

Crymlyn Tip Coed Darcy

Restoration Implementation Plan

St Modwen Developments Ltd
R1870/23/5260 - Final

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eNGLOBE

St Modwen Developments Ltd

R1870/23/5260 - Final

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1 Introduction

Englobe Regeneration UK Ltd (Englobe) has been commissioned by St Modwen Developments Ltd (St Modwen) to undertake pre-construction services to produce fully scoped and detailed restoration plans for 'Crymlyn Tip', also known as the 'Containment Area' within previous reports. The Crymlyn Tip is a closed landfill site within the wider Coed Darcy development area, located on the site formerly occupied by the BP Llandarcy Oil Refinery near Neath, South Wales. The A07 in-house closed landfill site is subject to a Cyfoeth Naturiol Cymru - Natural Resources Wales (CNC-NRW) Environmental Permit reference EPR/AP3990LR.

Englobe, on behalf of St Modwen, in conjunction with their advisors, Phil Jones Associates Ltd (PJA) and Cumming Management Group UK Ltd (Cumming) will fulfil their respective roles and obligations as summarised within Table 1. CNC-NRW and Neath Port Talbot Borough Council (NPTBC) have been included as lead regulatory authorities.

Table 1 - Organisational Roles

Organisation	Role
St Modwen	Client, Landowner and Permit Operator
Cumming	Client's Agent
PJA	Client's Consultant
Englobe	Principal Contractor and Designer
CNC-NRW	Principal Environmental Regulator
NPTBC	Local Authority

1.1 Planning Application and Permit Surrender Application

The overall remediation and redevelopment of the Coed Darcy site has been subject to a Section 106 agreement (S106) between NPTBC and other parties including St Modwen and BP Oil Llandarcy Refinery Ltd (BPLR), and this included specific requirements for the 'Containment Area', which includes the currently permitted landfill.

The S106 set out a Remediation Action Plan (RAP), known as the RAP Works, which were voluntary remedial works in relation to environmental issues pre-dating the transfer of site ownership from BP to St Modwen. These RAP works were set out in Schedule 7 of the S106 and

were agreed to be completed in lieu of the imposition of formal measures by any Environmental Authorities.

It is understood that the requirements of the S106 have been undertaken with regard to the 'Containment Area' and that the proposed restoration actions within this document are beyond the S106 requirements. It is therefore understood that these restoration actions may be subject to a separate, and full planning application and this document has been prepared to support such an application.

Separate to planning matters is the Permit surrender process, which Englobe are also assisting St Modwen with. Englobe, on behalf of St Modwen (as the holder and Operator of the Permit), are preparing updated reports in relation to two improvement programmes (IP1 & IP2) identified by CNC-NRW with the objective to establish a clear pathway to Permit surrender. IP1 includes updating the Hydrogeological Risk Assessment (HRA), Stability Assessment (SA) and Landfill Gas Risk Assessment (LFGRA). IP2 includes the requirement for an updated Closure and Aftercare Management Plan (CAMP).

It is therefore considered that the final restoration of the Tip can be viewed as two separate, but interlinked, issues:

- Completion of the Final Restoration Plans (this Restoration Implementation Plan report); and
- Completion of IP1 (HRA, SA, LFGRA) & IP2 (CAMP) associated with the Permit Surrender.

It is clear that the Crymlyn Tip is a very unusual situation, in that it is neither a typical landfill and nor is it a typical 'brownfield' site. It is therefore believed that separating permit surrender from restoration/redevelopment will help bring clarity, while also still enabling NRW to be involved in the approval process for both aspects.

This report will cover the requirements for the capping and re-profiling of the Tip as well as the quality criteria for the restoration layers. However, it is recognised that the Environmental Permit also deals with these same matters.

It is our proposal to deal with this aspect in the following way:

- This Restoration Implementation Plan will include the human health risk assessment dealing with the pollution linkages relating to capping and restoration layer soils (and deeper soil/groundwater/NAPL sources under the surface materials). This will include the quality criteria for the capping and restoration layers.
- The CAMP will adopt the same risk assessment outcome for the capping and restoration layers as the completion criteria and are presented in the restoration construction proposals and Construction Quality Assurance (CQA) validation plan.
- The Permit, at Schedule 2, Table S3.1 states that 'The nature and quantity of wastes that may be accepted for restoration will be as agreed in writing with the Environment Agency', and this is consistent with section 2.3.1 of the Permit and Table S1.2. Given this, it is considered appropriate to adopt the risk-based criteria from the Restoration Implementation Plan as completion criteria for the CAMP. The source of restoration materials and their use will be considered part of the CAMP and conducted under the terms of the Permit. It is noted that NRW see no barrier to utilising the CL:AIRE Definition of Waste (Development Industry) Code of Practice, 2011 (DoW CoP) to control the use of wider Coed Darcy development site wastes for restoration as long as wastes have been remediated fully and that DoW CoP is complied with.
- This CAMP will deal with reprofiling, capping and stability of the landfill, and this will be adopted on an interim basis by this Restoration Implementation Plan.

1.2 Report Objective

In light of the site-specific details described in Section 1.1, the key objectives of this report are as follows:

- Summarise the site setting, history and works completed to date at the landfill;

- Provide an updated conceptual site model, source-pathway-receptor linkage assessment and detailed quantitative risk evaluation;
- Appraise and provide rationale for further restoration actions and detail potential strategies and measures required;
- Provide verification/target criteria;
- Propose environmental management plans for the works; and
- Discuss the planning, permitting and licensing requirements to enable regulatory agreement and control of the works.

In delivering these works, Englobe further understands key issues for St Modwen include:

- Ensuring that the works are managed sensitively, with respect to potential nuisance to local residents by mitigating any potential impact of noise, vibration, dust and odour resulting from restoration activities;
- Gaining regulatory approval to the proposed Planning Application and Permit Surrender Application and Restoration Implementation Plan and timely 'sign-off' of the Verification Report; and
- Working collaboratively with St Modwen and the Construction Phase team of Consultants to achieve the above objectives.

