

REMEDIATION VERIFICATION REPORT

**FORMER HARES DAIHATSU
STATION ROAD, RUSTINGTON, BN16 3BH**

REC REFERENCE: 1CO100632/P5/R1

**REPORT PREPARED FOR: PEGASUSLIFE
ON BEHALF OF RENAISSANCE GROUP OF COMPANIES**

APRIL 2019



DELIVERING ENVIRONMENTAL AND RISK MANAGEMENT SOLUTIONS



QUALITY ASSURANCE

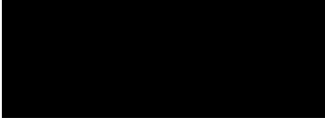
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1.0 INTRODUCTION

1.1 Background

Resource and Environmental Consultants Ltd (REC) have been instructed by PegasusLife on behalf of Renaissance Group of Companies ('the Client') to undertake verification of remedial works undertaken on the site known as the Former Hares Daihatsu, Station Road, Rustington, BN16 3BH ('the site'). A site location plan and pre-development layout plan (ref's 1CO100632-001 & 1CO100632-002 respectively) can be found in Appendix II.

1.2 Summary of Development

The development comprises a low-rise complex of 10no. retirement apartments within one large building, with a car park along the northern perimeter and soft landscaping within other external areas. A pre-existing adjacent building "Mowbray" is being renovated as a standalone property that will be outside of the retirement apartment site. A development plan (ref. 1CO100632-003) is presented within Appendix II.

1.3 Objectives & Scope

REC has previously completed 3no. rounds of ground investigation at this site during 2015 and 2016. Unacceptable hydrocarbon contamination was encountered during the Phase II works and consequently a Detailed Quantitative Risk Assessment (DQRA) was commissioned to characterise the potential hydrocarbon plumes identified. A Remediation Method Statement (RMS) was produced outlining the required remedial methodology. The purpose of this report is to enable sign off of planning condition 10 relating to this scheme to enable occupation. i.e.:

"Prior to occupation of any part of the permitted development, a verification report demonstrating completion of the works set out in the approved remediation strategy and the effectiveness of the remediation shall be submitted to and approved, in writing, by the local planning authority. The report shall include results of sampling and monitoring carried out in accordance with the approved verification plan to demonstrate that the site remediation criteria have been met. It shall also include any plan (a "long-term monitoring and maintenance plan") for longer-term monitoring of pollutant linkages, maintenance and arrangements for contingency action as identified in the verification plan, and for the reporting of this to the local planning authority."

The activities reported herein verify completion of groundwater remediation monitoring which has been ongoing since April 2017. Subject to approval of this report, it is proposed that there is no requirement for further intervention and it is appropriate to revert to the long-term monitoring regime outlined within the RMS.

Validation of soft landscaping areas was completed in April 2019. As such, it is considered that no unacceptable risk to human health is present and the site is suitable for occupation.



1.4 Previous Work

REC has previously undertaken a series of works on the site including the following:

- ❖ 51708p2r1 – Phase I and II Geo-Environmental Investigation Report (April 2016);
- ❖ 51708/1CO100632p3r0 - DQRA for Controlled Waters (April 2016);
- ❖ 1CO100632p3r2 – Remediation Method Statement (March 2017); and
- ❖ Remediation verification works (November 2016 to present).

1.4.1 Site Investigations

Three phases of intrusive ground investigation were completed on the site, in order to assess the extent of contaminants associated with historical use as a vehicle repair garage and petrol filling station, including the presence of underground fuel storage tanks (USTs). The pertinent findings of the investigation are summarised within Section 2.

Exploratory holes are included on the development site plans (ref's 1CO100632-002 & 1CO100632-003) presented within Appendix II and given as Figures 1.1 and 1.2.

Extensive hydrocarbon contamination was encountered in two source areas during the Phase II works (Northern and Southern sources). The site was considered to pose a potential risk to the underlying Principal Aquifer, Source Protection Zone (SPZ) 1 and a potable water abstraction 75m south [REC understand that the abstraction and SPZ are no longer active]. Consequently a Detailed Quantitative Risk Assessment (DQRA) was commissioned to assess the risks.

1.4.2 Detailed Quantitative Risk Assessment

In order to assess the risk of on-site hydrocarbon migration within the Principal Aquifer, REC utilised the Environment Agency's Remedial Targets Methodology (RTM)¹ combined with the physical/chemical characteristics of the contaminants to determine the likely impact to an off-site compliance point.

The DQRA model for Controlled Waters prepared was built upon and extended using the Tier I, 2 and 3 worksheets for soils to back-calculate and derive concentrations for soil. The ultimate aim of the modelling was to derive remedial targets for groundwater and soils which were considered likely to be acceptable for groundwater at the off-site compliance point (located at 50m from the site boundary).

These targets were reviewed and approved by the Environment Agency and local authority prior to finalisation of the Remediation Method Statement (RMS) which was subsequently produced. The remedial target values are reproduced as Appendix III.

¹ Environment Agency, January, 2013 'Hydrogeological Risk Assessment for Land Contamination Remedial Targets Worksheet, Release 3.2



Figure 1.1 Pre-Development Site Plan with Exploratory Hole Locations

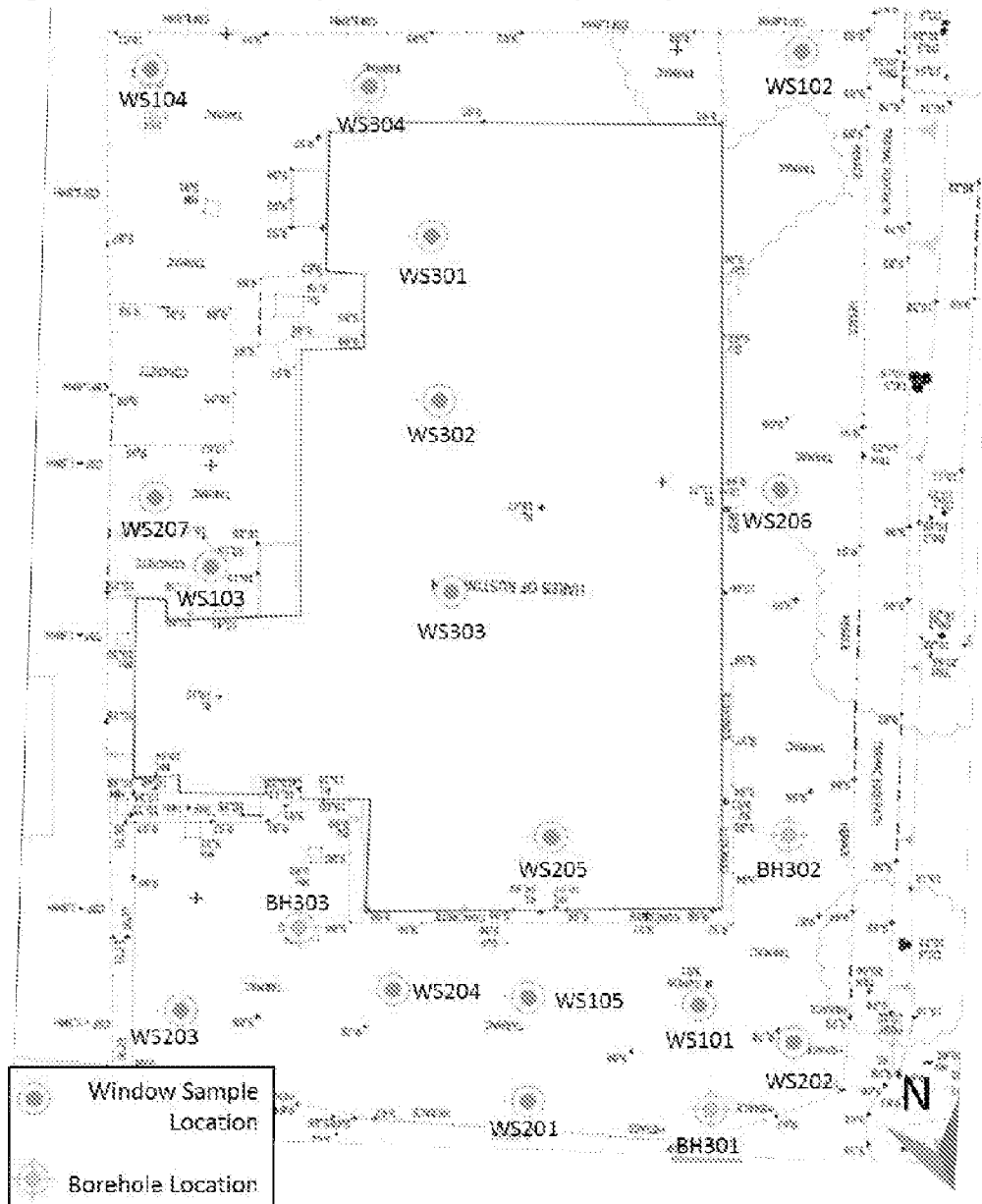
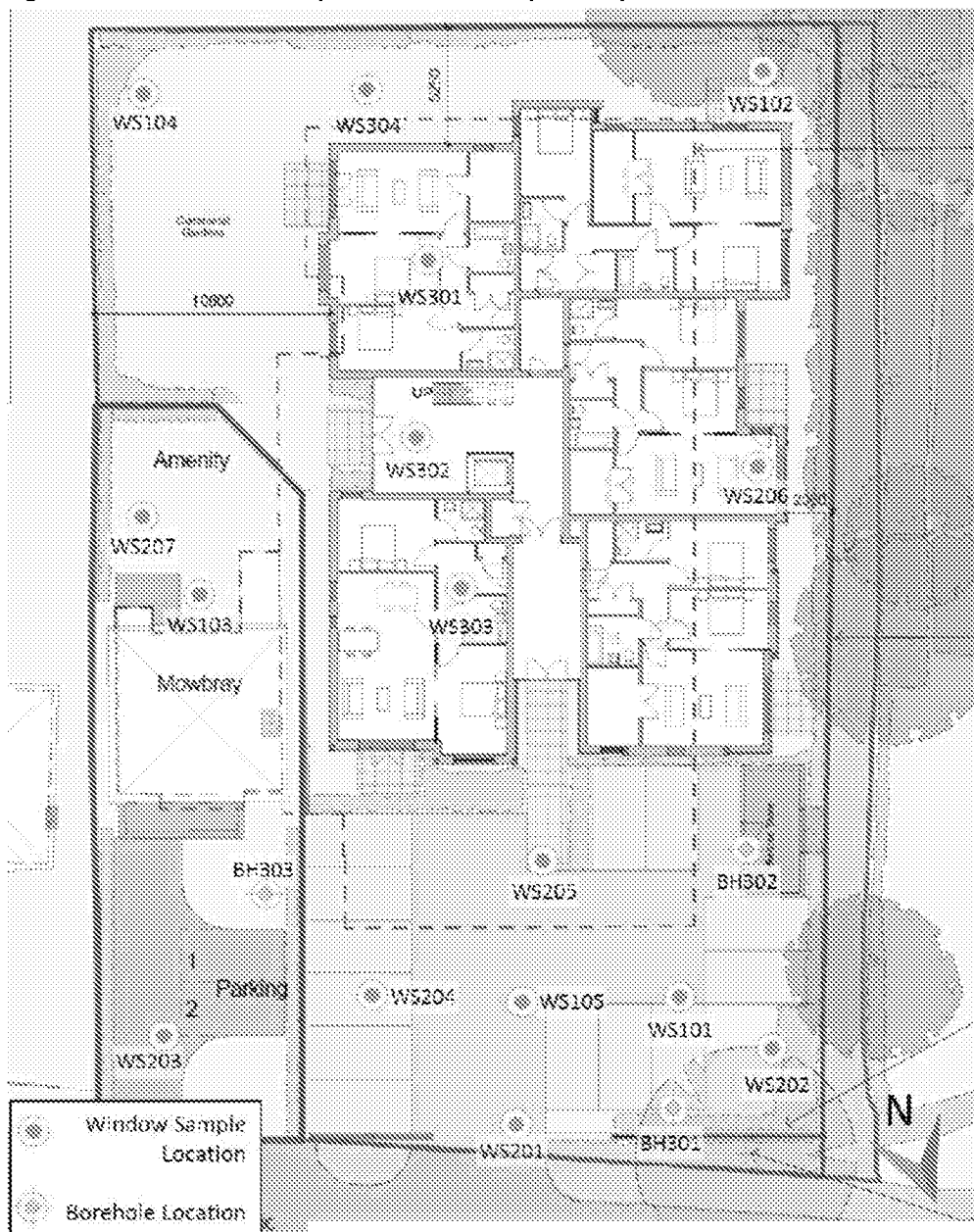




