made ground and may well exist elsewhere appropriate health and safety precautions need to be adopted when excavating and working within the made ground layer including For BH and trial pit locations refer to Appendix B – Dwg 6503-131

A watching brief should be implemented for Asbestos containing materials, such as pipe insulation or pieces of roofing sheets. The contractor is to employ suitably experienced and qualified personnel to undertake this watching brief.

- Appropriate PPE to be used
- Appropriate suppression methods are to be in place to limit generation of dust.
- Dust monitoring equipment is to be utilised as section 7.2

8.2 Health and Safety Procedures

All relevant health and safety measurements to be confirmed by the selected contractor and submitted as a separate document.

8.3 Dust and Odour

Dust monitoring locations will be defined and maintained for the duration of the works. Dust suppression measures will be available and utilised during works.

Dust control would include damping down excavations, stockpiles and haul roads during dry and breezy conditions when dust generation is highly likely.

With respect to monitoring odours, this would be undertaken using hand held equipment at specific times and also if odours are noted to be particularly strong. A flame ionisation detector (FID) or photo ionisation detector (PID) would be used to monitor volatile organic compound concentrations. This would be in addition to the subjective, olfactory assessment of site personnel.

The site investigations have not reported any significant strong or unpleasant odours. There will remain a slight possibility that pockets of strong odours might be encountered. The dust suppression measures might also be adequate to reduce odours as they would reduce airborne particulates. However, where odours are particularly strong, malodorous or lingering, odour suppressants might be employed. Care will be taken to ensure the correct concentrations are used to avoid creating additional odour issues.

8.4 Noise

Noise levels to be controlled through careful handling of materials; modern, quiet power tools, equipment and generators; low impact technologies; and wall structures as sound shields.

8.5 Surface Water Run off

All surface water runoff generated from specific site activities is to be collected in settlement tanks, screened and discharged appropriately. The remaining sludge is to be disposed of in accordance with environmental regulations.

All building materials such as cement, sand and other powders will be covered and inspected on regular intervals for spillages. All materials to be located where they will not be washed into waterways or drainage areas.

8.6 Discharges to Ground water

One of the potential effects of the construction phase is contamination of the controlled waters from a pollution incident resulting from construction equipment and materials on site. Transportation, storage and use of fuels oils and chemicals and handling of cement and concrete for construction purposes all pose a risk of pollution.

Procedures for pollution control and clean up will be provided by the contractor and included within the implementation plan. Utilising current legislation and good practice the potential impact should be considered low.

9.0 Outline Implementation Plan

In accordance with CLR 11 an implementation plan will be produced which will set out in detail the remediation activities for the site how this will be implemented and detailed verification, This document will require input from the selected contractor particularly with regard to Health and Safety provisions, method statements, pollution control measures and material management plan

It is intended that it will include the detail design elements of capping setting out the formation levels for ALL plots as per examples shown in Drawing 6503-008 in Appendix C

10.0 Outline Verification Plan

The verification plan will be completed upon completion of all works that impact on the ground and will collate the evidence to demonstrate that all works have been carried out in accordance with the remediation strategy and implementation plan. This will include:

- validation of clean capping depths to gardens
- Third party validation regarding gas protection installation.
- Contractors individual plot records and photo's
- WAC test certificates for waste off site
- Waste disposal Tickets confirming waste disposal to authorised Facility
- Plans and drawings as necessary

11.0 Conclusions

In accordance with the Environment Agency Contaminated Land Report 11 (CLR 11) this report has been compiled to detail the selected remediation strategy for dealing with the known contaminants associated with the proposed residential development at Glan Gors Wrexham. The remediation strategy presented has been informed by a number of detailed investigations and reports in line with CLR11 guidelines it is intended that this document will allow the local authority to approve the strategies detailed thus allowing the next stage works to be undertaken with preparation of the implementation plan to be developed in conjunction with a selected contractor.

Appendix A

Site Location Plan

Site Location Plans

The site is located approximately 1.5km east of the centre of Wrexham, North Wales. The site location is shown on Figure 1 and is centred at Grid Reference 335197,349858. The site which covers an area of approximately 0.6ha (Figure 2) is located off Anthony Eden Drive. Situated between an area known as The Dunks and Cefn Park the site is surrounded by residential properties.