1.3 Report Structure

This report is structured as follows:

Section 2	Site Information and Background of Previous Remedial Actions
Section 3	Detailed Quantitative Risk Assessments, and Landfill Gas Assessment
Section 4	Restoration Options Appraisal
Section 5	Restoration Strategy
Section 6	Restoration Verification Approach
Section 7	Environmental Management Plan
Section 8	Proposed Air Quality Control and Monitoring Approach
Section 9	Construction Phase Health, Safety and Environmental Plan
Section 10	Quality Management Plan
Section 11	Outline Programme



2 Site Information and Previous Remedial Actions

2.1 Introduction

The following sections summarise and reference available information from previous works in order to provide maximum understanding and comfort that free oil wastes are substantially depleted and residual free oil is prevented, as far as reasonably practicable, from migrating beyond the landfill's boundary. For more detailed historic information please refer to the relevant reports.

2.2 Site Setting

The Coed Darcy development area comprises 250 hectares and is located immediately west of junction 43 of the M4. The town of Neath is situated approximately 4 km to the east and the city of Swansea approximately 7 km to the west. The site location is illustrated on drawing D1870/23/5260/01, Appendix A.

The Permit boundary of Crymlyn Tip and proposed planning area of associated remedial works are shown on drawing D1870/23/5260/02, Appendix A. For the purpose of this report the planning area defines the extent of the 'site'.

Crymlyn Tip landfill covers an approximate area of six hectares and is approximately 600 m long by 130 m wide, tapering at the eastern and western ends. The Tip is located on the northern edge of the southern tank farm of the former BP Llandarcy Refinery. The site is bordered to the north and west by the Crymlyn Bog, a Site of Special Scientific Interest (SSSI) of international and ecological importance. To the east and southeast is vacant land associated with the wider Coed Darcy development.

Immediately south of the Tip are West Bay, Crymlyn Bog Lagoon and South Bay, known collectively as the Coed Darcy Wetlands. These waterbodies originally formed part of the Permit area but have since been remediated and successfully surrendered from the Environmental Permit. The waterbodies receive water from the drainage network across the former southern tank farm. Surface water runoff from the former southern tank farm drains into either West Bay, or 'Musson's Channel' - an elongated section at the eastern end of the Crymlyn Bog Lagoon. South Bay collects

some surface water drainage from the Permit area and also drains into Musson's Channel. West Bay is linked to Crymlyn Bog Lagoon by pipes, and an outfall at the western edge of Crymlyn Bog Lagoon drains to the Crymlyn Bog.

Beyond the wetlands to the south is the Demonstration Village, comprising a number of currently unoccupied residential properties, the closest being approximately 120 m to the southwest of the main landfilled area, with vacant land of the former southern tank farm beyond.

2.3 Site History

Prior to the refinery opening, the area of the Tip formed part of Crymlyn Bog and consisted of a series of natural ponds and marshland. The area forming the Tip was enclosed with an external bund comprising largely of ash, built out into the Crymlyn Bog. The bund, which still defines the northern extent of the Tip stands circa 10 m above the bog at its eastern end and reduces to approximately bog level in the west. The bund formed a boundary structure but has also been used as a primary access haul road into the Tip.

The base of the Tip is understood to be unlined and is likely to have accepted wastes straight onto natural bog strata. This is generally supported by data from boreholes which have penetrated the base of the waste and generally encounter natural peat.

Waste disposal is understood to have commenced in the Tip in the early 1920s and continued until the 1970s when relevant regulations for waste disposal were introduced, including the Deposit of Poisonous Wastes Act 1972 and the Control of Pollution Act 1974.

The photograph from 1947 shows the eastern end of the Tip looking towards the south east across the southern tank farm. The ash bund is clearly visible along the northern boundary of the Tip at the bottom of the photograph - this feature is reported to have been constructed in the late 1930s with the intention to act as a containment feature in the event of bombing of the southern tank farm during the second world war which could have resulted in uncontrolled releases of free phase hydrocarbons.

It appears that disposal of waste is active in the eastern part of the Tip. Waste is being spread from an access road in the north, and it appears that waste material is potentially being informally deposited from the railhead adjacent to the eastern Tip boundary. Tracks across the centre of the Tip suggest that waste disposal may have taken place in the west by this date. It is understood that at this time, the Tip was used for disposal of a range of refinery wastes including demolition waste, refractory waste and asbestos.

Graphic 1 - 1947 Photograph



A photograph from 1951 shows the entire area of the Tip looking to the west across the railhead. More extensive waste disposal appears to have taken place in the north eastern corner of the Tip, over the earlier waste deposits and to the same height as the ash bund. The western end of the Tip is flooded, and appears to be natural, marshy ground.

There are no formal records of waste deposited in the early operational phases of the refinery. The depth, volume, type and location of these wastes is largely unknown.

Outside the ash bund is a plywood oil/water interception which separates free phase hydrocarbon migrating towards the bog from the filled area of the Tip whilst allowing water to underpass into Crymlyn Bog. It is believed that the plywood bund was installed in the 1960s and is known to have undergone routine maintenance from the early 1970s to the present day.

Following enactment of the Deposit of Poisonous Wastes Act 1972 disposal in the Tip was controlled by an annual 'season ticket' issued by Neath Rural District Council, the permit covered:

- Site 1 - Non-notifiable waste;
- Site 2 - Oily Contaminated Waste;
- Site 3 - Oily Sludge;
- Site 4 - Pyrophoric material;
- Site 5 - Asbestos;
- Site 6 - Sanitary waste excluding septic tanks;

- Site 7 - Asbestos (1984); and
- Site 8 - Asbestos (1988).

These areas are illustrated on drawing D1870/23/5260/03, Appendix A.

Immediately adjacent to the Crymlyn Tip is the Crymlyn Bog, which in 1975 was designated as a SSSI.