Figure 1.2 Site Development Plan with Exploratory Hole Locations



1.4.3 Remediation Method Statement

The RMS was prepared in July 2016 and outlined remedial objectives based on site data at the time. The initial RMS included excavation of impacted soils and treatment within bioremediation windrows prior to being reused on site once chemically suitable. Upon commencement of works, the extent of contamination was found to be greater than anticipated. As such, a revised document was produced in March 2017, with the remedial methodology being approved by the Environment Agency prior to commencement of further works.



The revised remedial objectives are summarised below. Aspects validated within this report are given in **bold**:

- ❖ Watching brief for **removal of underground storage tanks**, associated interceptors, infrastructure, and other obstructions as identified;
- ❖ **Addition of chemical oxidation technology** by injection into the substrate to treat impacted soils and groundwater *in situ* [designed and implemented by a third party];
- ❖ **Groundwater hydrocarbon concentrations to be reduced to acceptable levels** using chemical oxidation to treat the residual contaminant sources identified on the site;
- ❖ **Groundwater and ground gas monitoring** performed both during remedial works and at two week intervals for a period of at least 3 months following completion of the remedial phase;
- ❖ **Groundwater sampling and analysis** performed both during remedial works and at two week intervals for a period of at least 3 months following completion of the injection phase;
- ❖ Soil sampling and analysis to be undertaken at approximately 3 months following completion of the remedial works (or earlier if contaminant levels suggest this would be appropriate);
- ❖ Once remediation boreholes are no longer required, they must be decommissioned in line with current industry best practice (Environment Agency guidelines);
- ❖ If required, and depending on the results of the shallow sampling above, **remediated soils in gardens and soft landscaping areas must meet the soil guideline limits** in the RMS and include an additional overlying layer of **topsoil of at least 150mm** thickness; and
- ❖ Validation of soils and groundwater should be carried out post remediation, with data summarised within a validation report.

1.4.4 Remediation Verification Works

Prior to November 2016, the existing building on site was demolished, the foundations grubbed out, and the site made ready for commencement of remedial works. REC were not required by the Client to be present for this phase of work.

Initially, remediation works were undertaken by the construction contractor Hackwood Group. This stage of works included removal of fuel storage tanks, for which REC provided a watching brief. Excavated soils and those in remediation windrows were sampled by REC engineers on multiple occasions to monitor effectiveness of the works. Samples were analysed for a range of contaminants of concern and screened against the target concentrations derived during the DQRA.

By January 2017, the initial remedial works being completed by Hackwood Group were proving ineffective. REC liaised with specialist remediation contractor McAuliffe / Geostream to devise an alternate methodology. The RMS was subsequently updated and approved, with the revised strategy comprising that outlined within Section 1.4.3.

In situ injection treatment was completed by McAuliffe / Geostream in May 2017, with ground gas and groundwater monitoring and sampling subsequently undertaken by REC. Additional in situ treatment was undertaken in August 2018 to promote continued betterment on the site.



1.5 Limitations of the Study

The limitations of this report are presented as Appendix I.

1.6 Confidentiality

REC has prepared this report solely for the use of the Client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from REC; a charge may be levied against such approval.



2.0 SITE CHARACTERISTICS

2.1 Site Details

Table 2.1 Site Location and Description

Site Address	Former Hares Daihatsu, Station Road, Littlehampton, BN16 3BH
National Grid Reference	505669, 102529
Site Area	0.17 ha

The site lies in a mixed residential and commercial area. At the time of the initial site investigations (2015 to 2016), the site comprised a vehicle repair garage which had been disused since December 2014, and an adjoining disused house/office ('Mowbray') occupying the east of the site. The site had been used as a petrol filling station between 1961 and May 1998. By 2014, the former forecourt area had been covered with asphalt.

At the commencement of the remedial supervision by REC in November 2016, the repair garage had been demolished and the foundation slab had been removed. The disused house Mowbray remained on site to be renovated as part of the development. The site was roughly level bare earth, with a tarmac roadway in the west.

By April 2019, the site had been fully developed to comprise a large residential retirement apartment building, with the adjacent Mowbray building as a separate plot. External soft and hard landscaping and infrastructure have been installed.

2.2 Geology

Ground conditions encountered comprised Made Ground overlying the London Clay Formation, as summarized in Table 2.2 below.

Table 2.2 Summary of Geological Strata

Stratum	Min / Max Depth to Top of Strata (m bgl)	Max Thickness (m)
Made Ground	Ground Level	0.80 (WS304)
River Terrace Deposits	0.35 / 7.70	7.30 (BH303)
Seaford, Newhaven, Lewes, Culver and Portsdown (Undifferentiated) Chalk Formation	2.90 / 7.70	>8.60 (BH302)



2.3 Groundwater

Where observed, groundwater was encountered within the River Terrace Deposits (RTD) as slow seepages at multiple locations across the site. Groundwater strikes were encountered within the chalk at approximately 7.00 mbgl. A piezometric survey was carried out as part of the DQRA which concluded that shallow groundwater was flowing towards the north / northwest.

During the first phase of remedial works in December 2016 and January 2017, groundwater was encountered within a remedial excavation in the southeast of the site at 7.00 mbgl.

2.4 Hydrogeology and Hydrology

The site was located within a Source Protection Zone (SPZ) 1 and 2, at the time of undertaking the works in 2015. Following subsequent correspondence with the Environment Agency, REC understands that the site has since been declassified and that the SPZ underlying the site no longer applies. Following an informal conversation with the Environment Agency in 2018, REC understands that the associated potable water abstraction licence (75m south) was revoked in June 2015.

2.5.1 Soils

The Phase II geo-environmental assessment identified the concentrations of Total Petroleum Hydrocarbons (TPH) and Volatile Organic Compounds (VOCs) which exceed the REC human health screening criteria for a residential use.

The TPH and VOC contamination was attributed to two distinct sources within the site:

- ❖ **Northern Source:** Area around the former fuel tanks of the filling station (north of the site, adjacent to Station Road); and
- ❖ **Southern Source:** A former soakaway in the southeast corner of the site. In November 2016 following the demolition activities, this was uncovered and found to partially be filled with an engine oil-like substance. Based on the results of the ground investigation, this contamination was anticipated to extend west beneath the footings of the former building (toward WS301).

Other Contaminants

A number of other elevated contaminant concentrations were identified on the site within the top 0.60 mbgl. These have been attributed to deleterious material within the Made Ground.



