



Groundwater Monitoring Plan

Date: March 2016

Preston New Road Groundwater Monitoring Plan				
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Reviewer:	Environmental Compliance Advisor, Hydrogeological Consultant		Date of Issue:	March 2016
Author:	Environmental Engineer			
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0.1	All	Draft text	June 2015	Environmental Engineer
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1.0	All	Submission to Environment Agency	June 2015	Environmental Engineer
1.1	All	Updated text and diagram 4, new text page 3.	September 2015	Environmental Engineer
1.2	All	Updated text and to CMT	September 2015	Environmental Engineer
2.0	All	Finalised text	September 2015	Environmental Engineer
3.0	All	Published text	March 2015	HSE Manager

1.0 Purpose

The Groundwater Monitoring Plan (GWMP) details the necessary requirements to enable Environment Agency approval for pre-operational measure PO4 in table S1.3 Permit EPR/AB3101MW. The document will be submitted to the Environment Agency and remain live for the duration of the exploration project and as a permit holder.

2.0 Scope

The GWMP includes the following sections:

1. Monitoring objectives;
2. Groundwater conceptual model & risk assessment;
3. Borehole location;
4. Borehole design and construction method;
5. Monitoring parameters and frequency: and
6. Reporting

3.0 Monitoring Objectives

As part of the permitting and planning application Cuadrilla committed to monitor groundwater throughout the lifecycle of the operation. The subsequent permitting conditions requires the approval of a GWMP before drilling starts. The following objectives list what the GWMP will achieve during the lifecycle of the operation:

- 1) Provide baseline of natural groundwater conditions prior to operations beginning;
- 2) Support the findings of the hydrogeological risk assessment and conceptual model;
- 3) Compliance with environmental permit conditions, planning conditions and Infrastructure Act 2015;
- 4) Triangulate directional flow of groundwater;
- 5) Monitor groundwater quality and dissolved gases before, during and after operations combining continuous and variable spot sampling;
- 6) Where possible screening and analysing key determinands at site supported with laboratory analysis; and
- 7) Documenting and reporting results.

To support Cuadrilla, an independent contractor will sample groundwater routinely. The independent contractor will be a member of a professional body with relevant competency and experience to carry out the sampling in accordance with best practice and ISO/ British Standards. Analysis will be carried out by independent UKAS/MCERTS accredited laboratories.

4.0 Conceptual Model & Risk Assessment

The conceptual model, (Preston New Road Environmental Statement, Arup 2014) assesses potential sources, pathways and receptors identifying credible migration pathways of containments to groundwater and surface water receptors. The conclusion from the Environment Statement for the potential impact on groundwater from site activities was low (not significant). Further assessment of gases flowing from below the Manchester Marl due to hydraulic fracturing of migrating to groundwater is assessed as not plausible. Table 1 provides an extract of the risk assessment within Chapter 11 of the Environmental Statement.

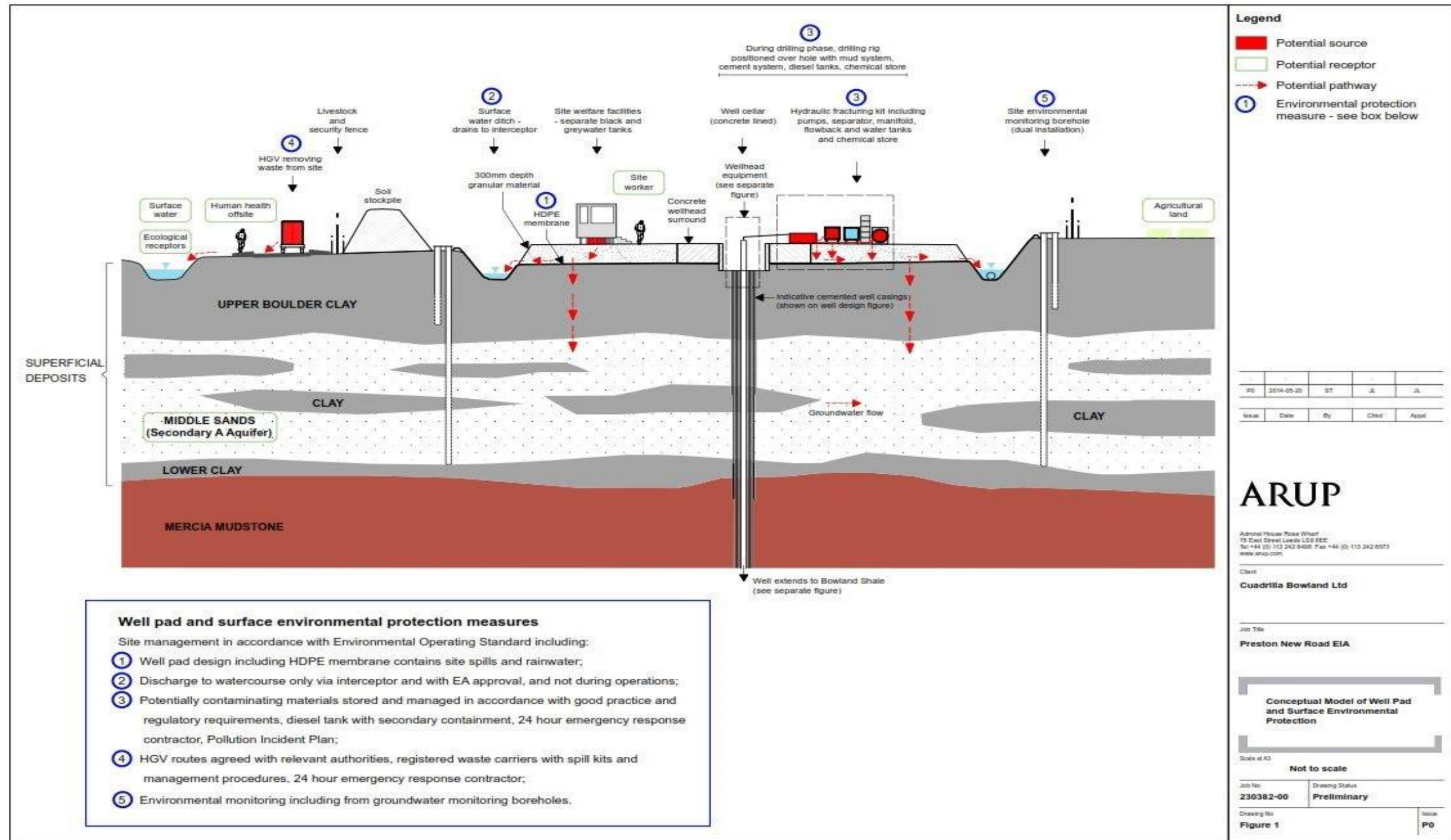


Table 1: Hydrogeology and ground gas assessment summary (Preston New Road Environment Statement, Arup 2014)