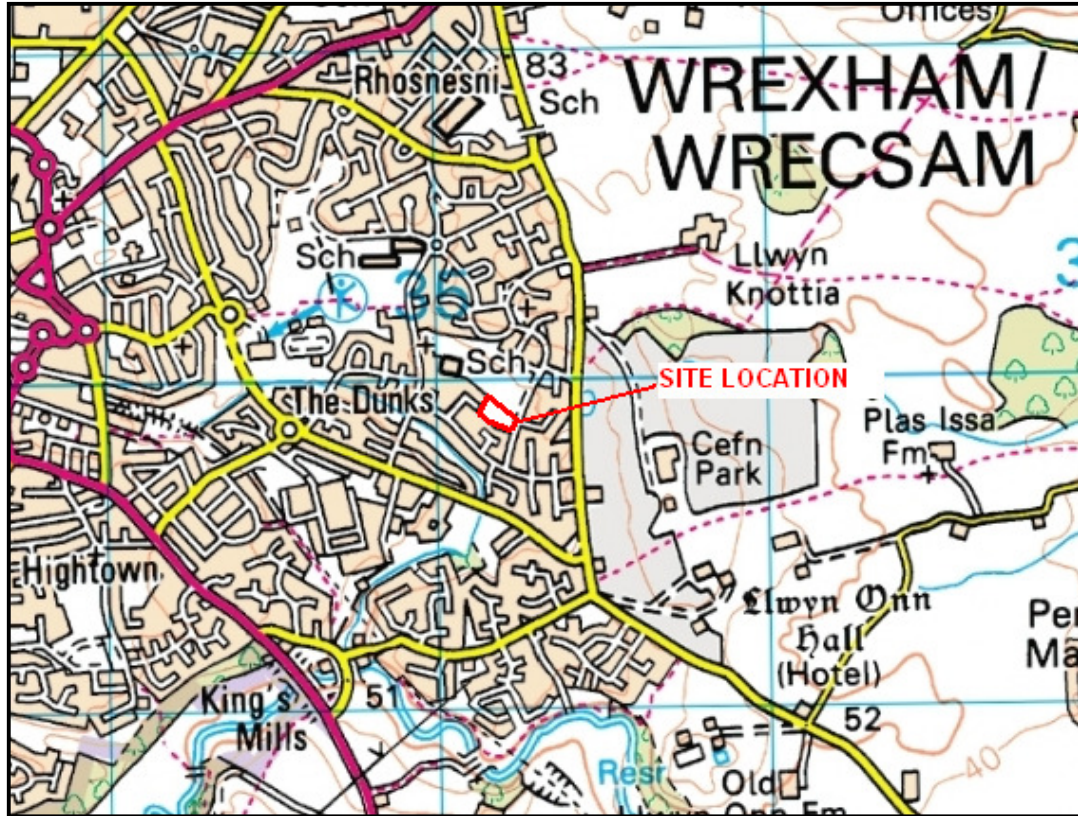


Fig 1

The extent of the site is shown on Figure 2. Access to the site is directly off Anthony Eden Drive to the east. The boundaries of the site are marked by a pathway to the north-west, south-west and south, Anthony Eden Drive to the east, and there is no boundary demarking the north-east boundary.