2.5.2 Groundwater

The DQRA for controlled waters identified the following CoC which are elevated above both Environmental Quality Standards (EQS) and Drinking Water Standards (DWS):

- ❖ **Total petroleum hydrocarbons (TPH):** C₅-C₇ aromatic; C₆-C₇ aromatic; C₇-C₈ aromatic; C₈-C₁₀ aromatic & aliphatic; C₁₀-C₁₂ aromatic & aliphatic; C₁₂-C₁₆ aromatic; C₁₆-C₂₁ aromatic; C₂₁-C₃₅ aromatic and aliphatic splits;
- ❖ **BTEX** (Benzene, toluene, ethylbenzene and M/P & o- xylenes); and
- ❖ Other VOCs: **1,2,4-trimethylbenzene**.

2.5.3 Ground Gas

The Phase II geo-environmental assessment identified the site as Characteristic Situation 3, indicating that ground gas prevention measures may be necessary. This was based on a worst case of gas monitoring results prior to any remedial works.

It was recommended that a reassessment of the site's Characteristic Situation should be made upon the completion of remedial works. Ground gas monitoring has been undertaken throughout the remediation monitoring works and the reassessment is given as Section 4.3.2.



3.0 REMOVAL OF CONTAMINATION SOURCES

3.1 Removal of Fuel Storage Tanks

3.1.1 Review of Petroleum Records

As part of the Phase I & II investigation works, a request was made by REC to the petroleum officer at West Sussex County Council. The response obtained on 25th August 2015 stated:

“The site was licensed for the storage of petroleum spirit from 1961 to May 1998.

There are 3 tanks, 2 were petrol tanks which have been foam filled, the 3rd tank we have no information, we assume it has not been used.

We have no information that any of the tanks have been removed.”

Based on the findings on the investigations, visual evidence on site and the contaminant distribution, REC made an estimate of approximate tank locations within the former forecourt area in the north. It was anticipated prior to commencement of the works that contamination in the south of the site was also related to a buried tank.

3.1.2 Tank Emptying and Gas Free

REC attended site to commence the Watching Brief of remedial works on 7th November 2016. By this time, the former vehicle garage had been demolished with all waste materials having been removed from site. The house in the east of the site (Mowbray) remained intact for redevelopment into the scheme.

South of Site (Rear of Former Building)

During the 07/11/2016 visit, the contaminant source in the south of the site was investigated. Upon excavation, no UST was encountered but impacted water was identified within a former soakaway within this area. It was concluded that this was the likely source of the contamination and that the liquid should be removed by an appropriately licenced contractor.

REC's role was to provide watching brief of the tank removal only, as such REC were not present when the soakaway was emptied. It is understood that the impacted water was extracted and removed from site by Malarly Ltd on 11/11/2016. Following pumping of the liquid, the soakaway was left to recharge and this liquid was also removed.

Select photographs of excavations within this area are given within Appendix IV.



North of Site (Former Forecourt)

Tank excavation commenced in the north of the site on 08/11/2016, for which REC provided a watching brief. Surface asphalt was scraped back and stockpiled. The subsurface concrete was then broken with an excavator and stockpiled separately.

In total, 6no. tanks were uncovered within this area. This includes the following:

- ❖ 1no. 4.88m long, 2.44m diameter tank with middle partition (22,800L) with no evidence of corrosion or holes. This tank was completely filled with liquid. An interface probe indicated this was water with no measurable thickness of product, however very high Photo-Ionisation Detector (PID) readings (>3,000 ppm) indicated the presence of volatile organic compounds;
- ❖ 1no. 3.66m long, 2.13m diameter tank (circa 12,900L) with no evidence of corrosion or holes. This tank was also completely filled with liquid, indicated to be water with no measurable thickness of product. Very high PID readings indicated the presence of volatile organic compounds; and
- ❖ 4no. 1.88m long, 1.37m diameter tanks (circa 2,700L) with evidence of corrosion and leakage from 3no. of the tanks which were found to be partially filled with liquid with high PID readings. The fourth tank was concrete filled.

REC made contact with the Petroleum Officer on 09/11/2016 for further records on the tanks, however none were available.

All of the tanks were emptied, cleaned and certified as “gas free” by Avanti Environmental on 01/12/2016. REC were not required to be present during this operation, however photograph copies of the “gas free” certificates are reproduced within Appendix IV.

Select photographs of tank excavation and removal are given within Appendix IV.

3.1.2 Tank Excavation and Disposal

The tanks were excavated and stockpiled on site during 01/12/2016 and 02/12/2016. Pipework associated with the tanks was chased out, removed and stockpiled with the tanks. Tanks were opened up to allow oxygenation and prevent the risk of gases re-accumulating. Flattened and opened tanks were placed into a large container and removed from site to H.D. White Ltd (scrap metal merchants) of Littlehampton. The REC engineer undertaking the watching brief has anecdotal evidence that this was completed, however REC were not required by the construction contractor to formally validate the disposal.



4.0 IN SITU REMEDIATION

4.1 Chemical Injection Strategy

As summarised within Section 1.4.4, the initial RMS for the site was revised in April 2017, following the tank removal, due to the extent of contamination being greater than previously anticipated.

Between 10/05/2017 and 31/05/2017, REC was present on site to provide a watching brief of chemical injection across the site. This phase of works was designed and implemented by McAuliffe / GeoStream in their role as Remediation Contractor for the scheme. REC was instructed by Hackwood Group on behalf of the Client to complete verification of all of the remedial works for the scheme.

During this period, 7no. wells were installed across the site at locations agreed between REC and McAuliffe, to allow for monitoring of ground gas and groundwater within the two areas of most concern. Monitoring well construction is summarised as Table 4.1. Well locations are given as Figure 4.1, and within drawing 1CO100632-004 in Appendix II.

Table 4.1 Groundwater Monitoring Well Details

Well	Target	Easting	Northing	Elevation (m AOD)	Well Depth (m)	Response Zone (mbgl)
MW1	Southern Source	505665	102525	9.94	8.00	2.00 – 8.00
MW2		505672	102528	9.93	8.00	2.00 – 8.00
MW3		505673	102533	9.86	8.00	2.00 – 8.00
MW4	Northern Source	505662	102569	9.83	8.00	2.00 – 8.00
MW5		505669	102567	9.85	8.00	2.00 – 8.00
MW6		505675	102568	9.70	8.00	2.00 – 8.00
MW7		505679	102560	9.89	8.00	2.00 – 8.00

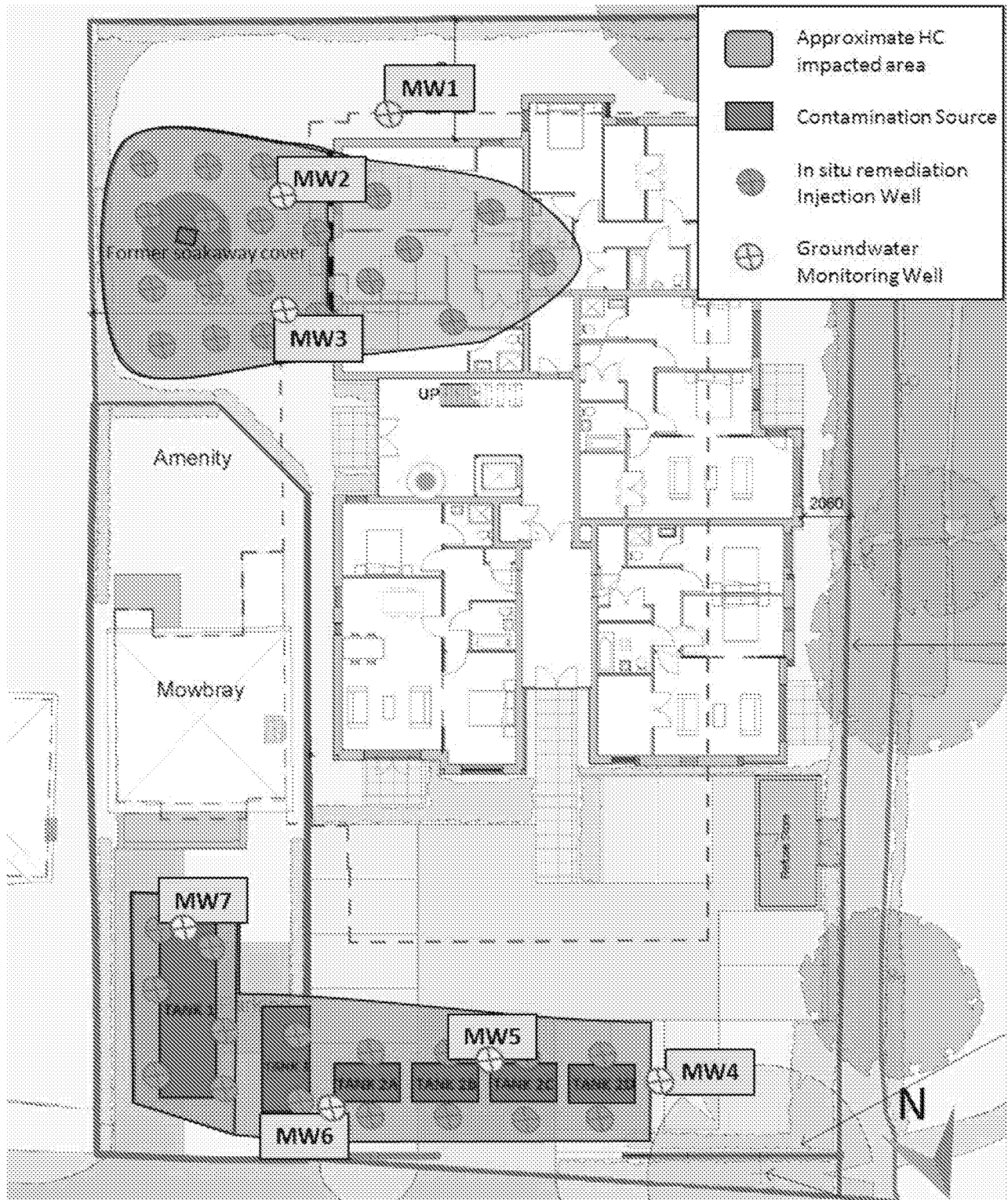
Prior to commencement of the injection works, the REC engineer obtained groundwater samples from each of the wells to determine baseline groundwater conditions on the site.