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
Project activity - Construction of well pad and access										
Sediment in rainfall runoff during earthworks	→	Overland flow	→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology	Low	Low	Low. Not significant.	None in addition to embedded mitigation – See section 5.0	Low. Not significant.	Not applicable (N/A)
Diesel or lubricants spilled from vehicles and plant during construction of pad or access	→	Seepage into the ground or overland flow	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Watercourses (Carr Bridge Brook and tributary), ponds and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Off-site human health (contact with contaminated surface water or soil)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Project activity - Drilling										
Pad and surface activities (during drilling)										
Spillage of fluids on the well pad due to failure of equipment or infrastructure, vehicle collision, or site operative error	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
				Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
→			Off-site human health (contact with contaminated water)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A	
Fire fighting foam or water	→	Vertical downwards migration through a defect in the membrane or well cellar	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow onto adjacent ground and infiltration	→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
				Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Collection in site drainage system and overflow into watercourse	→	Watercourses (Carr Bridge Brook and tributary) and any supported ecology	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
→			Off-site human health (contact with contaminated water)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A	
Failure of equipment causes release of fluid at high pressure	→	Liquid spray off site through the Site boundary fence	→	Crops and livestock	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A

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Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
			→	Off-site human health (a person standing outside the Site boundary fence)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Off site road traffic accident resulting in spill of potentially contaminating materials	→	Spill of contents of vehicle in transit onto public highway	→	Off-site human health (exposure to spilled material)	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Water environment along transit route	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Well construction and integrity (during drilling)										
Drilling fluids	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Naturally poor quality groundwater	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases from below the Manchester Marls	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater for use within a confined space	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
	→	Loss of well integrity resulting in gas migration to shallow soils followed by entry into buildings (or other confined spaces) on or off site.	→	On-site human health (site workers and visitors)	No plausible linkage					
			→	Off-site human health (users of off-site confined spaces)	No plausible linkage					
Project activity - Hydraulic fracturing										
Pad and surface activities (see ‘Pad and surface risks during drilling’ identified above)										
Well integrity (during fracturing)										
Hydraulic fracturing fluid	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Flowback fluid Naturally poor quality groundwater (from below the Manchester Marls)	→	Loss of well integrity caused by hydraulic fracturing resulting in release from the well	→	Sherwood Sandstone groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to induced seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases from below the Manchester Marls and dissolved in flowback fluidwell pad	→	Loss of well integrity resulting in gas migration to shallow groundwater and abstraction of groundwater for use within a confined space	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					

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Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
	→	Loss of well integrity resulting in gas migration to shallow soils followed by vertical migration into buildings (or other confined spaces) on or off site.	→	On-site human health (site workers and visitors)	No plausible linkage					
				Off-site human health (users of off-site confined spaces)	No plausible linkage					
Induced fractures										
Hydraulic fracture fluid Naturally poor quality groundwater (from the Bowland Shale)	→	Fractures propagating beyond the target zone which then connect to preferential flowpaths (natural discontinuities or deep boreholes)	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Hazardous ground gases (from below the Bowland Shale)	→	Gas migration along induced fractures, natural fissures and faults to shallow groundwater and abstraction of groundwater for use within a confined space.	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					
	→	Gas migration along induced fractures, natural fissures and faults to shallow soils and above ground confined spaces on-site or off-site	→	On-site human health (site workers and visitors)	No plausible linkage					
			→	Off-site human health (users of off-site confined spaces)	No plausible linkage					
Residual fracturing fluid in Bowland Shale	→	Groundwater flow, including diffusion, through bedrock	→	Sherwood Sandstone groundwater	No plausible linkage					
			→	Middle Sands groundwater						
Project activity - Initial and extended flow testing										
There are no additional S-P-R linkages in the initial and extended flow testing stage to those identified above.										
Project activity - Decommissioning and restoration										
(Only additional S-P-R linkages to those identified above presented below)										
Hydraulic fracturing fluid Naturally poor quality groundwater (from below the Manchester Marls)	→	Loss of well integrity due to poor well construction resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to natural seismicity resulting in release from the well	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
	→	Loss of well integrity due to long term well degradation	→	Sherwood Sandstone groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
			→	Middle Sands groundwater	Very Low	Low	Low. Not significant.	As above	Low. Not significant.	N/A
Ground gas (from below the Manchester Marls)	→	Loss of well integrity due to long term well degradation resulting in: migration to shallow groundwater and	→	Off-site human health (users of groundwater abstractions)	No plausible linkage					

Source		Pathway		Receptor	Probability	Consequence	Risk magnitude or significance	Additional mitigation	Residual effect/ risk magnitude	Offsetting and enhancement
		abstraction of groundwater for use within a confined space; or migration into buildings or other confined spaces.	→	Off-site human health (users of off-site other enclosed spaces)		No plausible linkage				