In 1977, Neath Borough council granted BP Oil Llandarcy Refinery a new waste disposal licence to operate the Tip. This licence incorporated the requirements of the Control of Pollution Act 1974 and covered the disposal of asbestos, boiler cleanings, oil sludges, bitumens and waxes, ion exchange resin, spent clay, pyrophoric material and contaminated debris. Additional sites for the disposal of asbestos were introduced in 1984 (Site 7) and 1988 (Site 8). The URS Tip Strategy 2006 outlines the boundaries of these areas further.

Around 1984, the sludge pits extending eastwards from the remaining sludge pit were refilled and consolidated.

In 1985, BP Oil Llandarcy was rationalised from a main fuels' refinery to a lube oil and special product refinery. In the short term there was an increase in waste disposal due to demolition works, following this refinery operations significantly reduced resulting in a reduction in waste disposal. Waste disposal in Site 1 (non-notifiable wastes) ceased in 1985. Site 2 was then used for the disposal of substantially oil free general waste.

In 1990, BP Oil Llandarcy handed management of the bog over to the Countryside Council for Wales (CCW) who developed it as a Nature Reserve.

In 1993, the Crymlyn bog was designated as a National Nature Reserve, and it is also designated as a RAMSAR site (wetland of international importance).

Modifications were made to the licence by Neath Borough Council on 25th March 1994 to include new legislation relating to classification of special waste. The modified licence was issued as a new consolidated version under reference number NBWD 5. The waste disposal licence was converted to a waste Management Licence under the Waste Management Licensing Regulations 1994.

In 1998, the Environment Agency issued a notice of modification to the licence, Appendix 1 of this licence replaced the modifications prepared by Neath Borough Council in 1994. The licence made provision for an aggregate of 1,500 tonnes for industrial waste, plastic, timber, paper, ion exchange resins and scrap metal; a total of 100 tonnes of asbestos and asbestos product was also included. Waste from powder sludges and liquid waste was prohibited. A landform survey and recording of inspections and maintenance of the plywood interceptor system around the perimeter of the tip was also required under the new licence.

Use of Site 2 for the disposal of substantially oil free general waste was discontinued in November 1999, no waste has been disposed of since 1999, with the site declared non-operational in 2001. The aerial photograph from circa 1999 coincides with the cessation of waste deposition at the Tip. The Tip is well vegetated with grass and scrub vegetation throughout, and dense patches of woodland in the north, east and west. A series of material windrows are located directly to the west of the road which passes through the centre of the permit area aligned north to south. To the east of the road there appears to be a large stockpile of loosely tipped material. Two lagoons are present in the east of the Tip which are understood to correspond with the reported locations of sludge pits.

An aerial photograph showing a proposed development site outlined in red. The site is situated in a rural area with fields and some trees. To the right of the site, there is a road and some industrial structures, including what appears to be a large storage tank. The surrounding landscape is a mix of green fields and brownish, possibly cleared or eroded, areas. The Google Earth logo is visible in the bottom right corner.

Cessation of oil storage in the tank farm and demolition of the tank farm was undertaken in 2002/2003.

2.4 Permit Variations

URS's records (URS, 2006), indicate that following correspondence between the then Environment Agency and site operators at BPLR, the landfill ceased accepting landfill materials in 1999 and the Environment Agency recorded the site as closed in July 2001. Since July 2001, reclamation and remediation works associated with the Coed Darcy development have been carried out within the permitted area (West Bay, South Bay and Crymlyn Bay) and up-gradient. Contamination of these areas is thought to have occurred due to leaks and spills from the tank farm historically located upslope of the Permitted Area and from inflow from the drainage system. Free product historically flowed both over ground and within the underlying strata prior to accumulating within these water features within the permitted area. The works to remove hydrocarbon impacted material and free product has included the following:

- Source removal of hydrocarbon impacted soils and free product to reduce migration of hydrocarbons into the Crymlyn Bog Lagoon from the former Southern Tank Farm area (now the Demonstration Village);
- Removal of hydrocarbon impacted sediments from West Bay and South Bay;
- Installation of various interception trenches and sumps to intercept residual free phase oil and to protect the remediated water bodies (including the Central Interception Trench);
- Removal and offsite disposal of over 400 oil drums from a former drum storage area; and
- Ongoing recovery of free phase oil from the landfill area.

Applicable validation and verification reports for completed works within and adjacent to the Permitted Area are documented within the Environmental Setting and Installation Design (ESID) Report, Atkins 2013, along with the site-wide monitoring report. These documents are:

- West Bay Verification report: 5041216-RAP-RPT-000541, May 2011
- South Bay Verification report: 5041216-RAP-RPT-000545, July 2011
- Development Village: 5041216-DV-RPT-000293, December 2010
- Containment Area Drum Disposal Validation Report R1353/10/3784, April 2010 & Drum Removal Extension Works 5041216-RAP-TN-0373, January 2011
- RAP Interpretive Report 5041216-RAP-RPT-327, Atkins, January 2011

Subsequently, in May 2012 a Site Condition Report (SCR) was prepared for St. Modwen by Atkins for partial surrender of the Permit and in September 2017 an application was made, with a final SCR, to surrender approximately one third of the permitted area known as the 'Coed Darcy Wetlands', covering approximately 49,000 m² and largely comprising lagoons and access tracks.

The wetland area was never used for waste disposal and historically formed part of the site wide drainage system with a direct outflow into the Crymlyn Bog SSSI to the west and north of the site. Since the closure of the refinery, the wetlands area was remediated through a combination of the agreed RAP works and other targeted remedial works to each of the various lagoons. This included the removal of impacts from the wider refinery. The SCR submitted as part of the application to surrender this area of the Permit detailed all of these aspects.

Accordingly, the Environmental Permit was part surrendered on 15th November 2017 and Schedule 1 of the Notice of Surrender provides the changed permitted site boundary. It has subsequently been retained as wetland habitat in line with the site masterplan.

2.5 Previous Risk Assessments

2.5.1 URS Tip Closure and Completion Strategy

In 2006, URS Corporation Ltd, (URS) produced a strategy document on behalf of BPLR.