Following installation of the monitoring wells, the remediation contractor applied Oxygen Biochem (OBC)² in a 20% slurry mix by pressure injection using a sonic drilling rig into the two impacted areas of the site. Works were completed in accordance with the methodology set out within Appendix VI of the RMS. A total of 20 injection locations were completed in the Southern Source and 16 injection locations in the Northern Source, as outlined within the RMS. The sampling frequency and distribution was determined based on the extent of contamination encountered at each source, and the results of the piezometric survey completed for the DQRA which identified a groundwater flow to the north.

² OBCTM: UN1479, Oxidising solid, n.o.s. (Sodium persulfate, Calcium Peroxide)



Figure 4.1 Remediation Monitoring Well Locations





4.2 Ground Gas and Groundwater Monitoring Strategy

Ground gas and groundwater monitoring visits were completed by REC engineers at two week intervals for 12no. weeks following the first phase of injection as specified in the RMS, decreasing in frequency thereafter once groundwater began to stabilise.

During the course of the remedial works, REC attended site to complete ground gas and groundwater monitoring on the following dates:

- ✧ First injection phase and baseline sampling (soil and groundwater) - 10/05/2017 to 31/05/2017
- ✧ Round 1 - 13/06/17 and 14/06/17;
- ✧ Round 2 - 26/06/17 and 27/06/17.
- ✧ Round 3 - 10/07/17 and 11/07/17;
- ✧ Round 4 - 24/07/17 and 25/07/17;
- ✧ Round 5 - 07/08/17 and 08/08/17;
- ✧ Round 6 - 21/08/17 and 22/08/17;
- ✧ Round 7 - 11/09/17 and 12/09/17;
- ✧ Round 8 - 30/10/17 and 31/10/17;
- ✧ Round 9 - 17/01/18 and 18/01/18;
- ✧ Round 10 - 14/02/18 and 15/02/18;
- ✧ Round 11 - 25/04/18 and 26/04/18; and
- ✧ Round 12 - 03/07/18 and 05/07/18.

A second phase of injection works was undertaken between 20/08/2018 and 22/08/2018. These additional injections were completed following a review of the results at the time, to promote further degradation of contaminant concentrations. Subsequent visits were taken at 4no. week intervals on the following dates:

- ✧ Round 13 - 12/09/18 and 13/09/18;
- ✧ Round 14 - 16/10/18 and 17/10/18; and
- ✧ Round 15 - 14/11/18 and 15/11/18.

Monitoring wells were installed with robust, protected and well-marked headworks/covers, to prevent any accidental damage from occurring during construction activities. The condition was checked prior to monitoring on each visit to ensure suitability for use.

4.2.1 Ground Gas Monitoring

Concentrations of methane (CH₄), carbon dioxide (CO₂) and Oxygen (O₂) were measured using an infrared gas analyser (GFM435), calibrated to a reference standard (before and after each survey) and gas flow rates were measured using an internal flow pod. Gas measurements were recorded for a minimum of three minutes at each location, at which point the maximum concentration of CH₄ and CO₂ together with the lowest concentration of O₂ were recorded.



A Photo-Ionisation Detector (PID) was used within each borehole to record the presence of VOCs.

Ground gas monitoring was undertaken during each monitoring visit within MW4 to MW7 in the north of the site where a potential ground gas risk had previously been identified. All wells, including MW1 to MW3, were monitored during the baseline visit and Round 15.

Results are presented and discussed as Section 4.3.

4.2.2 Groundwater Monitoring & Sampling

Groundwater monitoring and sampling was undertaken at each borehole during each return monitoring visit. Groundwater levels were recorded using a dual phase interface probe, which can discern between free phase hydrocarbons or (non-aqueous phase liquid [NAPL]) and water within the well.

Water samples were obtained using the low flow technique. Groundwater parameters including dissolved oxygen (DO), pH, Oxygen Reduction Potential (ORP), conductivity and temperature were monitored in situ using a YSI and flow cell, and allowed to stabilise prior to sample collection. Monitoring parameters and expected response were established as Table 3.4 of the RMS.

DO is expected to increase and remain at sustained elevated concentrations post application of the amendments.

Results of groundwater monitoring and sampling are given as Section 4.4.

4.2.3 Groundwater Chemical Analysis

During each monitoring visit, a groundwater sample was collected from each location using low flow sampling. Samples were stored within appropriate jars in cool boxes, to be sent directly to Concept Life Sciences, Braintree, which has UKAS accreditation for all required analyses.

Samples were scheduled for the following physical and chemical analyses, in accordance with the RMS:

- ✧ Total Petroleum Hydrocarbons (Criteria Working Group) [TPH (CWG)];
- ✧ MTBE (Methyl tert-butyl ether) & BTEX (benzene, toluene, ethylbenzene, and xylenes);
- ✧ Volatile Organic Compounds (VOC);
- ✧ Manganese;
- ✧ Iron;
- ✧ Total Hardness;
- ✧ pH;
- ✧ Biological Oxygen Demand (Allyl Thiourea) (BOD); and
- ✧ Chemical Oxygen Demand (COD).



The sampling schedule was derived from that specified within the DQRA and RMS. Results are presented and discussed as Section 4.5.

4.3 Ground Gas Monitoring Results

4.3.1 Summary of Data

Peak concentrations of CH₄ and CO₂ and PID readings are given as Figure 4.2 to 4.4. Full ground gas monitoring results are included as Appendix V.

Due to limitations of the equipment, the infrared gas analyser (GFM435) will record false positive readings of methane in the presence of hydrocarbon vapours. Thus very high concentrations recorded have been attributed to the presence of hydrocarbon vapours rather than methane specifically.

Within MW5, MW6 and MW7, O₂ concentrations in excess of 100% were recorded on a number of occasions. This has been attributed to the presence of oxidising agent within the groundwater. During the final monitoring visit, O₂ concentrations within these wells was between 19.1 and 20.4 %v/v, which is considered as normal levels.