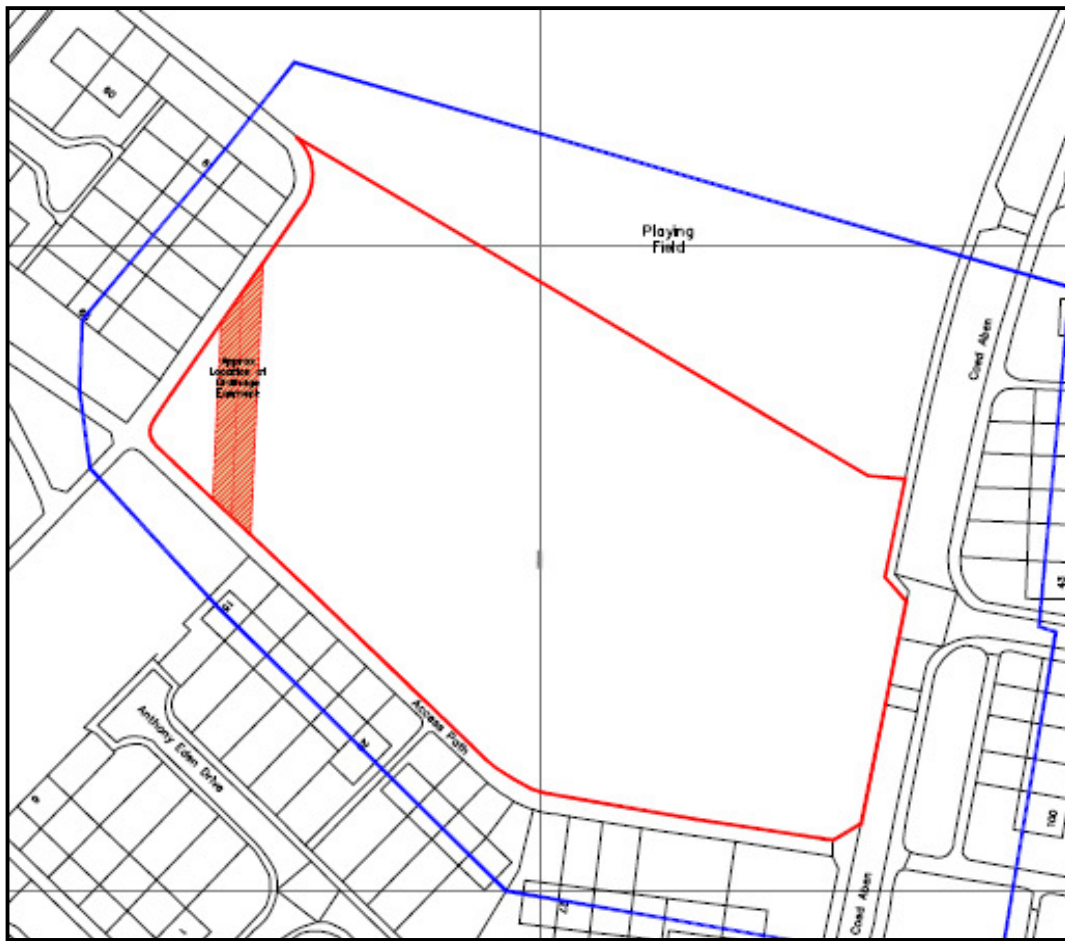


Figure 2 – Site Boundary (red)

Site Description and Topography

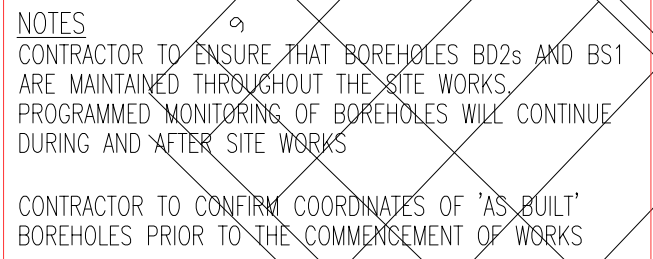
The site is an area of maintained green open space within a residential estate. It is used for recreational use and comprises a grassed relatively flat area of ground. An aerial photograph is shown as Figure 3. The ground surface within the site is generally level and slopes very gently from north-east to south-west from 58.90m aOD to 57.60m aOD. There are residential properties to the east, south and west to north-west. To the north-east is a further area of grassed open space used for informal recreational use.



Figure 3 – Aerial Photograph

Appendix B

BH/Trial Pit Locations and Constraint Plan



GENERAL NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES UNLESS NOTED OTHERWISE.
3. ALL LEVELS RELATE TO ORIGINANCE DATUM UNLESS NOTED OTHERWISE.
4. DO NOT SCALE FROM THIS DRAWING: USE FIGURED DIMENSIONS ONLY.
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EXISTING BOREHOLES

- S17 – SGP BH (2005)
- S18 – SGP BH (2005)
- BH6 – WCBC (2004)
- BH7 – WCBC (2004)