The URS report presented relevant existing information for the Tip up until that time, produced environmental risk assessments, defined post-closure monitoring programmes, and proposed a final landform and restoration profile.

This report provided details of existing data up until 2006, this included geology, hydrogeology, hydraulic gradients, soil quality, free phase, groundwater quality and surface water quality. Much of this is relevant detail today and has been taken into account, together with details of remedial action and monitoring works since 2006. The risk assessments within this report are based upon the site's current status.

One aspect of the 2006 report that remains relevant and of key importance is the detailing of the status of the Crymlyn Bog. Relevant extracts from the URS report are provided below.

Crymlyn Bog:

Section 3.10:

'It is of importance to note that much of the immediate environs of the Tip have historically been subject to what must have been relatively extensive releases of hydrocarbon from the site. Although such operational losses are impossible following cessation of refinery operations, they have left a legacy of contamination in the form of residual hydrocarbon within parts of the shallow soil of the bog, albeit not necessarily visible at surface due to subsequent deposition of plant material.

URS has undertaken extensive sampling of the bog soils West of the Tip as part of the assessment of the risk posed by the site to the Crymlyn Bog and has assessed the risk potentially posed by this residual hydrocarbon and the potential leaching of hydrocarbon to groundwater and degradation of that hydrocarbon. This assessment concluded in summary that while the contamination observed may affect the water quality in areas of the bog and potentially affect the ecology in those areas, the most sensitive ecological features were likely to be protected by the hydrology of the bog, with the Glan Y Wern canal effectively providing a barrier to westward migration. On this basis, remediation of the residual source was considered likely to be much more destructive than beneficial to the bog, an assessment agreed with by CCW.

This data is considered of relevance to the Tip closure assessment in terms of the practical selection of compliance points, as dissolved phase discharge in groundwater from the Tip is in effect simply entering a source zone for similar material beyond the Tip itself. A summary of the contaminant data collected during this work is provided below.'

It is noted that the assessment of risk and the sampling referred to above relates to the Dames and Moore Historical Oil Spill Report June 2000. The objectives and scope of that report related specifically to a historical oil spill located west of the Containment Area, i.e., outside, but adjacent to, the permit area. The 2000 investigation concentrated on the oil plume from this spill moving west towards the Glan Y Wern canal. However, as URS did in 2006, the report provides useful comparisons with the potential impact from the Tip on the Crymlyn Bog in north and northwest direction.

2.5.2 URS Controlled Waters Risk Assessment Conclusions

Dissolved Phase

Section 5.2.7:

'Quantitative risk assessment simulates that dissolved phase hydrocarbon emissions from the Tip could cause exceedances of freshwater Environmental Quality standards in the bulk surface waters close to the Tip for benzene (whole Tip area) 1,2-dichloroethane (eastern area) and xylenes (western area).

Measurable concentrations of lighter molecular weight TPH fractions and toluene and ethylbenzene (these substances do not have EQS) are also simulated to occur as a result of groundwater discharge from the licensed area.

Modelling simulates that the EQS for BTEX would be complied with at a distance of between 15 and 65 m of the Tip margin. This indicates that the effects of contaminated groundwater discharge from the licensed area are unlikely to extend very far into the bog.

Regular monitoring of bog surface and groundwater indicates that BTEX compounds are present at lower concentrations than simulated by the assessment. Detection of BTEX compounds at concentrations above the method detection limit of 1µg/l has been rare, and EQS are substantially complied with for benzene and xylene. The model therefore probably underestimates the attenuation of BTEX, and although a risk is simulated it does not clearly exist in reality.

TPH concentrations in bog surface and groundwater are significantly higher than modelling simulates. The reason for this is likely to relate to contamination within the bog related to historic spillage. Measured TPH concentrations in the bog are therefore not necessarily a good indication of TPH discharge in groundwater from the Tip.'

This final conclusion is key, in effect a fate and transport model for contaminants of concern from the source within the Tip cannot be relied upon to simulate concentrations in dissolved phase downgradient of the Tip in the Crymlyn Bog since the bog itself is a source of contamination from decades of historical pollution.

In summary URS concluded in their detailed controlled waters risk assessment that no organic or inorganic contaminants posed any significant risk to controlled waters. Based on analysis undertaken it was concluded that the effects of contaminated groundwater discharge from the licensed area are unlikely to extend very far into the bog.

2.5.3 URS Ecological Assessment

The URS controlled waters risk assessment suggested that hydrocarbon which does migrate from the Tip is likely to attenuate quickly in the margins of the bog. This conclusion provided the basis for the RAP Works which focused on free oil containment and recovery as opposed to dissolved phase. In considering the potential ecological impact from the deposited wastes, URS state:

'..it is essential to consider the Tip in the context, as demonstrated in studies by both CCW and URS, of historical hydrocarbon loss to the bog and the resultant residual hydrocarbon source that is expected to decay, but over a long period of time.'

URS went on to suggest that:

'..future dissolved phase hydrocarbon release at the bog margin around the Tip is likely to be of limited significance in an area which has unfortunately been contaminated by hydrocarbons for an extended period. The sensitive plant assemblages (M9 and S27) for which the bog has been designated a SAC are, in any case, more than 500 m west of the Tip, adjacent to the Glan-Y-Wern Canal in an area where contamination from the refinery is considered unlikely on the basis of previous investigation work.'

2.5.4 URS Human Health Risk Assessment

The URS report considered that in a future restored scenario direct exposure to waste would be prevented by the cover materials and that, based upon assessments from other areas of the site, the risk to health from vapour migration in a public open space model were unlikely to be significant.

2.5.5 URS Landfill Gas Assessment

At the time of the URS report there had been no detailed assessment of the data collected to that date. It was considered that:

'..a minor source of landfill gas is likely to exist as a result of degradation of hydrocarbons.'

Conceptually, at the time, it was considered that any gas would migrate directly upwards and to atmosphere and even if permeability of the cap reduced, an underground gas migration pathway beyond the site is unlikely to exist since the site generally has a high-water table.