5.0 Embedded Mitigation

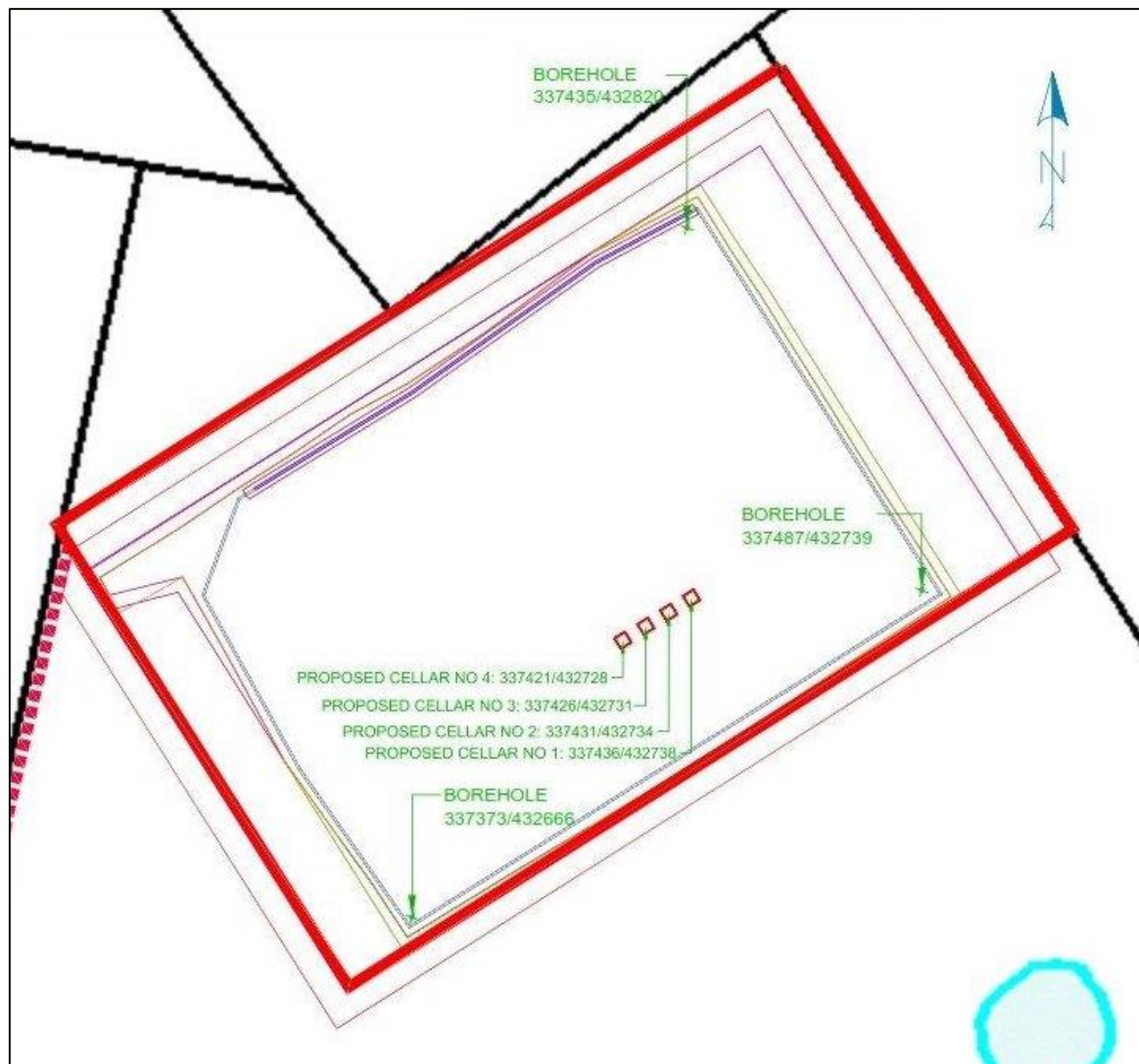
Pressure testing, formation integrity testing (FIT), and/ or wireline logging (such as cement bond logs “CBL”) will be used to confirm cementation integrity, or identify anomalies from drilling muds if present, to verify that the integrity of the well system. A report will be submitted to the Environment Agency consistent with pre operational measure PO5 and PO6.

Throughout the life of the well, the three annuli A, B and C are monitored using a digital gauge or equivalent method to download readings on annuli pressure. The frequency of monitoring will be dictated by the data being downloaded ranging from potentially daily to quarterly downloads.

6.0 Borehole Location

Borehole locations will be located as per indicative drawing 1 along the site perimeter fence line consistent with the planning application, LCC/2014/0097. There is provision to increase the number of boreholes at the site if requested by the Environment Agency. The 3 dual sampling boreholes will triangulate the groundwater flow by measuring the hydraulic gradient from the three dual wells.

Drawing 1: Preston New Road Borehole Locations



7.0 Borehole Design & Construction Method

The design of the proposed 3 monitoring boreholes is in accordance with relevant guidance and standards including Environment Agency Guidance (Environment Agency, 2006), BSI standards (BS 8576: 2013) and relevant publications; Clarke L, 1988. In addition, previous knowledge gained by installing groundwater monitoring boreholes at other operational sites, such as Preese Hall, Anna's Road, Beconsall and Grange Hill have contributed to the design of the borehole.

There are two different designs being proposed, the first is a nested borehole and a second option is to utilise the discrete zone CMT multilevel system.

Both groundwater monitoring borehole options will target two discrete horizons; shallow Glacial Till (Upper Bolder Clay) ~0.6m to 7.5m below ground level and deeper Middle Sands estimate to be approximately ~16m to 30m below ground level). The nested borehole installation in a single borehole is illustrated in Diagram 2, 3 and 4. The CMT option is illustrated in Diagram 5 and 6. The depths and locations are based on the site conceptual model from Diagram 1 and the site condition report (HSE-Permit-INS-PNR-003) which provides a geological context for the site. Due to the expected high water table experienced from previous sites the GasClam®, in order to operate correctly, will be installed above the surface in a specialist designed steel casing headwork's as illustrated in Diagram 3, 4 (nested option) and 6 (CMT option).

7.1 Nested Borehole

Each borehole will operate a GasClam® to continually monitoring methane and carbon dioxide levels, as well as providing groundwater temperature, atmospheric and borehole pressure and a groundwater level logger. A standard diameter of ~50mm uPVC or HDPE standpipe has been selected to account for the GasClam® installation as well as being able to access groundwater to undertake dissolved ground gas sampling and groundwater quality monitoring.

Selection of materials is based on the monitoring objectives and longevity of the borehole installation. Either a uPVC or HDPE standpipe is the preferred option accounting for the monitoring parameters of hydrocarbons, metals and salts. Selection of other materials including bentonite pellets and sand bridges have been made in accordance with guidance and standards.

Material selection within response zone is designed to ensure the material does not react with the groundwater and provides an inert environment. Details of the filter pack are shown in the design drawing "greater than 95 per cent silica or preferably 99 per cent silica". Based on the particle size of the Middle Sands; range of 187µm to 500µm, a screen slot size of 1mm has been designed and 0.7mm for the Glacial Till to prevent 90% of the filter pack material entering the monitoring borehole. Lubricants used during drilling of the monitoring wells wherever possible be inert or non-contaminative, such as vegetable oil, to reduce the possible effects on the groundwater quality.