ADDITIONAL BOREHOLES

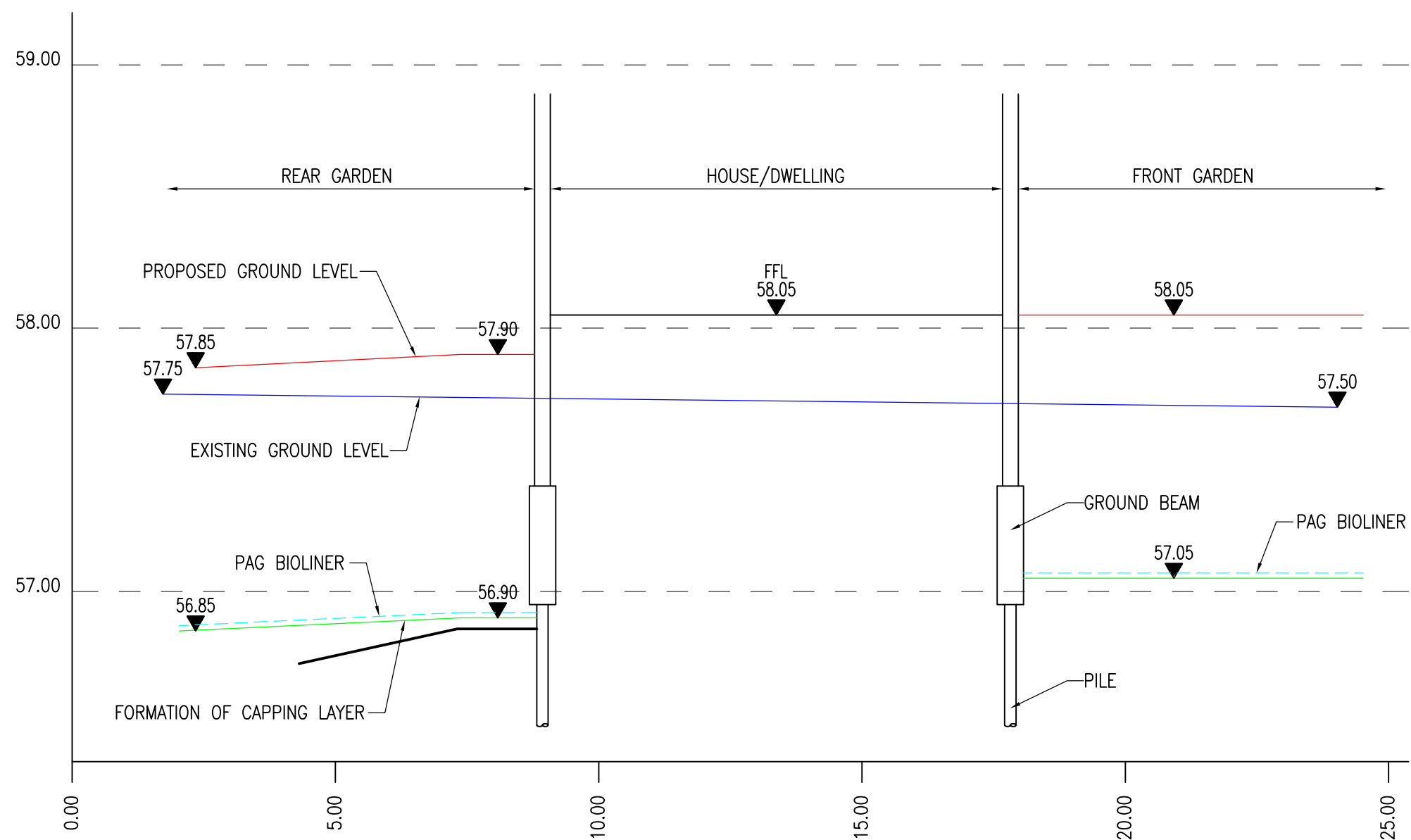
	BD 1 - 3 - NEW DEEP BOREHOLES FOR GEOTECHNICAL, GROUNDWATER, GAS AND SOIL SAMPLING
	BS 1 - 3 - SHALLOW BOREHOLE FOR GROUNDWATER, GAS, VOC'S AND SOIL SAMPLING
	SS - SOIL SAMPLES TO BE TAKEN AT APPROXIMATELY 1 - 1.5M DEEP FROM WASTE LAYER
	CBR - CALIFORNIA BEARING RATIO TEST LOCATIONS

Rev	Date	By	Ch	Revisions	Client	Project	Drawing Title
					PENNAF HOUSING GROUP	RESIDENTIAL DEVELOPMENT GLAN GORS WREXHAM	BOREHOLE CONSTRIANTS PLAN
					Drawing Status FOR INFORMATION	Scale 1:500@A3	Date 24.10.12
						Design By SR	Drawn By SR
						Job No: 6503	Drawing No. 131
							Rev. -
					Bay Associates Civil + Structural Engineers 21/22 Neptune Court, Vanguard Way, Cardiff, CF24 5PJ t:029 2045 1011 f:029 2037 4690 e:bay@bayassociates.co.uk w:www.bayassociates.co.uk	  	CARDIFF ☒ REDDITCH ☐ LONDON ☐
							