2.5.6 URS Outline Restoration Plan

Within the 2006 report an outline restoration plan was provided. This recognised the need for changes to ensure the final layout and topography provided long-term stability, control of surface water run-off, containment of wastes and a suitable aesthetic appearance.

Regarding the re-profiling and capping the report stated that:

'An estimated 40,000 m³ of material is required to deliver the scheme modelled in Appendix K to raise the levels and smooth out the slopes between the ash bund and South Bay. There is insufficient suitable material already within the licenced area, and it will therefore be necessary to import material to complete the restoration. No movement of existing deposited waste is envisaged during the reprofiling work to minimise the health and safety risk that hazardous materials such as asbestos are unexpectedly disturbed.'

This is broadly consistent with this 2023 Plan and as such the current Environmental Permit will need to enable suitable and verified material to be imported from other areas of the wider Coed Darcy development site or otherwise from an alternative source. Options appraisals undertaken as

part of the development of this 2023 Plan have also concluded that the deposited waste should, as far as possible, be left undisturbed. This is for health and safety as well as local environmental reasons, and also minimising wider environmental impact and the carbon footprint of extensive excavation and disposal.

Regarding the upgraded perimeter trench, this had not been designed at the time of the 2006 report, however, the reports stated that:

'It is proposed that this feature will be operated for a minimum period of 15 years. The system will be designed to minimise the potential for odour release and will be designed to be as 'invisible' as possible from the bog level and Tip access road.'

2.5.7 URS Aftercare Monitoring

The URS report proposed an aftercare monitoring programme to be performed until the Permit was surrendered. The report stated that:

'Monitoring data already collected for the site over the last 6 years forms the start of the closure monitoring programme and establishes a valuable baseline against which to assess stabilisation and elimination of significant risk to health or the environment.'

2.6 Atkins 2015 Closure and Aftercare Management Plan

The Closure and Aftercare Management Plan produced by Atkins Limited (Atkins) in 2015 was based upon a conceptual site model derived from a number of documents submitted in 2013 as part of the improvement plan set out within the Environmental Permit. These documents were:

- Environmental Setting & Installation Design (ESID) Report;
- Landfill Gas Risk Assessment & Gas Management Plan (LfGRA);
- Hydrogeological Risk Assessment (HRA);
- Capping of Crymlyn Tip -Construction Quality Assurance Plan; and
- Topographical Surveys for Settlement of Crymlyn Tip.

The documents were commented upon by NRW and discussed in a meeting in January 2014. A key aspect of this meeting was the scope of future monitoring of the Tip, the results of which are discussed in Section 3.19.8.

2.6.1 Atkins Monitoring Strategy

At the time of the 2015 Closure Plan, the assessments were based upon preliminary groundwater monitoring by Atkins between May 2008 and November 2010. It was noted that this monitoring was limited in scope, but also that it was conducted some 9 years after closure of the landfill and as such should be representative of how groundwater had been impacted by the landfill.

This report noted that monitoring undertaken indicated exceedances in TPH, BTEX and MTBE outside of the permit boundary, both up-gradient and down-gradient.

The report noted that further groundwater and surface water monitoring was required, and this is covered in Section 3 of this report.

The 2015 report noted that gas monitoring had taken place between October 2010 and May 2013 and then between October 2013 and May 2014. The report stated that:

'The findings of the monitoring identified that the landfilled area is still producing landfill gases, this is predominantly within the centre of the landfill as methane readings within this area were consistently and significantly above the 1 % value that is conventionally used for screening. The boreholes within the landfill, yet located around the periphery, seldom exceeded the methane threshold. The source of a landfill gas is plausibly to be from the degradation of placed hydrocarbon sludge waste.'

'Note: the landfill is built over alluvium and peat deposits and high levels of methane is also plausibly derived from natural gas production from organic rich soils. Localised gas bubbles are frequently observed within the lagoons on site, most notably West Bay and the Crymlyn Bog lagoon.'

The 2015 report concludes that further gas monitoring was required, and this is covered in Section 4 of this report.

2.6.2 Atkins Dissolved Phase

The Hydrogeological Risk Assessment undertaken by Atkins (2013) concluded:

'Groundwater monitoring data demonstrates that elevations of the COCs identified are not due to the presence of landfill material. For the most part, elevations and exceedances are sporadic, and a linkage cannot be made between the groundwater and potential landfill source. Further to this, concentrations of contaminants were generally found to be high in the boreholes outside of the permitted site boundary, particularly those to the south. This suggests that any contamination noted in the groundwater is the result of the Llandarcy Refinery.'

No numerical modelling was deemed necessary in view of the available monitoring data.

2.6.3 Atkins Free Product Migration

The 2015 report acknowledges that there are works to control free phase oil required as part of the section 106 agreement. The report notes that whilst the RAP works sit outside of the formal permit surrender process these items are considered contributory to the eventual permit surrender. The report notes that the specific RAP items include the active collection of oil from within the Tip as well as installation of permanent measures to prevent free phase migration including the peripheral trench and the central trench. The report goes on to say that the collection of residual oily free phase is ongoing and currently collected on a regular basis and removed from site and references the 2015 completion reports covering the peripheral and central trench features. The Completion Reports for these oil recovery trenches are discussed in Section 2.7.3.6 of the report.

2.6.4 Atkins Capping of Landfill

The 2015 report references the design and construction proposal for the capping and restoration of the land filled area submitted in 2013 to NRW. This report noted that the tasks involved in capping the landfill included reprofiling of the surface of the waste, installation of a cap on top of the waste, and installation of a restoration layer on top of the cap. This 2015 closure report proposed that materials for the capping works would be sourced from existing stockpiles of suitable soil in the wider Coed Darcy development site.

2.7 Remedial Actions Since the 2006 Closure Plan

2.7.1 The S106

As discussed in the previous section, the URS 2006 Closure Plan was issued prior to the completion of a substantial range of remedial actions.