Diagram 2: Dual Installation Design of Groundwater Boreholes

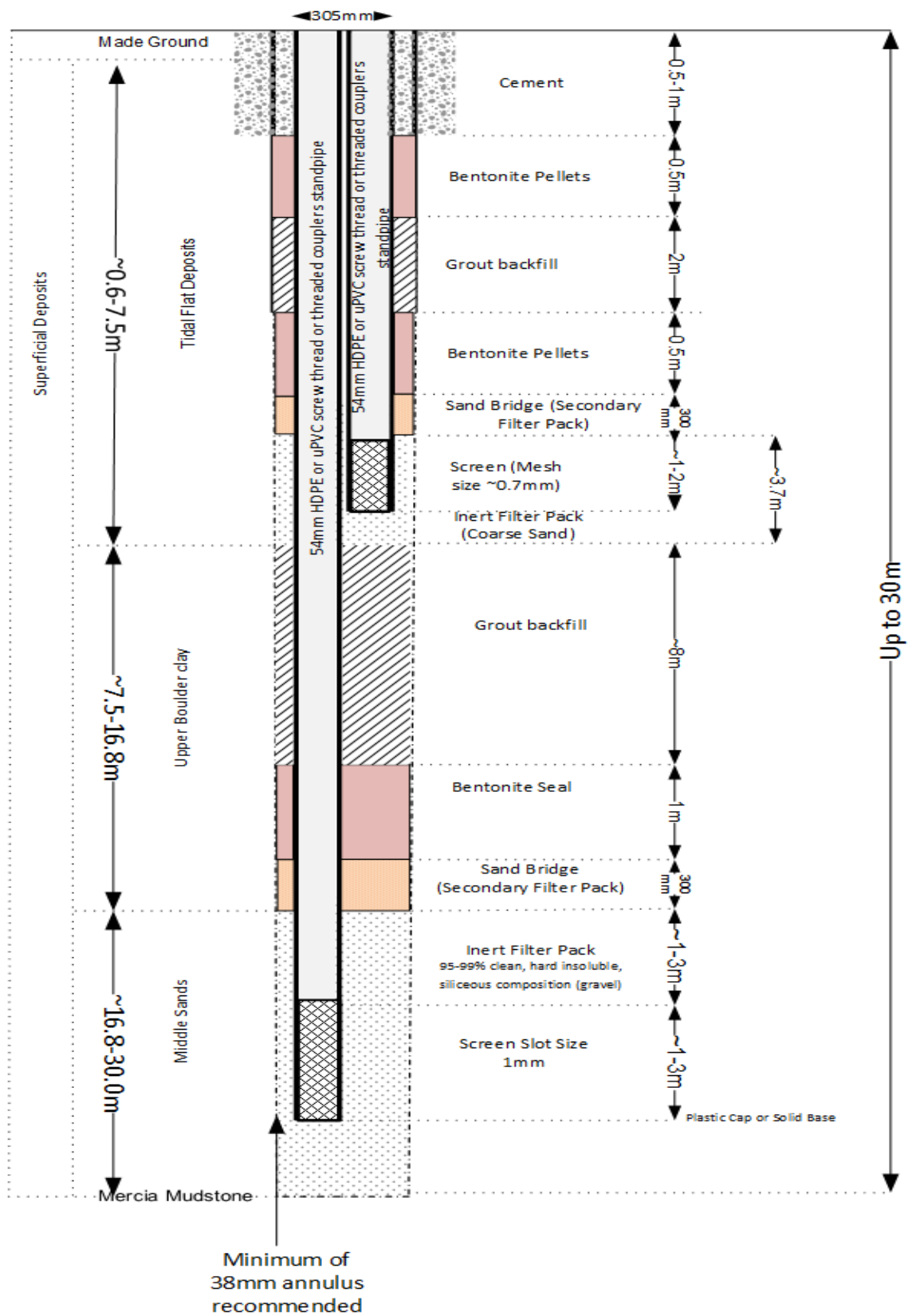


Diagram 3: Headwork's of Dual Installation Borehole

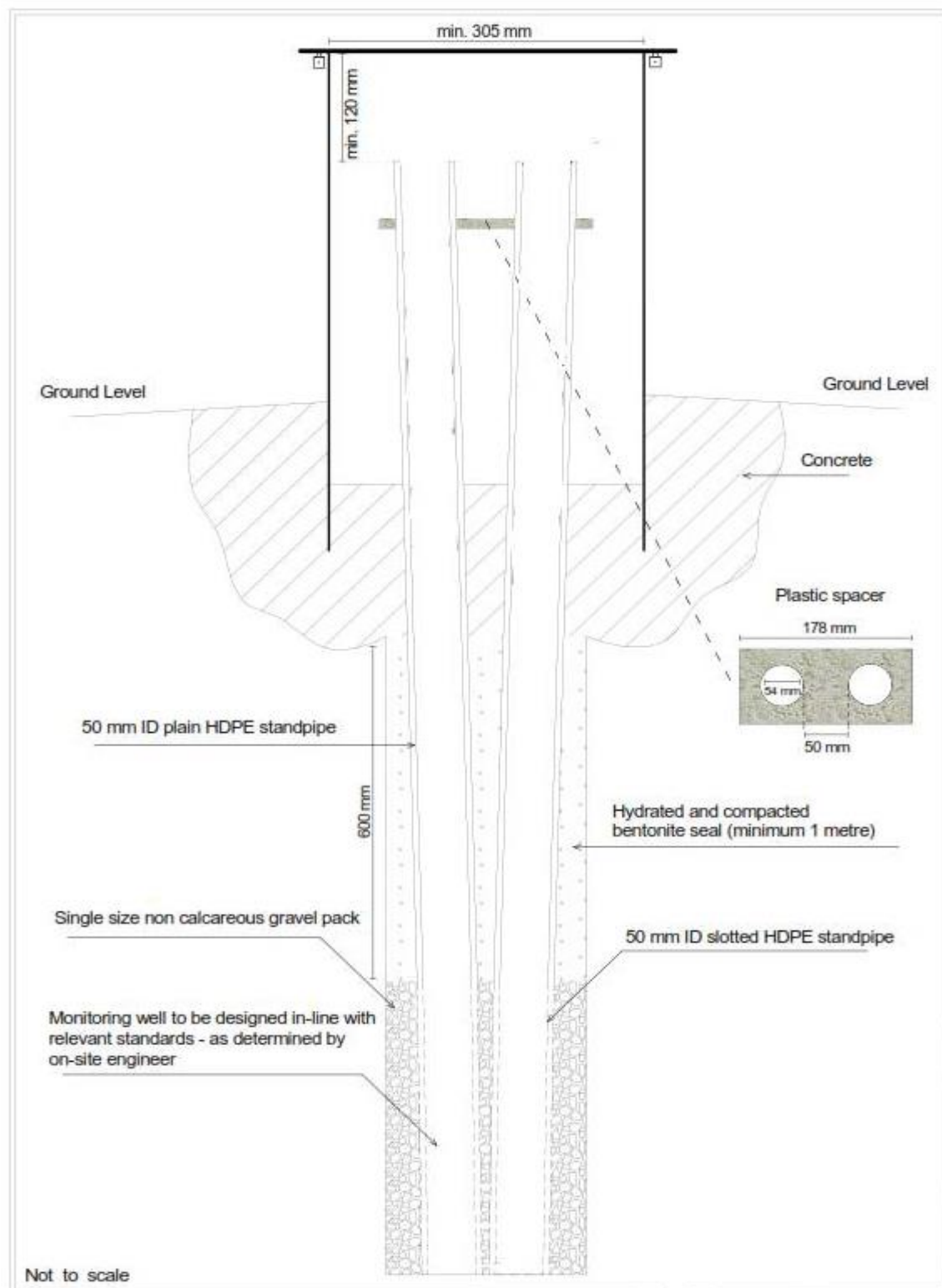
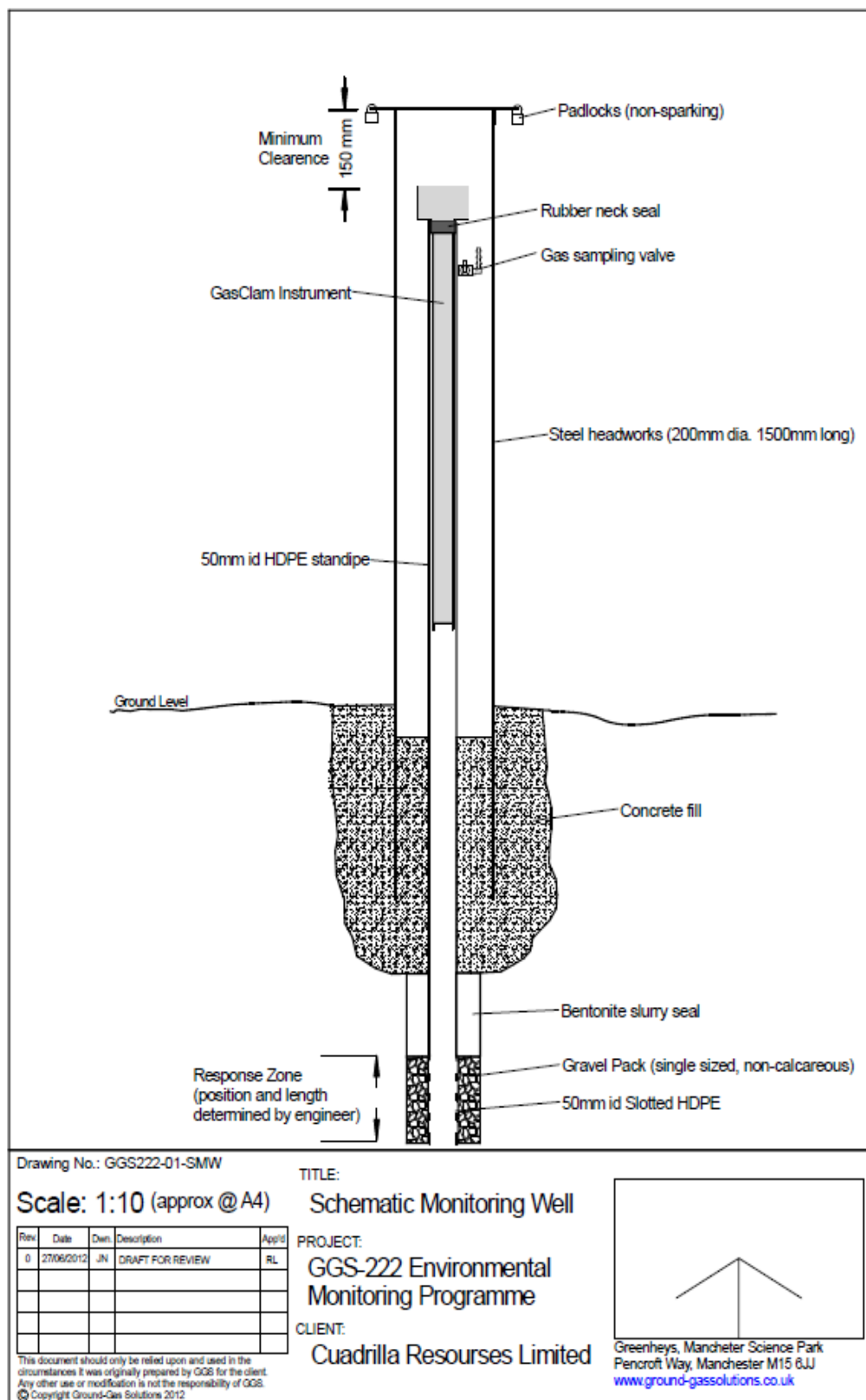


Diagram 4: Example of a GasClam within the Headwork's*



*This drawing is representative of how the GasClam is installed within a 50mm standpipe. This would simply be duplicated in the dual installation borehole as per diagram 3.

The gravel filter pack will cover the top of the screen slots between 1000 and 1500mm to allow for settlement, however the design drawing indicates a wider area to accommodate potential variation during construction of the borehole.

7.2 CMT Multilevel

The Solinst CMT Multilevel discrete well system provides the best available approach to monitoring multiple discrete zones within the target groundwater zone formation without the need to drill multiple boreholes. Photo 1 provides an illustration from RS Hydro website of how the multilevel system splits into intervals targeting discrete zones. A hyperlink to the pdf installation manual accompanies this plan within Appendix A.

Each borehole, similar to the nested borehole will have a GasClam® installed within the headworks to continually monitoring methane and carbon dioxide levels, as well as providing temperature, atmospheric and borehole pressure. A groundwater level logger shall also be installed at the site.



The materials selection and construction installation of the CMT system is the same as the nested borehole apart from replacing the 50mm HDPE standpipe with the CMT multilevel system.