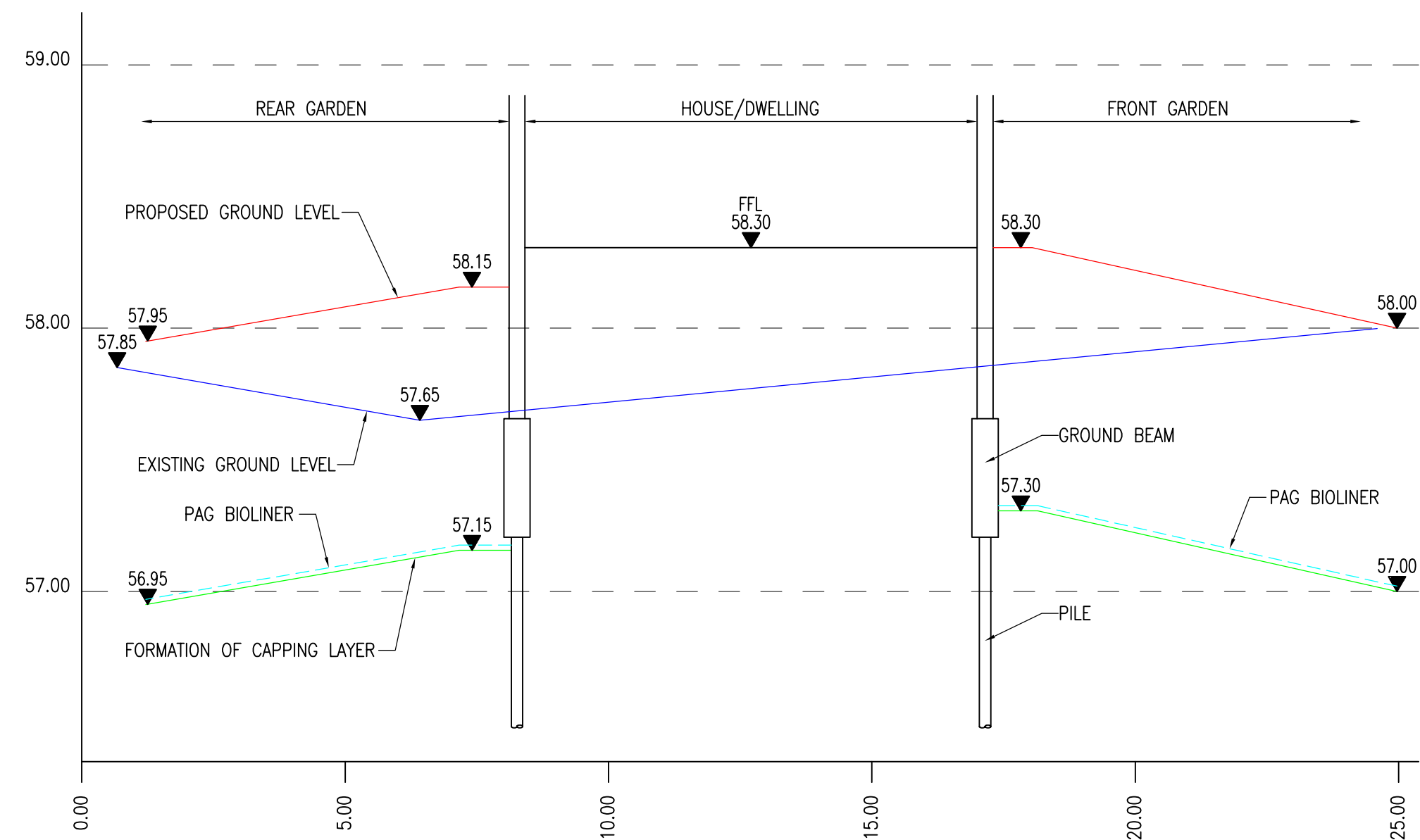
Appendix C

Drawings

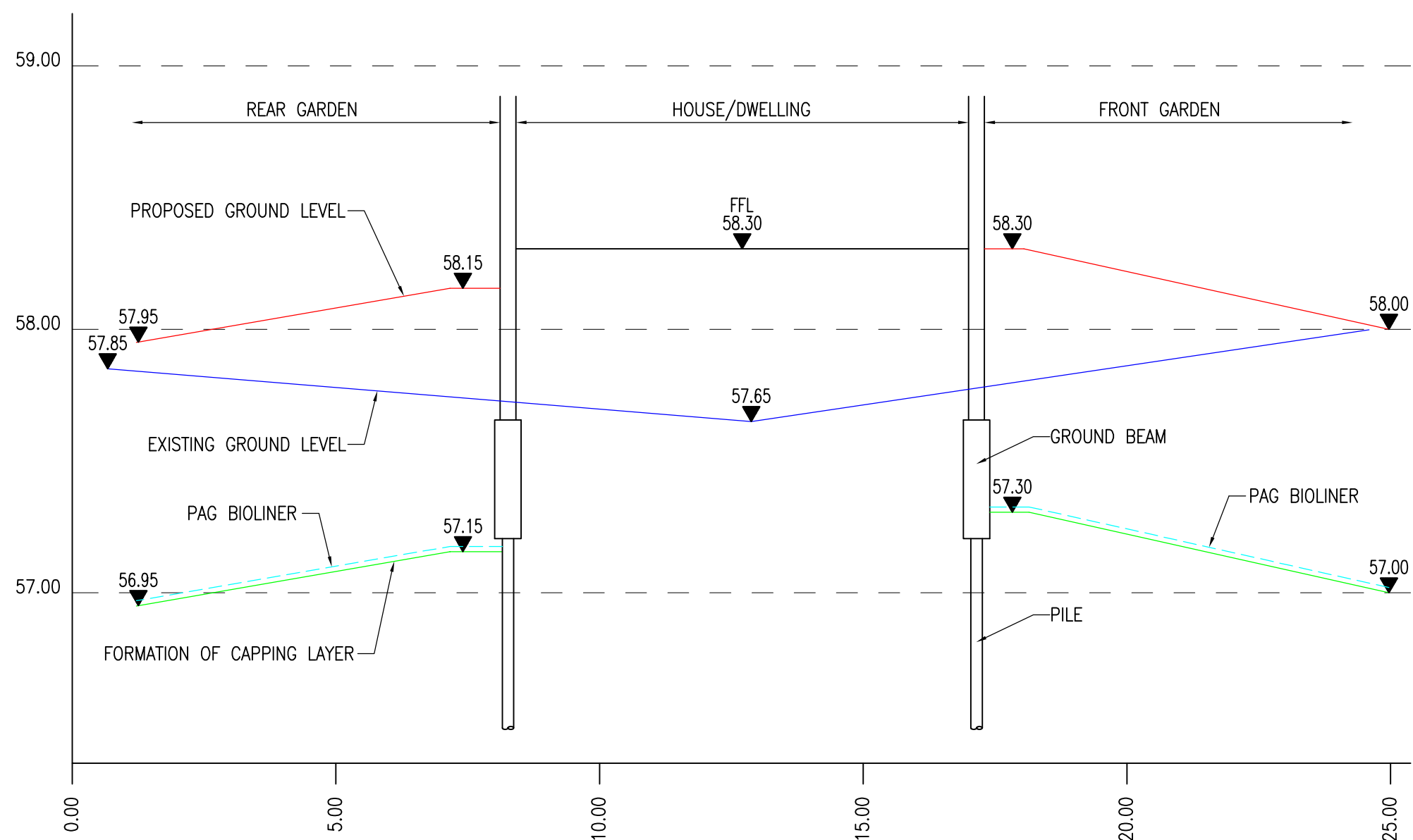
Dwg – 6503-122	Capping Plan
Dwg – 6503-008	Residential Gardens Capping Sections
Dwg – 6503-0011	Gas Membrane Details