The original permitted area, also referred to as the Containment Area, had a range of required Remedial Actions Works (RAP Works) agreed as part of a Section 106 agreement. It is emphasised that these remedial works were agreed as part of the planned redevelopment of the former refinery; and surrender of the Environmental Permit is not directly relatable to the detailed RAP Works. Detail is provided within this report, however, to provide context as to how landfill conditions have improved in comparison to the conditions and wastes pre-1977.

The objectives of the RAP Works were set out in Part 1 of Schedule 7 of the S106. These objectives included:

'Sub-Paragraph 1.3 (including paragraphs 1.3.1-1.3.5)'

'The parties to the S106 Agreement agree that the purpose and objectives of the RAP Works are the carrying out of the appropriate Remedial Action necessary, and sufficient in the context of both the current use of the Property and the Intended Use or such other use as may be determined from time to time:

'to prevent (or where that is not possible, minimise, remedy or mitigate as far as reasonably practicable the effects of) any harm to the Environment or any pollution of controlled waters or any possibility of such harm or pollution being caused in each case by or as a result of any Pre-Transfer Date Environmental Matter including containment of free phase Hydrocarbons with the Property boundaries; and

to avoid where reasonably practicable any Environmental Claim by any relevant Environmental Authority in relation to or in connection with any Pre-Transfer Date Environmental Matter, including without limitation to avoid service on any party in relation to or in connection with any Pre-Transfer Date Environmental Matters of:

a 'remediation notice' under Part IIA of the Environmental Protection Act 1990.

to take all reasonably practicable steps to seek to secure the final and unconditional acceptance by the relevant Environmental Authority of the surrender of the Waste Management Licence as soon as reasonably practicable.

The Developer shall carry out or procure the carrying out of all outstanding Remedial Action identified in Table 1 (of the S106 Agreement) in order to achieve the purpose and objectives set out in sub-paragraph 1.3 (including 1.3.1-1.3.5 thereof) of Part 1 of Schedule 7 of the S106 Agreement and the performance criteria specified in Table 1 (of the S106 Agreement) (and shall do so to the satisfaction of relevant Environmental Authorities) subject to any variations thereto that may be required in writing by the relevant Environmental Authorities from time to time.'

2.7.2 Purpose of the RAP Works

The RAP works were an outline programme of remedial actions agreed between the previous site owner (BP) and the relevant environmental regulators which were designed to protect ecological and controlled waters receptors close to the site. The environmental receptor identified as the focus of remedial actions for the RAP works associated with the landfill was the Crymlyn Bog.

The RAP Works relating to the Containment Area listed the following key issues:

'Free product migration from filled area into Crymlyn Bog, Crymlyn Bog Lagoon and South Bay.'

The performance criteria broadly consisted of removal of free product from the main landfill area to asymptotic conditions and installation of permanent measures to prevent free product from leaving the site boundary towards the Crymlyn Bog, while permitting the free flow of groundwater past any interception features and to permit recovery of product. At the time of the S106, a temporary recovery system had been installed in 2005 and the original periphery trench bund was in place.

'Hydrocarbon-containing peat and sludge'

This involved the removal of contaminated sludges from South Bay, West Bay and Crymlyn Bog Lagoon in order to allow the surrender of the WML.

'Surrender of Waste Management Licence EAWML34004'

The objectives were to agree a programme of works with the EA to permanently restore the Tip and secure the Waste Management Licence surrender. Ensuring long term security and immobilisation of wastes in the filled areas.

'Dissolved-phase hydrocarbon discharge to Crymlyn Bog'

This involved the construction of a permeable cap over a re-profiled fill area, with an altered drainage regime such that flow to the Crymlyn Bog from the site is diffuse. The aim was to reduce dissolved phase hydrocarbon load in groundwater and surface water leaving the Tip and entering the Crymlyn Bog.

2.7.3 Summary of Remedial Actions Completed

The following sections summarise the remedial actions completed at the site to date.

2.7.3.1 1990s - To Date - Peripheral Trench

The peripheral trench is a linear oil interception feature that runs around the outer boundary of the ash bund of the Containment Area, separating the Tip from Crymlyn Bog. The trench was originally installed in the early 1990s by BP, and recovery of oils was undertaken periodically since that time by BP.

This original peripheral trench was subsequently upgraded as required by the S106 RAP Feature 7 and now consists of an approximately one-metre-wide trench with a 600 mm plywood interceptor to allow water to pass freely beneath whilst surface oil is intercepted and prevented from entering Crymlyn Bog.

Atkins carried out an audit of the peripheral trench in 2008. The audit identified areas of ineffective containment and damage to boards and areas of overgrowth preventing proper inspection.

The audit highlighted the need for works to be carried out to improve the integrity and efficiency of the collection trench. A further walkover was carried out by Atkins and Hawk in February 2009 to review the serviceability of the trench during periods of higher water levels and the most practical options for trench maintenance. A technical note (ref 5041216/RAP/299/CLI/HM/TN/0067 'RAP - Peripheral Collection Trench Maintenance Works Update - February 2009, Appendix B of Atkins, RAP 7 Completion Report) was produced highlighting key issues with the trench, areas identified for further review and recommendations to improve the peripheral trench including;

1. Insertion of baffles within the trench at 50 m Intervals (25 m in the worst affected areas) in order to allow:
 - definition of the areas of greatest free product discharge.
 - improve skimming efficiency through greater product thicknesses in trench sections.
 - reduce trench vegetation discolouration where baffles prevent the migration of free product along the length of the trench.
 - an automated system of skimmers to be commissioned in the most productive sections of the trench in terms of free product recovery.
2. Provision of a working platform on the Crymlyn Bog side of the collection trench to allow:
 - a safe working area from which to carry out maintenance, alterations or additions to the trench and baffles.
 - a safe working area from which to carry out free product recovery.
 - clearance of vegetation beneath the length of the working platform.
3. The provision of netting over the collection trench to prevent leaf litter and vegetation debris from entering the trench to:
 - remove the need for hand clearance of dead vegetation within the trench prior to product removal.
 - improve monitoring of the free product within the collection trench and reduce the build-up in unsightly dead vegetation heavily impacted by hydrocarbons.
4. Repair of breaches in the boarding forming the trench to:
 - prevent free product from migrating to the Crymlyn Bog.