The multi-level system main advantage in comparison to the nested borehole is that it can target several depths of the groundwater bearing unit, providing a larger source of data e.g. stratification of water quality.

The headworks has been designed to accommodate the installation of the GasClam® and the CMT system. To gain access to the surface of the CMT system the steal headworks and a 50mm standpipe accommodating the GasClam® will split into two parts once the GasClam® has been removed.

The sequencing of monitoring will follow a set process;

1. Monitor the headspace first;
2. Data download from the GasClam®; and
3. Groundwater quality parameters

Diagram 6 provides a drawing of the arrangements for accessing the CMT pipe.

7.3 GasClam® Monitoring using CMT

The ability to monitor multiple discrete zones with a single GasClam® at the surface will not be able to identify the source of gas. The intention of the GasClam is to screen for changes in ground gases on a continually basis. In the unlikely event a significant variation in the baseline data is identified each discrete zone will be sampled for dissolved ground gases for offsite laboratory analysis. This shall be conducted in accordance with section 8.4. The sampling will indicate the origin of the dissolved ground gas.

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Diagram 5 CMT Multilevel System targeting 5 discrete zones.

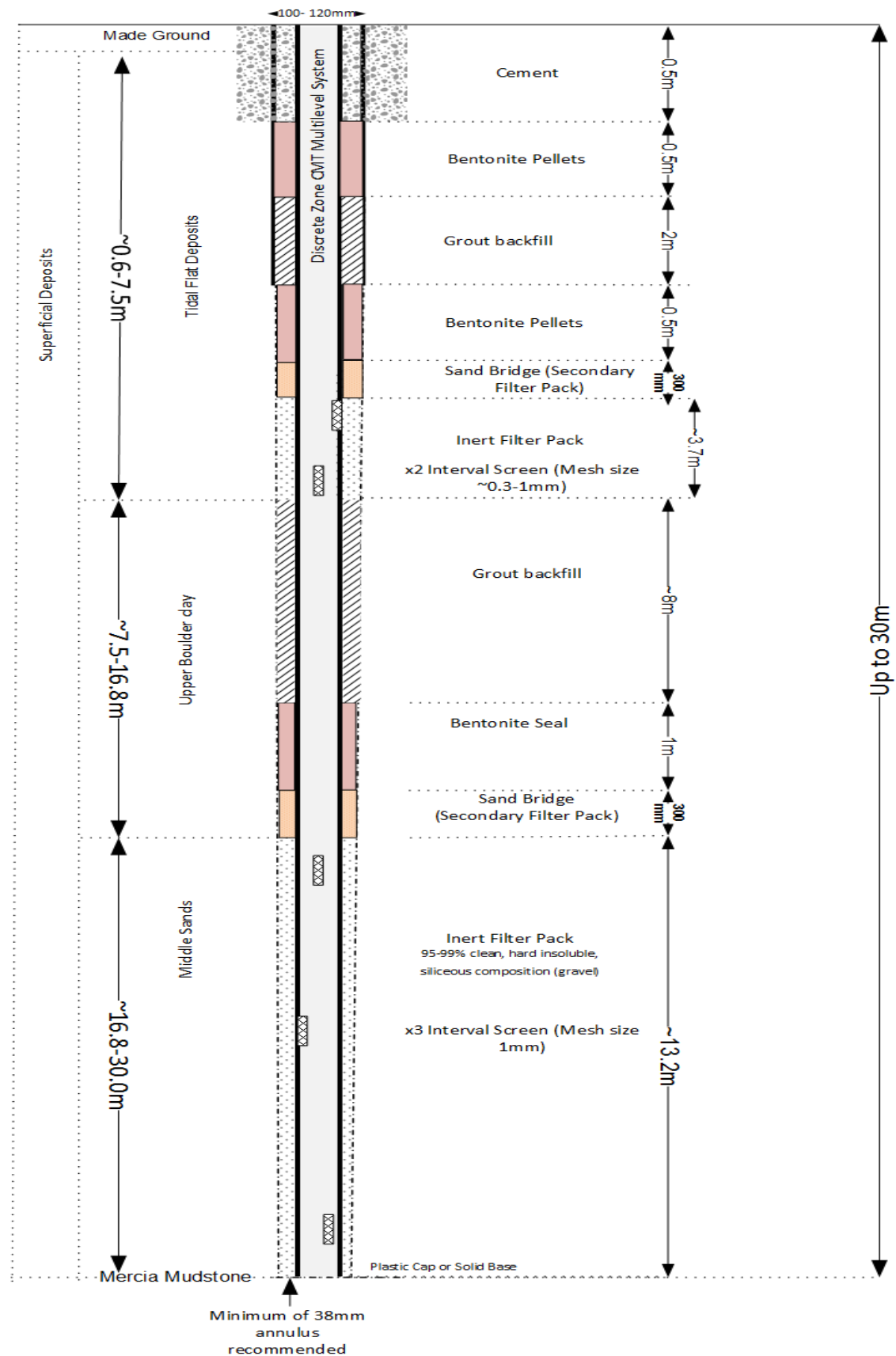
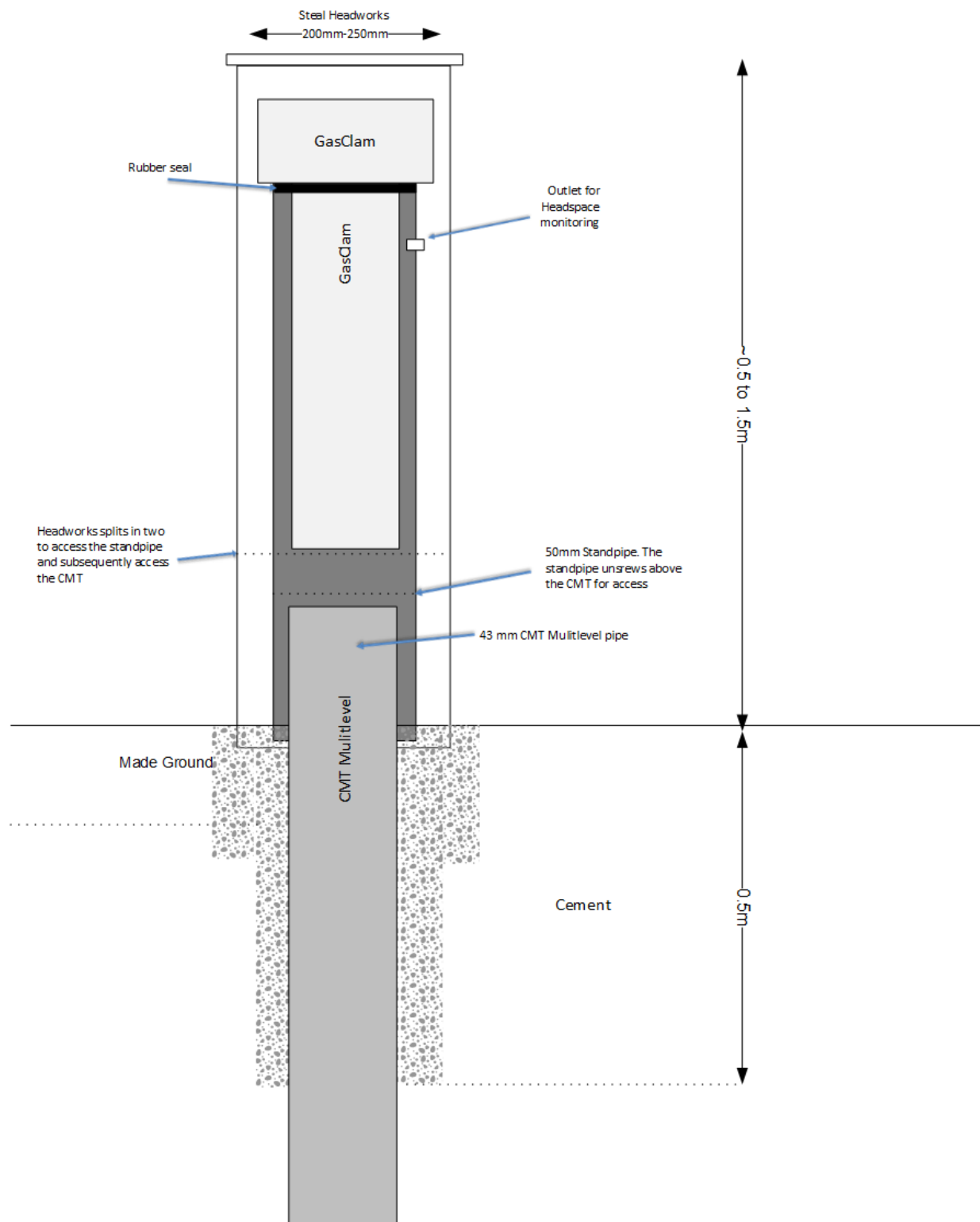