SECTION A-A PLOTS 1/2
(SCALE 1:100 HORIZONTALLY 1:500 VERTICALLY)



SECTION C-C PLOTS 5/6
(SCALE 1:100 HORIZONTALLY 1:500 VERTICALLY)



SECTION B-B PLOTS 3/4
(SCALE 1:100 HORIZONTALLY 1:500 VERTICALLY)



SITE PLAN KEY
SCALE 1:500

Notes:

0mm 50mm A1
original sheet size

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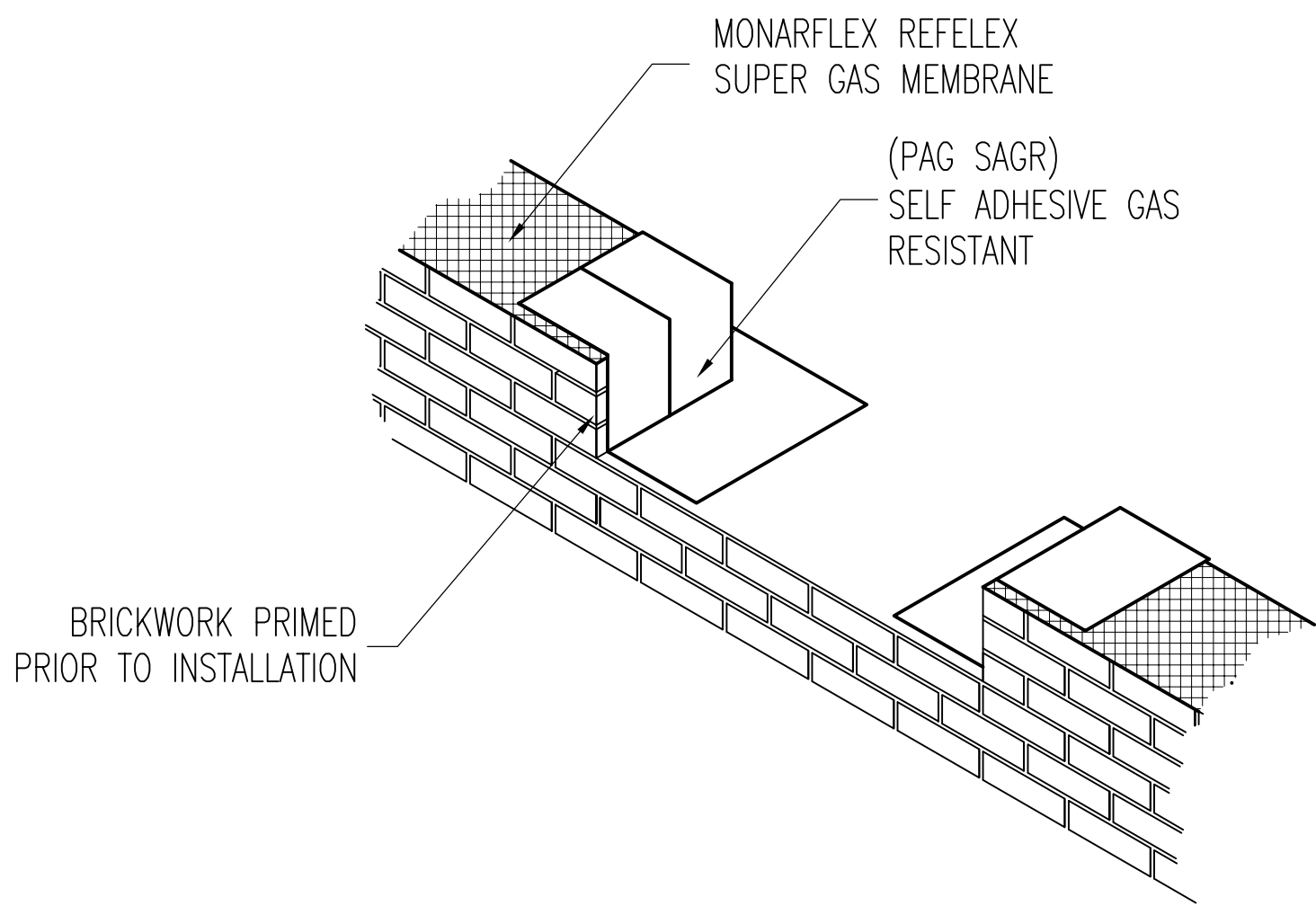
- GENERAL NOTES
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 2. ALL LEVELS ARE IN METRES UNLESS NOTED OTHERWISE.
 3. ALL LEVELS RELATE TO ORDNANCE DATUM UNLESS NOTED OTHERWISE.
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NOTE:
ALLOWANCE SHOULD BE MADE TO REMOVE UP TO 1M OF SOFT LANDSCAPING WITHIN GARDEN AREAS AND REPLACE WITH 1M OF CLEAN INERT MATERIAL WHICH WILL INCLUDE MINIMUM OF 200mm TOPSOIL. POS TO BE 600mm INERT MATERIAL, 200mm TOPSOIL