The reasons for these upgrades were outlined in the technical note.

In winter 2010, works on the peripheral trench were undertaken by Hawk, to include the recommendations above. Areas of the trench were also re-modelled with areas of oil saturated ash cleared out at the base of the Tip slope, increase in board height to prevent overtopping and installation of a defined eastern terminus.

A photo audit was undertaken during 2012, the audit shows visibly reduced spatial distribution of oil following trench maintenance and improvement works. A photo audit of the trench was also undertaken during 2015.

A RAP Completion Report for the upgraded peripheral trench was completed by Atkins in May 2015. The report concluded that, following trench inspection and upgrades:

'it is considered that the works have achieved the requirements of the RAP in relation to the installation of the RAP feature 7 as set out in the Section 106 Agreement for the Coed Darcy development. A continuous programme of free phase recovery is envisaged together with a monitoring and maintenance programme to ensure continued effective operation'.

The Atkins RAP Completion Report also included an operational assessment of the peripheral trench, the main conclusions were:

- Observations during oil recovery have continued to show the main areas of oil release is in the area opposite the main, or Upper Tip.
- This area is highlighted on Atkins RAP 7 Status Plan in Appendix A as the zone of moderate to high seepage. These higher seepages are clearly linked to the significant volumes of residual oil which remains within the Upper Tip.
- In the lower area, west of the Upper Tip, seepages at the northern margin have been of much lower intensity and anecdotally more responsive to rainfall events when greater product volumes are recovered. Remediation works in the lower area in 2014 and 2015 targeted residual areas of oil and revealed a series of waste filled product pockets and layers which were previously unrecorded. This, to an extent, explained, the unpredictable pattern of oil recovery.
- The northern boundary of the lower area is still formed by the ash bund, which was not removed during these remedial works, due to risks of significant pollution of the Crymlyn Bog. The ash in this area remained oil saturated at that time.
- Although not proven, a historic hydraulic link along the ash bund to the main Tip is entirely plausible and which would have comprised a significant conduit for the westward migration of oil along the northern margin. This link whilst not wholly severed is considered much reduced by the presence of the open central trench (see Section 2.7.3.6).
- In the former southern limb of the BP trench, west of the Crymlyn Bog Lagoon, observations since 2008 have continued to show little evidence of significant oil seepage along this margin. Although the presence of oil in the ground in this area is possible, ground levels in this area are close to groundwater level and the presence of Crymlyn Bog Lagoon has plausibly acted as a hydraulic cordon preventing the westward migration of significant volumes of oil in a reduced hydraulic gradient.
- In the east, beyond the existing eastern terminus of the trench, observations of product seepage were restricted due to the presence of vegetation and steep gradients.
- An access track created in 2014 has allowed observations to be made along the whole of the margin of the Crymlyn Bog which confirms the general absence of significant oil seepage.

The report concluded that; the western 'southern' limb is not required for oil retention/recovery and can be abandoned. The eastern extension of free phase release from the Containment Area is well established through observation and no further extension of the trench east and north-eastwards is required. In the trench section opposite the main Upper Tip, free phase recovery remains a necessity to manage the continued flows from the Tip. In the trench section opposite the 'lower' containment area, although works have reduced some sources, a retention and collection capacity is still required in the short to medium term.

Historically, monitoring has indicated that most of the central and eastern portion of the peripheral trench to have moderate to high oil seepages with the western and most eastern portion to have low to moderate levels of residual sheening and oil observed.

Collection Points 1 and 4 along the eastern portion of the peripheral trench tended to have the highest monthly oil recovery during the monitoring period of November 2019 to June 2022, with these collection points being the main focus of recovery. Oil recovery has continued at a relatively steady rate throughout this period.

Recent on-site observations indicate oil in the peripheral trench has visibly reduced in spatial distribution. Englobe conducted a survey of the peripheral trench during November 2022 to compare against photographic evidence of oil distribution from the period 2008-2015 to present. The photographic audit shows that areas of oil on the surface of the water in the peripheral trench are now limited in extent and sporadic. The photo audit is included in Appendix B along with a Drawing of photo locations. Atkins 2008 photographic audit is also included in Appendix B for comparative purposes.

2.7.3.2 2008 Capping Material

Just prior to the transfer of ownership from BP to St. Modwen there was a placement of approximately 15,000 m³ of soil material won from the wider site (known to contain asbestos), across central and eastern areas of the Tip. This was intended to be initial capping material with thicknesses of between 0.5 and 1.5 m. The capping appears to have included the sludge pits to the southeast of the main Upper Tip, which themselves had been subject to prior remedial action and infilling with material of unknown origin. It is assumed that similar covering was made to the deposition areas for asbestos, vanadium and pyrophoric wastes situated in the southeast of the Permit area.

2.7.3.3 2009 - 2011 Main Tip Free Phase Recovery

Delineation and free phase hydrocarbon recovery from the Upper central and eastern Tip areas was completed by Celtic Technologies Ltd between 2009 and 2011. The works included installation of 45 initial boreholes, followed by a further 20 boreholes in areas of high free oil recovery to increase coverage of the plume. This was over five times the amount recommended by the Section 106 RAP Feature 6.

These boreholes enabled the broad delineation of the main upper landfill area along with the distribution of free oils.

After 80 weeks of operation, 484,000 litres of LNAPL were recovered from the fill area. Recovery rates dropped from a peak of 6,000 litres per day to 55 litres per day, equating to a reduction of 99 %. Asymptotic conditions were reached in December 2010 and sustained for 16 weeks prior to the shutdown of the treatment system.

The validation report for these works, (R1296/11/3742 Free Product Recovery Validation Report, July 2011), received RAP sign off and NRW approval.