Diagram 6 CMT Multilevel Headworks



7.4 Construction Method

The construction method for either proposed borehole options is a cable percussive method. The rig is equipped with a winch, which is driven by a diesel engine, and a tripod derrick of about 7m height. The derrick folds down so that the rig can be towed by a four-wheel drive vehicle. Cable percussive rigs are equipped with in-situ sampling equipment to establish and log the boreholes. The soil and arising extracted from the borehole will be sampled at the surface. The Preese Hall groundwater monitoring wells utilised cable percussive technique. The option has been chosen as the preferred choice in accordance with BS 5667-22-2010 through very soft to firm to fine soils. The construction method will avoid, where possible, the use of drilling fluids to prevent cross contamination of the unsaturated zone. If drilling fluid is to be used then Cuadrilla will notify the Environment Agency before use. Once a drilling contractor is selected Cuadrilla will notify the Environment Agency, including a date of when the drilling will commence. The drilling technique will also be documented within the groundwater borehole installation report as required by pre-operational measure PO7.

The drilling contractor shall provide the necessary spill kits for the operation, store chemicals and liquids in accordance with Pollution Prevention Guidance (PPG 1 and PPG6) and manage waste in accordance with the planning condition and waste regulations. The mixing of bentonite/grout or cement will also be managed on an impermeable membrane. The drilling contractor shall submit a method statement to Cuadrilla for approval before operations start detailing how they will comply with planning conditions and general industry best practice.

The construction of the boreholes strata encountered will be recorded in accordance with the relevant BS EN ISO 14688-1, BS EN ISO 14688-2 and BS EN ISO 14689-1. The descriptions of the strata encountered will include reference to the presence of any biodegradable material or other material that might give rise to gas, including the proportion of such material when this is practicable. If the method of installation does not allow the strata to be recorded, the ground conditions around the response zone should be inferred from other nearby investigation points, such as other boreholes from Anna's Road. Each well will be logged and recorded to demonstrate that the site conceptual model is consistent with the boreholes. The records will form part of the report in accordance with pre-operational measure PO7.

The position of each of the boreholes will be surveyed to National Grid and the ground level will be determined to Ordnance Survey Datum to allow the groundwater elevation to be calculated and hence groundwater flow gradient to be estimated.

8.0 Monitoring Parameters

A combination of ground gas and groundwater quality will be monitored at each borehole. Surface watercourses will also be monitored at the same time as groundwater throughout the lifecycle of the operation. Please review Preston New Road Waste Management Plan for further details regarding surface water sampling. Monitoring will occur prior to construction (baseline monitoring) in accordance with pre-operational measure PO8, during the well pad construction and well drilling, fracturing and flow testing, and decommissioning (well abandonment and site restoration) stages.

Sampling of the unsaturated zone will be conducted during borehole installation. In upper sections e.g. superficial deposits, a cable percussion technique can be driven into the upper layers with hollow tools. The hollow tools retain the soils and rocks within an inner cylinder and return the rock/soils to the surface. The soils will be logged in accordance with BS 5930: 1999 and sent off site for chemical analysis.

8.1 GasClam

Cuadrilla's monitoring contractor will install both a GasClam® and a water quality down-hole probe into the monitoring well. The purpose of the GasClam® is to monitor methane, carbon dioxide and

oxygen concentrations within the Middle Sands and Glacial Till. In addition to the gases other parameters will be monitored: groundwater level, pressure and temperature. The GasClam® will be set to record at intervals (range 1minute to 1 hour) and subject to monthly maintenance visits to change moisture filter, batteries and conduct bump tests (site calibration). Records of the GasClam® maintenance will be documented per visit and downloaded data reported as part of the quarterly permit reporting requirements.

8.2 Ground Gas Sampling

The presence of methane alone does not provide evidence of its source. It is therefore necessary to carry out a suitable level of gas-sampling and laboratory analysis to fully characterise the provenance of any methane or associated gases identified.