Figure 4.2 Peak Concentrations of CH₄ for each borehole during monitoring period

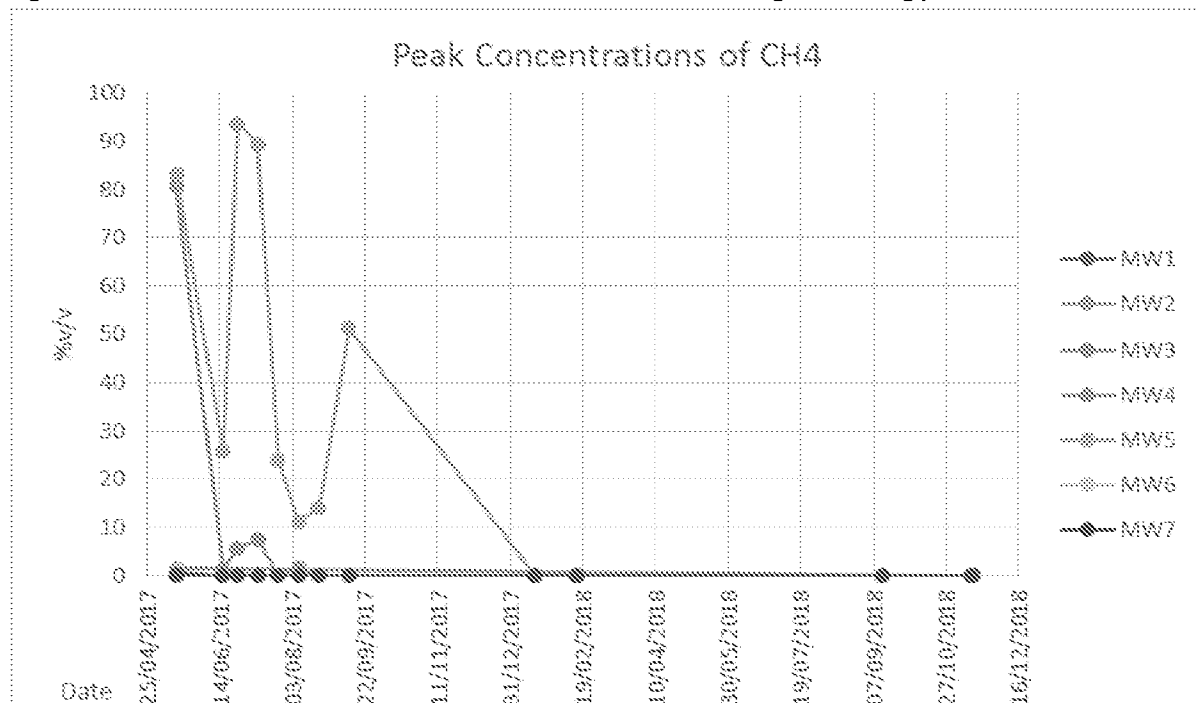




Figure 4.3 Peak Concentrations of CO₂ for each borehole during monitoring period

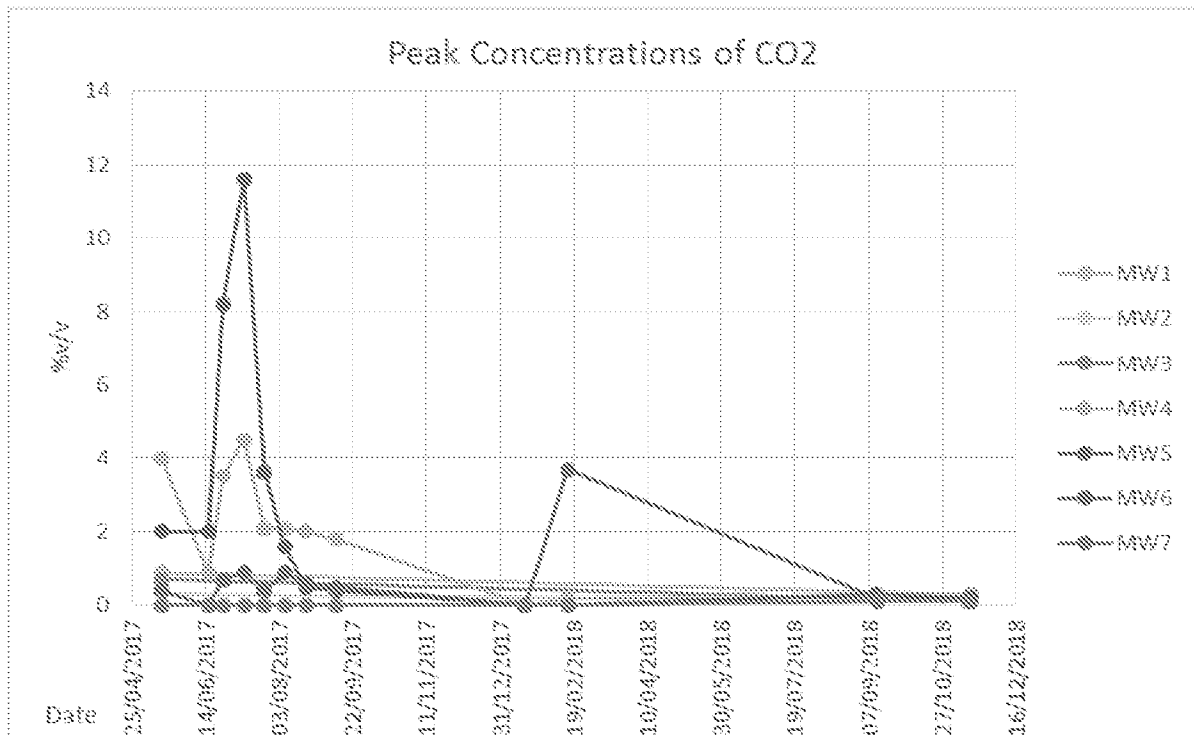
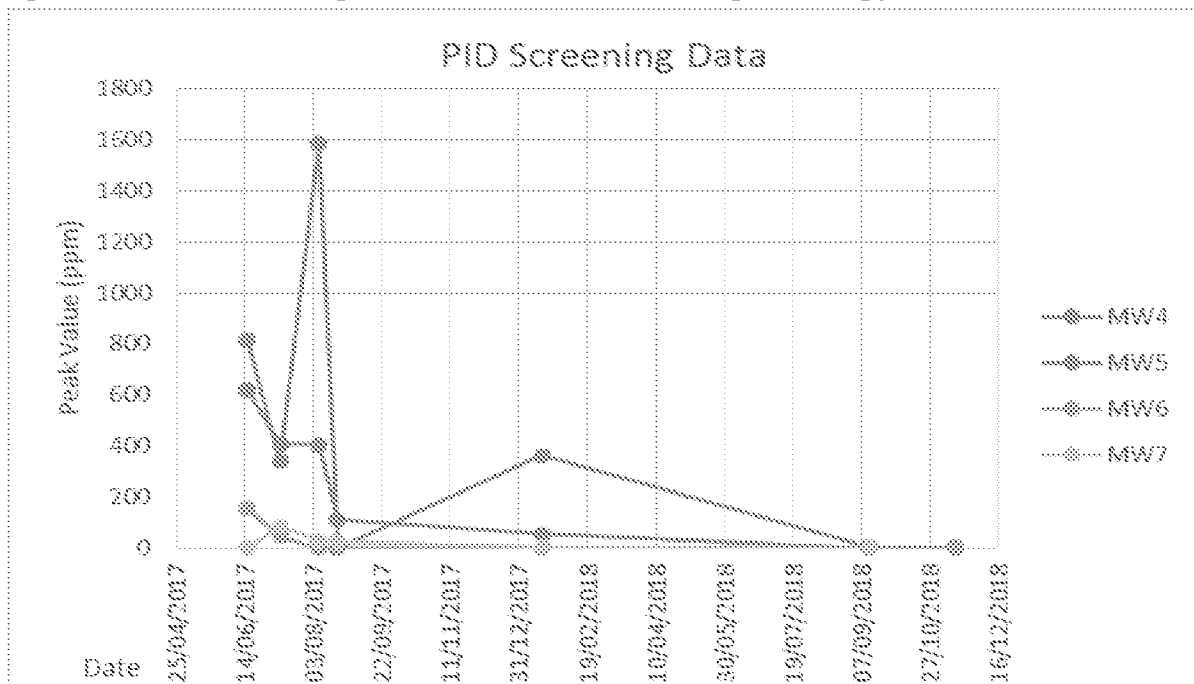


Figure 4.4 Peak Readings from PID for each borehole during monitoring period





During 2018 (4no. visits) the maximum concentration of CH₄ recorded within any borehole was <0.1 %v/v. The maximum concentration of CO₂ was 3.7 %v/v (MW6). Gas flow rates were typically <0.1 l/hr across the site. A peak flow of 50.0 l/hr was recorded within MW6 on a single occasion (14/11/2019); this has been regarded as an anomalous result for the following reasons:

- All other gas flow results from other boreholes during this visit were <0.1 l/hr; and
- The second highest recorded flow from this borehole was 1.8 l/hr (24/07/17), with a steady flow of 0.2 l/hr. All but three monitoring visits in this borehole recorded a peak of <0.1 l/hr.

As such, this result has been discounted.

4.3.2 Revised Ground Gas Assessment

Following the remedial works, the potential impact on the development from ground gases has been re-assessed with reference to standards and guidelines published within BS 8485:2015.

In accordance with the methodology outlined within BS8485:2015, REC have utilised the results of the ground gas monitoring surveys to calculate a tentative borehole hazardous gas flow rate (Q_{hg}), given on Table V.1 in Appendix V. This has been done based on all 2018 monitoring data, as a representation of the site in its current state.

The maximum implied characteristic situation for the site has therefore been calculated by combining the maximum observed flow rate and maximum observed concentrations during 2018 monitoring. This methodology provides a 'worst case scenario' in order to characterise the highest potential risk to human health from ground gas at the site, with results summarised as Table 4.2.

Table 4.2 Ground Gas "Worst Case" 2018 Data and Implied Characteristic Situation (CS)

Flow rate (l/h)	Maximum CH ₄ (%)	Maximum CO ₂ (%)	CH ₄ Q _{hg} (l/h)	CO ₂ Q _{hg} Rate (l/h)	Implied CH ₄ CS	Implied CO ₂ CS
0.2*	<0.1	3.7	<0.0001	0.0074	1	1

CS: Characteristic Situation

Q_{hg}: Hazardous gas flow rate

*: Anomalously high flow rates have been omitted.

On the basis of the data summarised as Table 3.1, a maximum site hazardous gas flow rate of 0.0074 L/h lies well within the upper range of GSV values for CS1 (<0.07 L/h). As such, REC are satisfied that the site can now be designated as **Characteristic Situation 1** and therefore no gas protection measures would be required.

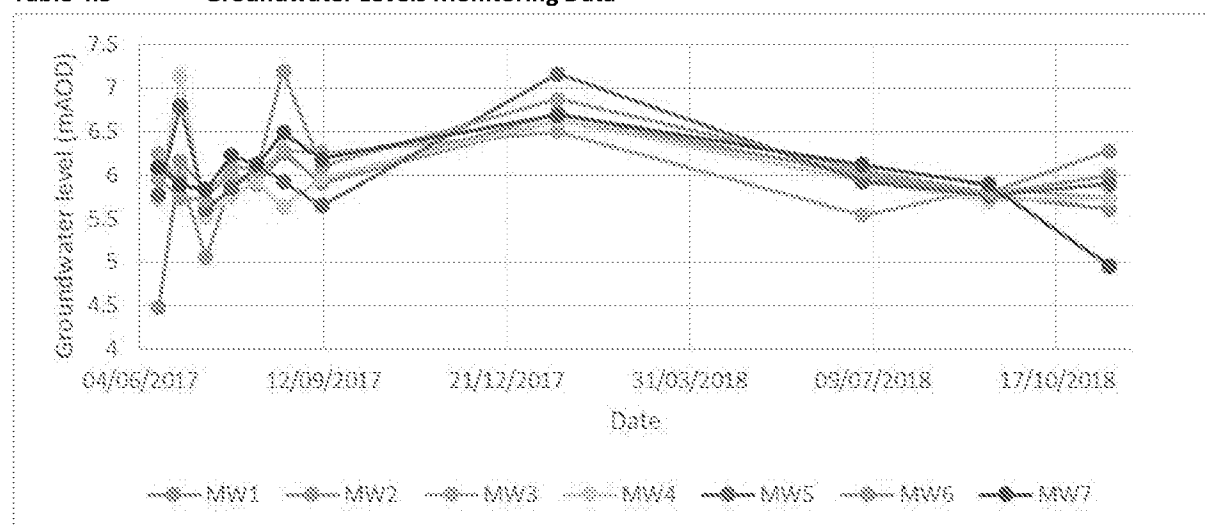


4.4 Groundwater Monitoring

4.4.1 Groundwater Levels

Groundwater levels have been recorded during each monitoring visit and referenced to ordnance datum to confirm the subsurface flow regime. Groundwater levels in the bedrock chalk relative to Ordnance Datum (AOD) are reproduced as Figure 4.5.