KEY:-

RED = PROPOSED GROUND LEVEL
BLUE = EXISTING GROUND LEVEL
GREEN = FORMATION LEVEL EXCAVATION
DASHED CYAN = PAG BIOLINER SEPARATION LAYER

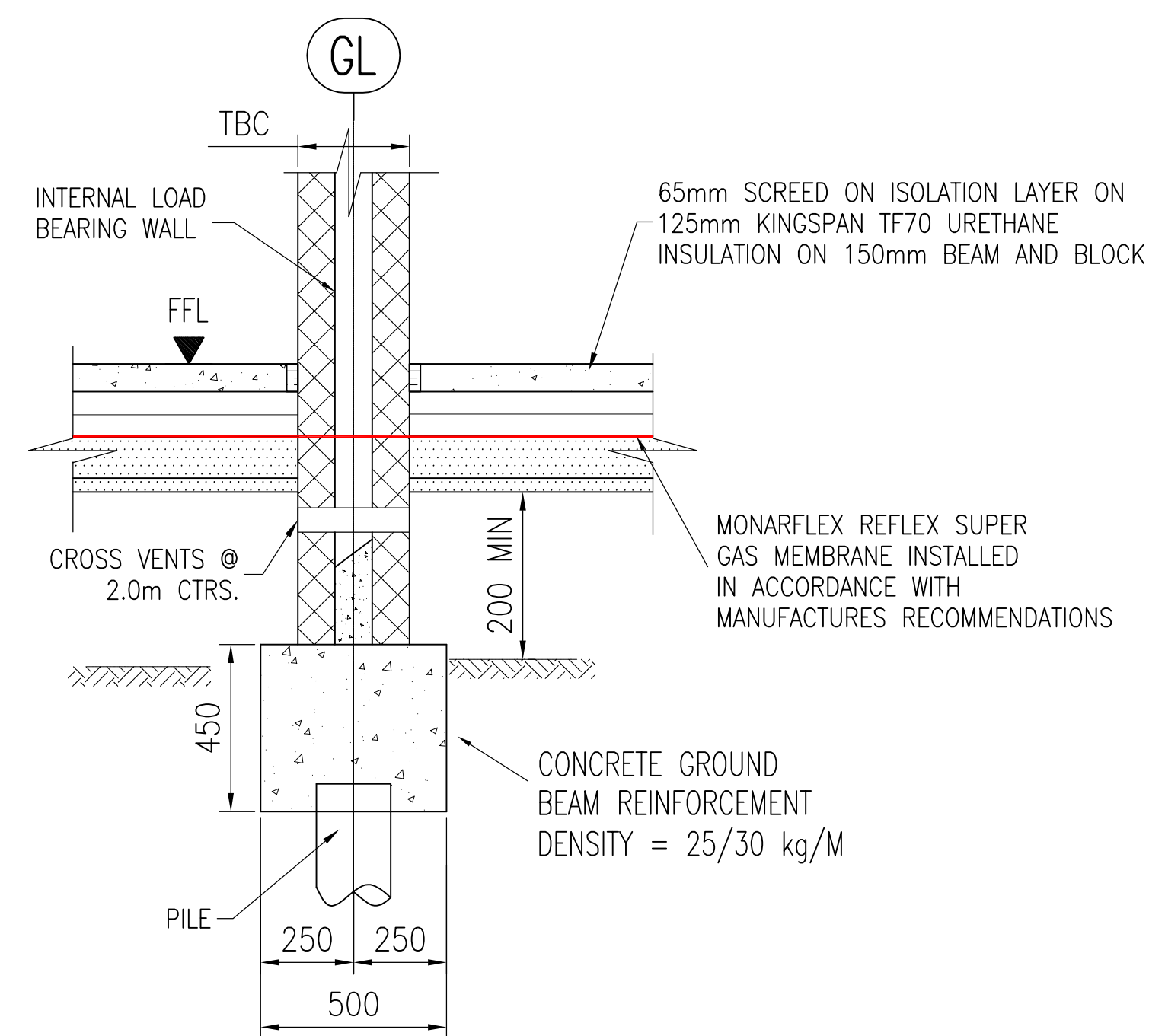
Rv	Date	By	Ch	Revisions	Client		Project				Drawing Title			
					PENNAF HOUSING		RESIDENTIAL DEVELOPMENT GLAN GORS WREXHAM				RESIDENTIAL GARDEN CAPPING SECTIONS			
Drawing Status					TENDER ISSUE		Scale	Date	Design By	Drawn By	Checked	Job No.	Drawing No.	Rev.
							AS SHOWN	26.11.13	NL	SO	NL	6503	008	
Bay Associates Civil + Structural Engineers 21/22 Neptune Court, Vanguard Way, Cardiff, CF24 5PJ					  									
t:029 2045 1011 f:029 2037 4690 e:boy@bayassociates.co.uk w:www.bayassociates.co.uk										CARDIFF ☒ REDDITCH ☐ LONDON ☐				



(N.T.S)

(N.T.S)

(N.T.S)



(N.T.S)

(N.T.C)

Rv	Date	By	Ch	Revisions	Client	Project	Drawing Title
					PENNAF HOUSING	RESIDENTIAL DEVELOPMENT GLAN GORS WREXHAM	GAS MEMBRANE DETAILS
					Drawing Status TENDER ISSUE	Scale AS SHOWN	Date 26.11.13
						Design By NL	Drawn By SO
						Checked NL	Job No. 6503
							Drawing No. 011
					Rev.		
					Bay Associates Civil + Structural Engineers 21/22 Neptune Court, Vanguard Way, Cardiff, CF24 5PJ t:029 2045 1011 f:029 2037 4690 e:bay@bayassociates.co.uk www.bayassociates.co.uk		
					 ice Construction & Design  UKCA  BSI CARDIFF ☒ REDDITCH ☐ LONDON ☐ 		

Notes:

0mm

50mm

A1

original sheet size

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KEY

FOOT PATHS = 860mm HARD CAPPING

CARRIAGEWAY = 950mm HARD CAPPING

BUILDING FOOTPRINT = 790mm HARD CAPPING

DRIVEWAY/PARKING BAYS = 850mm HARD CAPPING

LANDSCAPING = 600mm SOFT CAPPING

GARDEN SPACES = 1000mm SOFT CAPPING

GARDEN PATHS = 210mm SOFT CAPPING

NOTE:--

REFER TO REMEDIATION STRATEGY FOR DETAILS OF HARD CAPPING

Rv Date By Ch Revisions - - - - -	Client PENNAF HOUSING	Project RESIDENTIAL DEVELOPMENT GLAN GORS WREXHAM	Drawing Title CAPPING PLAN					
Drawing Status TENDER ISSUE	Scale 1:200@A1	Date 06.12.13	Design By NL	Drawn By SO	Checked NL	Job No. 6503	Drawing No. 122	Rev. /
Bay Associates Civil + Structural Engineers 21/22 Neptune Court, Vanguard Way, Cardiff, C F 2 4 5 P J		ice Cardiff REDDITCH LONDON		BAY CIVIL + STRUCTURAL				
t:029 2045 1011 f:029 2037 4690 e:bay@bayassociates.co.uk w:www.bayassociates.co.uk								