The following gas sampling and testing approaches shall be adopted to provide a baseline dataset. Additional testing may be required dependent on findings.

8.3 Headspace Sampling

Gas samples will be taken from each borehole and scheduled for laboratory analysis for presence and concentration of selected bulk gases and trace compounds. Sampling of boreholes headspace will confirm the accuracy of the GasClam® and also eliminate potential stratification of gas within the borehole. This will be achieved by circulating the gas around the headspace before sampling.

Gas sampling methods will typically comprise the use of Tedlar bags and/or Gresham tubes. Samples of the headspace will be taken on a quarterly basis or more frequently if there is significant difference in accuracy of the GasClam® detection.

Where sufficient concentrations of methane and/or carbon dioxide are detected, these will be scheduled for C12/C13 isotopic analysis to provide evidence of the gases' age and provenance.

8.4 Dissolved Gas & Groundwater Quality Sampling

Further groundwater sampling will be undertaken to monitor the quality of groundwater and dissolved ground gas monitoring as per pre-operational measure (PO8). Water sampling of the boreholes will use a bladder pump system or equivalent (peristaltic pump, micro double valve pump,) depending on the design in order to reduce the chance of 'de-gassing' of the water sample. As a minimum six sample rounds (1 round of sampling will equal 6 samples: 3 site dual boreholes x 2 nested boreholes) or six sample rounds from the discrete locations (x3 boreholes, x6 discrete zones) will be taken before drilling to establish a baseline and further sampling will continue at frequencies outlined in Table 3 Column 3.

As part of the water quality monitoring a number of parameters will be collected at site during purging. The parameters; pH, electrical conductivity, temperature and dissolved oxygen are collected for 3- 5minute intervals until stabilised. The stabilisation of these measures will indicate when a groundwater sample can be taken. The quantity of purging of the borehole shall follow the requirements established in BS ISO 5667-18:2001 e.g. 3 times the borehole volume but subject to the site requirements.

The targets used to determine stabilisation are presented in Table 2 and are based on the US EPA methodology (Puls, 1996).

Table 2: In situ groundwater stabilisation criteria

Parameter	Stabilisation Target
Dissolved Oxygen	+/- 10%
Eh	+/- 10mV
pH	+/- 0.1 [pH units]
Electrical Conductivity	+/- 3%

Each sampling technique shall be taken in accordance with BS ISO 5667-11:2009 with records of the site sample and chain of custody for the transfer of the sample being documented.

8.5 Monitoring Frequency

The proposed monitoring frequency is designed to provide a robust assessment of continuous and judgemental sampling based on the risk assessment.

The utilisation of the GasClam® continuous monitoring provides a screen complimenting laboratory analysis for dissolved gases and groundwater quality as described in section 7.0.

Table 3 outlines the frequency of monitoring for the different phases of operations.

Table 3: Preston New Road Groundwater Monitoring Frequency

Phase	GasClam	Judgemental Dissolved Gas and Water Quality	Justification
Baseline	Continuous	Monthly*	Site condition report HSE-Permit-INS-PNR-003) did not identify potential sources of contaminants which could impact groundwater e.g. landfill. The site is based on an agricultural setting. Limited activity from site operations.
Site Construction	Continuous	Monthly	Continuation of monthly monitoring during site construction. No drilling into the groundwater bearing zones will take place.
Drilling	Continuous	Weekly	Weekly during drilling and then extending to monthly once the upper sections of Sherwood sandstone is cased off.
Hydraulic Fracturing	Continuous	Weekly	Well is cased off, stimulation of hydrocarbon bearing zone at depth. Increased monitoring as a precautionary approach.
Initial Well Testing	Continuous	Monthly	Well is cased off, continue surveillance monitoring of the groundwater based on the risk assessment
Extended Well Testing	Continuous	Monthly	Well is cased off, continue surveillance monitoring of the groundwater based on the risk assessment
Plug and Abandonment	Continuous	Monthly	Well is plugged and abandoned with no migration pathway.
Post Abandonment	Continuous	Monthly - Quarterly**	Subject to change once the site history has been reviewed.

**Depending on the consistency with the site conceptual model a total of 3 monthly baseline samples are to be taken prior to the commencement of drilling of the injection wells (Pre-operational condition 8).*

*** This monitoring frequency is provisional and will be subject to the prevailing regulatory conditions at the time. The duration and frequency of the Post Abandonment monitoring will be agreed with the regulator prior to abandonment, based on the findings of the preceding monitoring programme.*

The total duration of sampling before hydraulic fracturing is subject to the requirements outlined within the Infrastructure Act 2015 and future secondary legislation. Once secondary legislation has been established and transposed into legislation, Cuadrilla will comply with the requirements.

9.0 Reporting

Once the groundwater boreholes have been constructed a report will be submitted to the Environment Agency to meet the requirements of pre-operational measure PO7 detailing the installation of each borehole.

Reporting will continue throughout the lifecycle of the operations to comply with the permit. The parameters outlined in pre-operational measure PO8 will remain consistent throughout the operations and reported to the Environment Agency on a quarterly basis unless agreed in writing with the Environment Agency.

In accordance with schedule 4 of EPR/AB310MW the reporting of groundwater data will be submitted to the Environment Agency on a quarterly basis in Groundwater 1 format unless agreed in writing with the Environment Agency.

10.0 References

Arup; Preston New Road Environment Statement, June 2014

BS ISO 5667-11:2009, Water quality. Sampling. Guidance on sampling of groundwater

BS ISO 5667-18:2001, Water quality. Sampling. Guidance on sampling of groundwater at contaminated sites

BS 5930:1999+A2:2010, Code of practice for site investigations

BS 8576:2013, Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds (VOCs)

BS 10175:2011, Investigation of potentially contaminated sites – Code of practice (+A1:2013)

BS EN ISO 14688-1:2002+A1:2013 Geotechnical investigation and testing. Identification and classification of soil. Identification and description

BS EN ISO 14688-2:2004+A1:2013 Geotechnical investigation and testing. Identification and classification of soil. Principles for a classification

BS EN ISO 14689-1:2003 Geotechnical investigation and testing. Identification and classification of rock. Identification and description

Clarke, L; The Field guide to Water Wells and Boreholes, 1988

Environment Agency; Guidance on the design and installation of groundwater quality monitoring points, 2006

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Appendix A CMT Data Sheet

<http://www.rshydro.co.uk/PDFs/Solinst/403-7channel-Manual.pdf>