Table 4.5 Groundwater Levels Monitoring Data



The estimated direction and (relative) hydraulic gradient of groundwater flow at monitoring points across the site has been modelled using GSWDAT software³. Flow directions were calculated to be highly variable during the monitoring period, flowing north, east and west on numerous occasions each with generally shallow hydraulic gradients.

Plots showing groundwater contours, flow direction and gradient, averaged over one month periods, along with concentrations of TPH C₁₂-C₁₆ (aromatic) are included as Appendix IX.

4.4.2 Groundwater Parameters

Groundwater parameter monitoring results are included as Appendix VI. Data are presented as figure 4.6 to 4.9.

The recorded responses generally matches that which was anticipated, except in MW3, showing that the reagent is within the water and aerobic conditions are expected. Results from MW3 show evidence of anaerobic conditions, which would be expected at the plume core: this is consistent with site observations in the Southern Source area.

³ GSWDAT (GroundWater Spatio-Temporal Data Analysis Tool), Version: 2.12.



Figure 4.6 Summary of pH Data

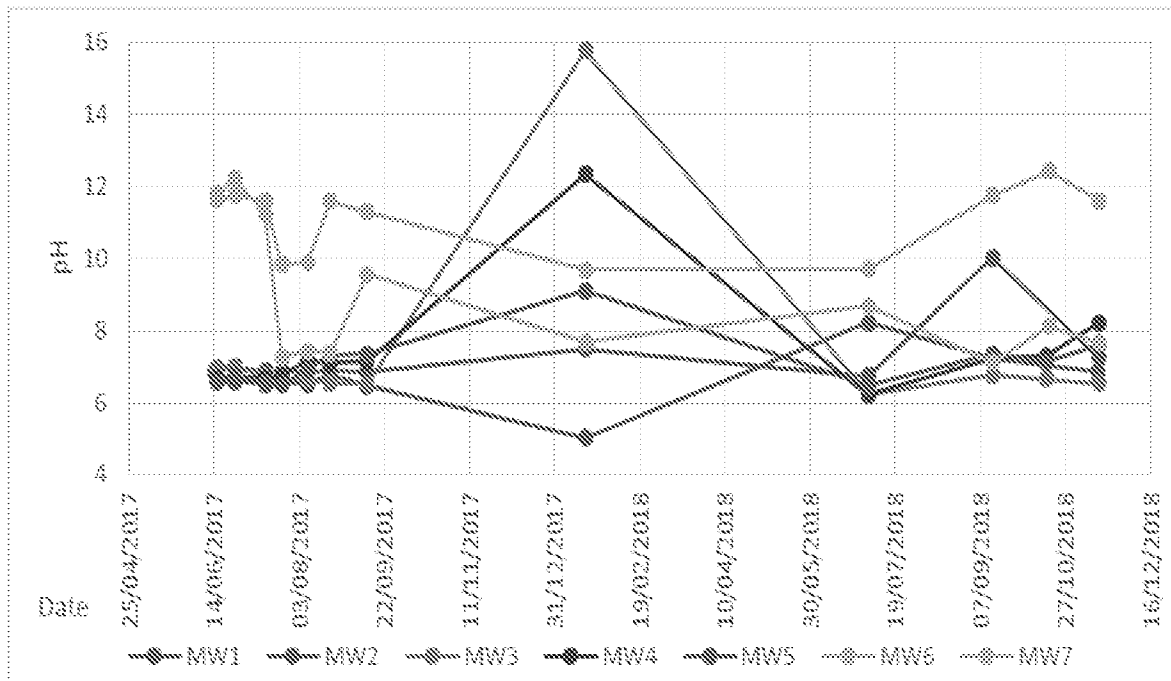


Figure 4.7 Summary of Conductivity Data as Measured

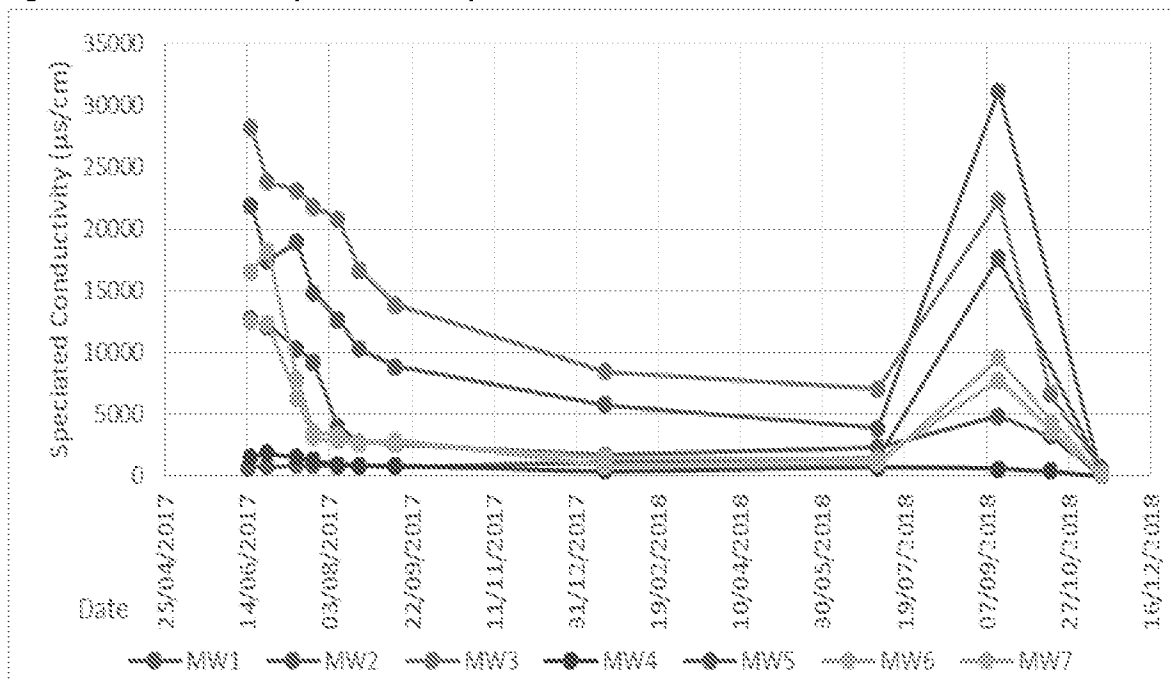
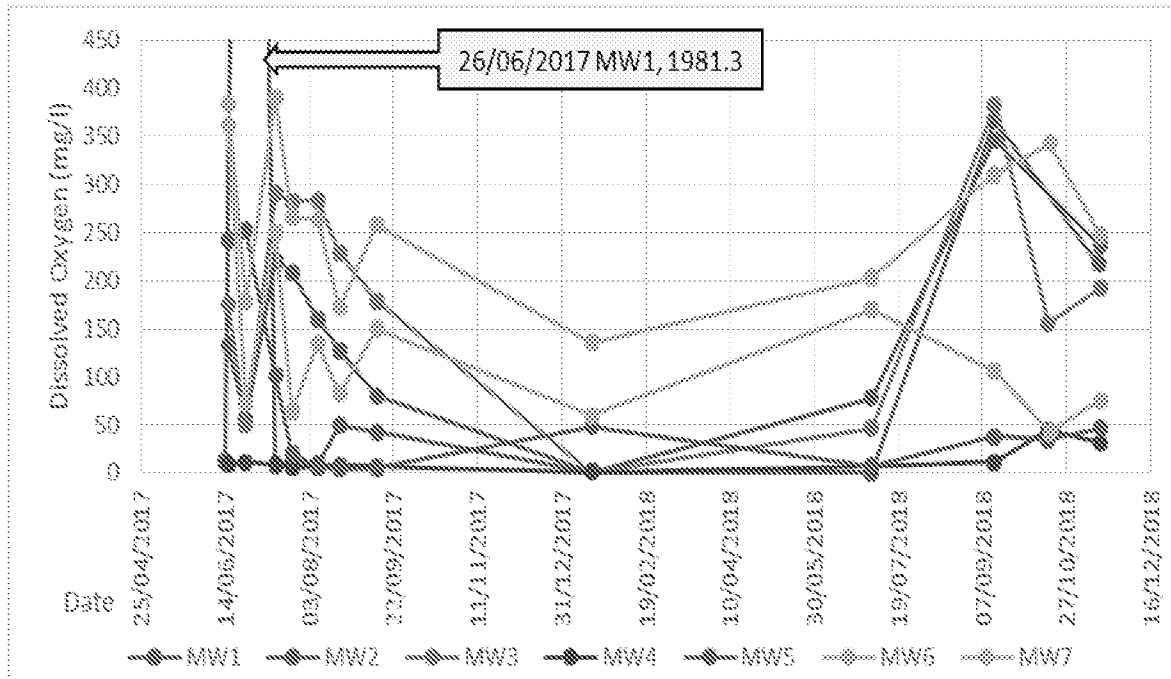
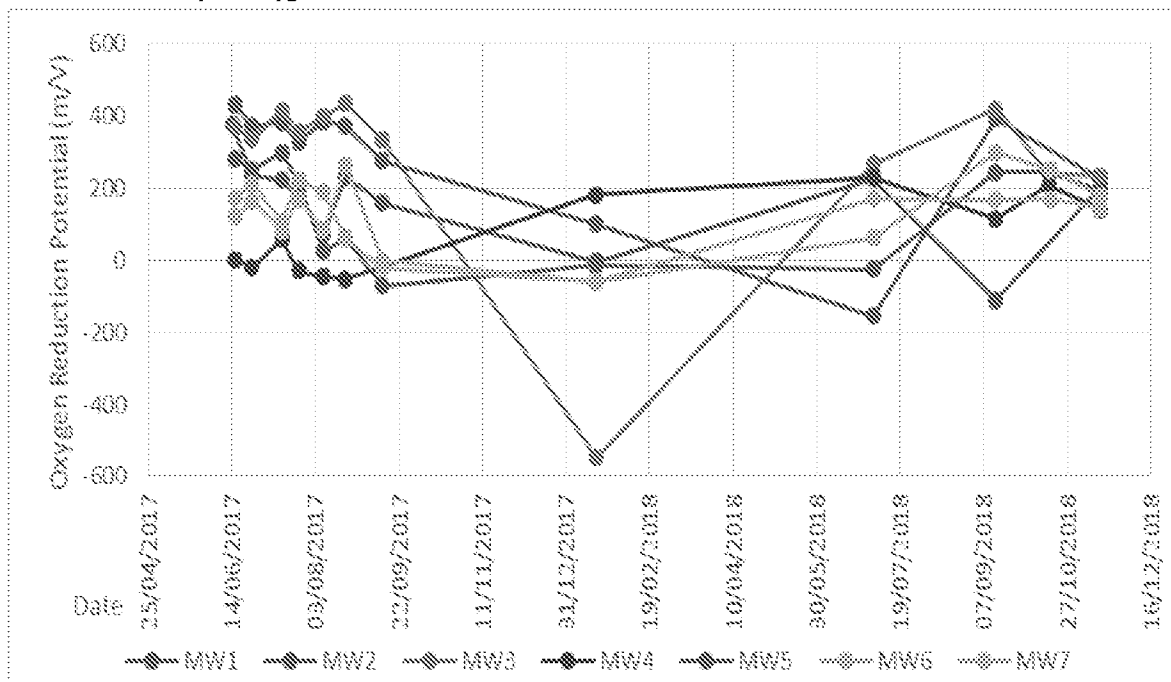




Figure 4.8 Summary of Dissolved Oxygen Data as Measured



4.9 Summary of Oxygen Reduction Potential Data as Measured





4.5 Groundwater Chemical Assessment

4.5.1 Chemical Testing Rationale

The Controlled Waters DQRA was used to derive target concentrations for groundwater. Results of the groundwater analyses were screened against these criteria to determine the effectiveness of the remediation. Prior to the first injection, groundwater samples were obtained to provide “baseline” values for comparison.

Copies of the laboratory analysis certificates are given as Appendix VII - A. Groundwater chemical screening tables and charts are given as Appendix VIII.

4.5.2 Summary of Results

Across all of the monitoring wells, the results of the analyses confirmed a general decrease in CoC concentrations over time. As anticipated, a number of locations showed an initial positive response followed by a minor increase in CoC concentrations then stabilisation.

A summary of results and groundwater response at each borehole is given as Table 4.4.

Table 4.4 Summary of Groundwater Response at Each Monitoring Well

Well	Initial State	November 2018 State	Response / Comment
MW1	All CoC below RTV.	All CoC below RTV.	Slight reduction in chemical concentrations. Physical parameters relatively stable throughout.
MW2	3no. CoC above RTV. Very high COD.	3no. CoC above RTV.	Numerous CoC elevated throughout monitoring period at discrete periods. TPH C ₁₂ -C ₁₆ (aromatic) consistently elevated. By November 2018, 3no. CoC are elevated but concentration very inconsistent. COD reduced.
MW3	5no. CoC above RTV. Very high COD.	1no. CoC above RTV.	General improvement in all CoC throughout monitoring. TPH C ₁₂ -C ₁₆ (aromatic) frequently elevated. By November 2018, only TPH C ₁₂ -C ₁₆ (aromatic) is elevated. COD reduced.
MW4	9no. CoC above RTV. High BOD, COD, Fe and Mn.	All CoC below RTV.	Improvement in all CoC throughout monitoring. By October 2017, all CoC consistently below RTV. Reduction in BOD, COD, Fe and Mn.
MW5	10no. CoC above RTV. High BOD, COD and Mn.	All CoC below RTV.	Improvement in all CoC throughout monitoring with rare isolated elevations. By October 2018, all CoC consistently below RTV. General reduction in BOD, COD and Mn throughout.
MW6	All CoC below RTV. High COD.	All CoC below RTV.	Slight reduction in chemical concentrations. Physical parameters relatively stable throughout, but TPH C ₁₂ -C ₁₆ (aromatic) exceeds on 2no. occasions. By October 2018, all CoC consistently below RTV. General reduction in COD throughout.
MW7	All CoC below RTV. High COD.	All CoC below RTV.	Chemical concentrations relatively stable throughout. General reduction in COD throughout.



Based on chemical analyses of groundwater alone and alongside the ground gas and groundwater monitoring, the results demonstrate that degradation has been occurring and that the remediation has been effective. Remedial works have been especially effective within the north of the site (MW4 to MW7), where all CoC concentrations are now below the RTV.

Within the south of the site (MW2 & MW3), only TPH C₁₂-C₁₆ (aromatic), TPH C₁₆-C₂₁ (aromatic) and TPH C₂₁-C₃₅ (aromatic) persist above the RTV. Recorded DO, ORP and pH values suggest that anaerobic conditions have generally persisted in these locations until the second injection phase. Since September 2018, MW2 & MW3 have seen a notable increase in DO and ORP.

TPH C₁₂-C₃₅ (aromatic) can most commonly be associated with either heavy fuel oils or lubricating oils. This is consistent with the contamination identified in the south of the site, and inconsistent with that found in the north. Therefore, it is considered that any residual contamination derives from the source in this location.

4.5.3 TPH C₁₂-C₁₆ (aromatic)

The results of all groundwater monitoring and sampling have been analysed using the GWSDAT software to determine the potential residual risk posed by elevated concentrations of TPH C₁₂-C₁₆ (aromatic).

The groundwater contour plots referred to in Section 3.4.1 include concentrations of TPH C₁₂-C₁₆ (aromatic) at each well point over time (averaged over one month periods where data allow). Based on the concentrations recorded and flow directions inferred, REC considers that residual contamination within MW2 and MW3 is likely to be of low mobility and not likely to impact groundwater within the north of the site. Further to this, consistently low concentrations recorded within MW1 indicates that the TPH C₁₂-C₁₆ (aromatic) is not migrating in this direction.

4.6 Conclusions of In Situ Remediation

The results of ground gas and groundwater monitoring during 2018 have demonstrated sustained betterment across the site, albeit with higher readings associated with the second injection phase. As such, it is concluded that there is sufficient evidence that degradation of contaminants has occurred to such an extent that concentrations of contaminants are less than RTV in the northern part of the site.

It is considered that residual concentrations of TPH C₁₂-C₃₅ (aromatic) in excess of the RTV in MW2 and MW3 are likely to be of low mobility, based on the relative hydraulic gradients and absence of elevated concentrations in the adjacent monitoring borehole (MW1). Given the results of chemical analyses to date, these contaminants are anticipated to continue undergoing degradation without requirement for further intervention.

A long term monitoring strategy is therefore recommended, as previously advised in the RMS to verify that concentrations continue to decline.



4.7 Validation of Soft Landscaping Areas

4.7.1 Existing Soils

REC attended site in December 2018 to obtain samples of existing soils in areas of proposed soft landscaping to determine whether these met chemical assessment criteria for the scheme. The primary aim of this exercise was to potentially reduce the amount of soil requiring disposal from site, therefore minimising creation of unnecessary waste.

Based on the proposed development plan, REC estimated the total soft landscaping area in the development to be circa 580m². REC understands that in final designs, an additional 100m² has been surfaced with paving and therefore not requiring topsoil. Of this, circa 60m² was in the south and east, with the remainder in the west and north.

At the time of the visit site levels were circa 150 to 200mm below finished floor level. Samples were taken from 6 no. locations in the south, east and west of the site (covering circa 450m², allowing for a single sample per 75m²). This sampling frequency satisfies the 1 per 100m³ for site-derived remediated soils recommended within the RMS. Sample locations are shown as drawing 1CO100632-005 within Appendix II and as Figure 4.10.

Samples were collected from a range of depths up to 600mm below finished floor levels and were analysed for the following determinands at Concept Life Sciences, Braintree:

- ❖ Heavy metals;
- ❖ Asbestos screen;
- ❖ Cyanide;
- ❖ Phenols;
- ❖ Polycyclic Aromatic Hydrocarbons (USEPA16); and
- ❖ Total Petroleum Hydrocarbons.

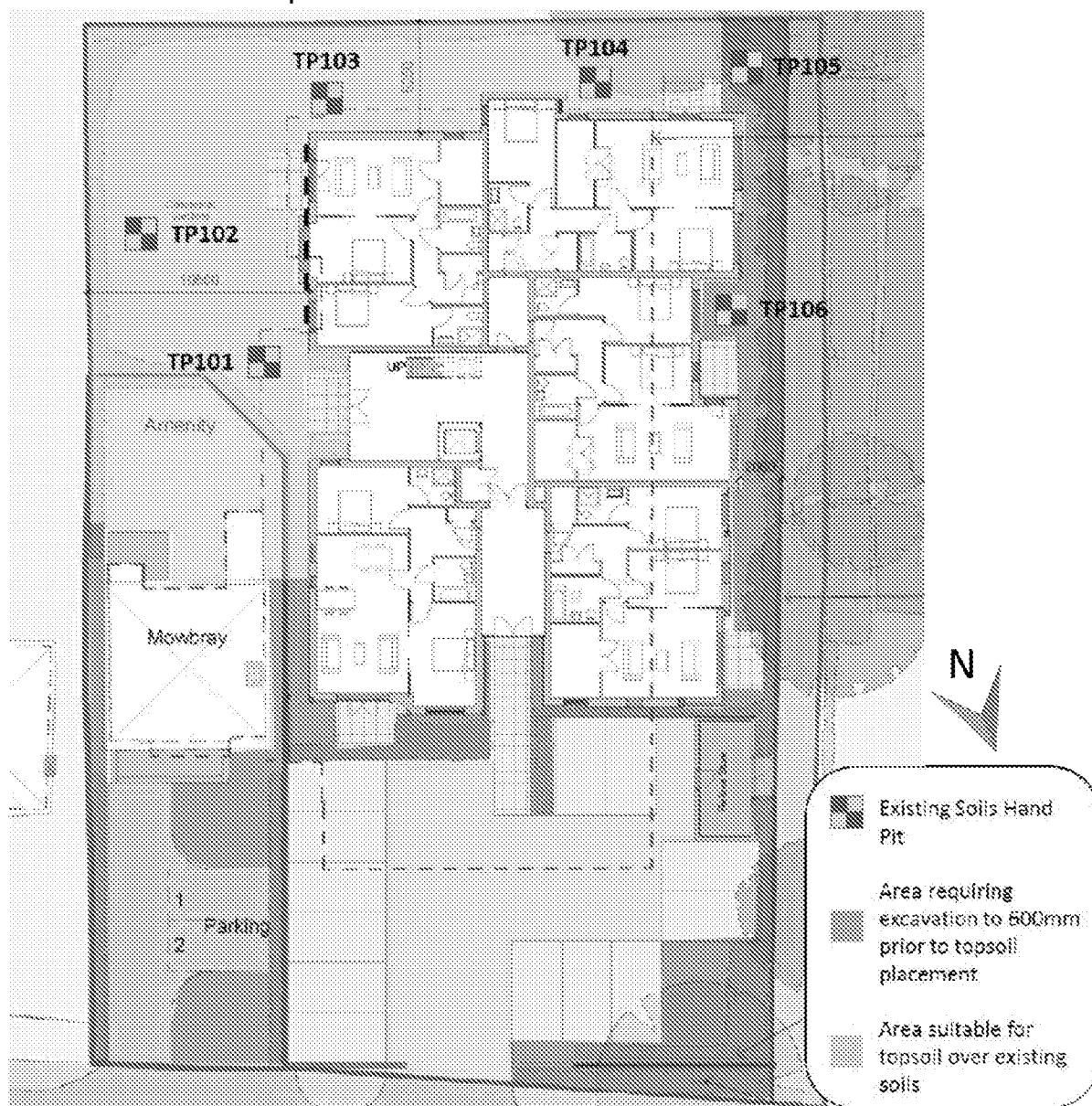
Chemical test certificates are given within Appendix VII – B. The results were screened against the site specific assessment criteria (SSAC) given as Appendix III, which were derived in the DQRA. Chemical screening is reproduced as Table X.1 within Appendix X.

Samples from TP101 to TP104 were found to be within the SSAC for all determinands. As such, it was recommended that these soils would be suitable for reuse, with imported topsoil placed on top to make up required site levels.

Exceedances were recorded in the remaining 2no. samples, which were both obtained from the land west of the development (TP105 and TP106).



Figure 4.10 Sampling location plan for existing cover soils and clean cover thickness requirements. N.B. additional paved areas are not shown.



Soils from the vicinity of TP105 and TP106, as well as soils from the north which were not accessible to be sampled, were recommended for excavation and disposal. Excavation to 600mm was recommended in accordance with the Remediation Strategy. Waste soils were to be removed from site to appropriate receiving landfill and the excavations infilled with chemically suitable imported material.

Table 4.5 provides an overview of calculated topsoil import requirements based on this assessment. Validation of this imported material is given as Section 4.7.2. Estimated volumes of external hard standing are also given for waste soil disposal calculations (e.g. soils from beneath car park area).



Table 4.5 Estimate of Imported Topsoil and Soil Disposal Volume Requirements across Proposed Soft and Hard Landscaping Areas

Section of Site	Approximate area	Depth of Excavation Required	Volume to be excavated for disposal	Thickness of topsoil required	Volume of topsoil required
South and east gardens (in vicinity of TP101 to TP104)	340 m ² (was 400m ² excluding additional paving)	N/A – topsoil to be placed on top of existing to raise to finished levels	N/A	Up to 200 mm dependent on pre-placement levels	Up to 68 m ³
West landscaping (in vicinity of TP105 & TP106)	140 m ² (was 180m ² excluding additional paving)	Up to 600mm below finished levels (pre-placement levels typically zero to 250mm below finished)	Up to 84 m ³ (assuming 600mm excavation)	600 mm	Up to 84 m ³
North landscaping (in car park area)					
Soft Landscaping Total	480 m²	-	84 m³	-	Up to 152 m³
Car Parking Area	325 m ²	Circa 300 mm	97.5 m ³	N/A	N/A

4.7.2 Imported Topsoil

The Construction Contractor supplied documents verifying the source of the soils as The Woodhorn Group, Tangmere Compost Site. The supplier has provided evidence of compliance with BS3882:2015 *Specification for Topsoil*. A copy of the supplier's certificate is included within Appendix VII – B.

REC engineers attended site on 05/02/2019, 20/02/2019, 05/03/2019 & 21/03/2019 to sample stockpiles of imported topsoil destined for use within the soft landscaping areas. On each occasion, 3no. samples were obtained in accordance with the minimum frequency given in the RMS. In total, 180 tonnes of soil (circa 120m³ based on 1m³ soil being 1.5 tonnes) was imported.

The estimated 152 m³ of imported soil required did not take into account where less than 200mm soil was required in the south and east, for shallowing for service runs and at boundaries where foundations and concrete fencing/paving supports extend beneath topsoil. As such, the imported volume is considered sufficient.

Samples of stockpiled material were submitted for the same suite of analyses listed in Section 4.7.1 to confirm suitability compared to the SSAC. Copies of laboratory testing certificates are given within Appendix VII – B. All samples analysed were found to satisfy the criteria (see Table X.2 in Appendix X).



Soil was described on each occasion as “dry and friable brown to dark sandy clay with frequent rootlets. Gravel is fine to coarse”. Photographs of imported soil are included in Appendix IV.

4.7.3 Depth Verification and Soil Placement

During the site visits on 05/03/2019 and 21/03/2019, the REC engineer inspected the depth of excavation where unsuitable soils had been removed from the western side of the site as required. The depth was found to be 600mm along the extent of the area, excluding an area with buried live services that could only be excavated to 200mm below finished levels for safety reasons. Where services had been laid, these were within an imported granular fill material.

Photographs of the excavated areas and placed soils are given in Appendix IV.

4.7.4 Disposal of Waste Soils

Soil waste transfer certificates supplied (see Appendix X) confirm that the waste material was removed from site by a suitably licensed haulier. Based on the tickets supplied, the volume removed is approximately 182m³. REC understands that this includes additional dug out during construction of the car parking area in the north of the site.

4.7.5 Soft Landscaping Conclusions

Based on the evidence presented above, including results of sampling and site visits undertaken by REC engineers, REC is satisfied that the soft landscaping has been installed in accordance with the Remediation Strategy and subsequent discussions.



5.0 REQUIREMENT FOR FURTHER WORKS

5.1 Overview

Based on the results of groundwater sampling and ground gas monitoring completed to date, REC considers that sufficient remedial works have been completed to make the site safe for human occupation with respect to groundwater and deeper soil contamination, and to remove any unacceptable risk to future site users.

Given the exceedances within groundwater samples in MW2 and MW3, the potential risk to controlled waters cannot be ruled out, however based on the data trends it is considered that improvement in water quality will continue without further intervention.

The recommended long term monitoring and sampling works are detailed as sections 5.2 & 5.3.

5.2 Deeper Soil Sampling and Verification

Results of the Controlled Waters DQRA were used to derive target concentrations for groundwater, and subsequently extended using the Tier 1, 2 and 3 worksheets for soils to back-calculate and derive concentrations for soil.

Due to the minor exceedances remaining within the groundwater following the December 2018 monitoring, soil validation testing is yet to be undertaken. Within the RMS it was recommended that this be undertaken approximately 3 months following completion of the remedial works. During this visit, groundwater samples should also be obtained and ground gas monitoring should be completed to add to the dataset.

Soil analysis results should be compared against the remedial target values, as well as the baseline values obtained during the May 2017 injection phase.

5.3 Long Term Groundwater Monitoring

As outlined within the RMS, REC recommend that an additional ground gas and groundwater monitoring visit be undertaken at 12 months from the time of writing (i.e. circa December 2019), to verify that chemical concentrations have continued to fall and/or remain stable.

Boreholes must remain clear and serviceable during this period. Boreholes must be decommissioned in line with the specification given in the RMS.



5.4 Long Term Monitoring Reporting

Upon completion of the final long term monitoring visits at approximately 12no. months from December 2018, a supplementary report will be submitted to the local planning authority. The report should discuss the results of the final soil, groundwater and ground gas monitoring and analysis, including confirmation that remedial targets have been achieved.



6.0 CONCLUSIONS

REC has verified that the following remediation measures have been correctly implemented in accordance with the Remediation Method Statement:

- ❖ Completion of groundwater remediation and primary phase of monitoring;
- ❖ Re-evaluation of ground gas regime of the site and verification that no unacceptable risk to human health remains; and
- ❖ Validation of soft landscaping areas to confirm that no unacceptable risk to human health remains.

Based on the site observations and chemical testing results completed to date, REC considers that no further intervention is required to remediate TPH contamination relating to the North and South sources. It is appropriate to revert to the long-term monitoring regime outlined within the RMS.

Given the above, REC recommends sign off of the planning condition such that properties can be occupied.

Soil analysis and further groundwater monitoring is required to confirm the ongoing effectiveness of the groundwater remediation. These should be completed at approximately 3no. and 12no. months respectively from December 2018 as outlined within the RMS. Additional monitoring data should be submitted to the local planning authority for final sign off in due course.