2.7.3.4 2010 Drum Removal

Atkins were commissioned by St. Modwen to investigate a known drum storage area to determine appropriate management measures. The drum storage area was located to the north of the Crymlyn Lagoon within the Permit area. Following trial pitting works a detailed assessment was undertaken. Atkins concluded that the majority of the drum contents had either long since escaped or may have originally been placed empty. The remaining remnant materials appeared to be either partially contaminated or of low physical mobility.

The continuing impact of material within the drums was considered marginal, given the existing contamination within the Permit area in general and for this reason, removal of the remaining drums was deemed unlikely to lead to a demonstrable improvement in water quality. Due to long-term proposed open space end-use, actions were recommended to manage perceptions and residual risks including removal of remaining liquid product from intact drums where practicable and placing of fill, marker layer and restoration soil in the area.

In 2009, Celtic Technologies Ltd were commissioned by St. Modwen to undertake the removal of these wastes. The drum removal/contaminated soil excavation works enabled the recovery of an approximate total volume of 5,450 m³ (approx. 1,930 tonnes) of waste which was disposed of to landfill.

The drum removal works consisted of 103 lorry loads and the removal of approximately 600 drums from within the identified 'drum grave' area. The removal works, including validation, were completed on 13th November 2009.

The works undertaken were considered sufficient to reach the agreed target of removal of all the drums within the area delineated by Atkins, which was reported in Atkins 2015 Drum Grave Validation Report.

2.7.3.5 2010 - 2012 Sludge Removal

Over the course of the period 2010-2012, the removal of 4,000 m³ of hydrocarbon impacted sludge from South Bay, 2,000 m³ from West Bay, 8,500 m³ from Crymlyn Bog Lagoon East, and 5,000 m³ from Crymlyn Bog Lagoon West was completed as required by RAP Features 10 and 11.

This was a key aspect that facilitated the partial surrender of the Environmental Permit covering these drainage features and surrounding land, and the interaction of this area with surface waters and the Crymlyn Bog.

2.7.3.6 2011 - 2014 Oil Interception Trenches

A free product interception feature was installed between the former main Upper Tip area, and the key waterbodies (South Bay and Crymlyn Bog Lagoon), as shown on Drawing 5041216-REM-DWG-1010 in Appendix A. The installation of the trench was carried out by Celtic Technologies Ltd in December 2010. This feature was designed to prevent residual free phase hydrocarbons migrating from the landfilled area to the north into the Coed Darcy Wetlands and to comply with the RAP Feature 8 requirement of the Section 106 to 'demonstrate environmental improvement'.

The trench was excavated to intercept the groundwater table at a depth of between 2 and 5 m bgl and was backfilled with a 6F2 granular fill to create a preferred pathway for product migration. Details of the trench installation are more comprehensively discussed in the validation technical note produced by Celtic.

The free product was directed to 20 monitoring/abstraction sumps installed along the length of the trench at 20 m intervals. During an active recovery phase, each sump was monitored by Atkins on a weekly basis between January and July 2011 then at a fortnightly to monthly frequency until February 2014.

Product recovery was undertaken from the central trench following its installation and commissioning in January 2011. Product recovery was initially managed and conducted by Celtic from December 2010 until June 2011 followed by Hydrock from October 2011.

20,000 litres of product were recovered from the Trench by Celtic between January and July 2011, predominantly from the western limb of the trench. From summer 2011, product recovery was undertaken on a Containment Area wide basis, including from the Central Trench. Definitive volumes for product recovery from the Central Trench are therefore not available after summer 2011 as recovery volumes provided by Hydrock related to all product recovered within the Containment Area.

During 2012, Hydrock conducted a series of product recovery trials over the wider Containment Area, which included the Central Trench, in order to explore options to maximise product recovery. Following the trial additional works were undertaken to optimise product recovery, including;

- Excavation of a French drain/channel from the landfilled area to Sump 19. Monitoring results in 2012 suggested a source of significant quantities of free product that was being monitored at Sump 19. Excavation around Sump 19 was carried out to extend the trench towards the adjacent landfilled area. Consistent with the Central Trench itself, this additional section of trench was backfilled with granular material.
- Installation of a clay cut-off bund between Sumps 10 and 11 Based on monitoring data, a distinct boundary appeared to exist between mobile free product impacted ground and non-impacted ground. The clay bund was installed between Sumps 10 and 11 to prevent down gradient migration of free product to the east along the trench.

Recovery operations were then focussed upon the western limb of the trench. This included the excavation of an open sump feature (RAP recovery trench A) located between Sumps 9 and 10, to further facilitate product recovery and flow. (This was undertaken to increase the efficiency of oil recovery behind the Central Trench and not due to faults within the trench).

No evidence of free product has been noted upon either of the two adjacent waterbodies (South Bay and Crymlyn Bog Lagoon) since the installation of the trench.

It was considered unlikely, in the long term, that sole reliance would be placed on the Central Trench to manage all free phase migration within the Containment Area. Monitoring of the trench was continued as one part of the active oil recovery system across the Tip and the wider Containment Area.

Free product has not been seen to outbreak at any locations downgradient of the trench.

Additional investigations have been carried out to the north and south of the trench together with localised free product removal since this time. Ongoing monitoring of the waterbodies to the south of the central trench to date continues to show no sign of hydrocarbon impact as reported in Atkins 2012 Partial Surrender Report.

Since at least 2018 pumping has not been undertaken from the Central Trench, with pumping focussed on recovery points along the Peripheral Trench and a number of sumps and boreholes across the site.

2.7.3.7 2014 - 2015 Lower Tip Remediation

In 2014, the Site 1 area underwent an intensive investigation for sources of residual free phase product. The intention of this works was to remove 'significant' areas of free phase with the Site 1 and reduce reliance on the sections of the Peripheral and Central trenches which lie adjacent to the Crymlyn Bog and the Crymlyn Bog Lagoon, respectively. These sections of the interception trenches were historically the least impacted and it was anticipated that, after a suitable period of monitoring and agreement, sections of the trenches could be progressively abandoned allowing natural vegetation to re-establish itself.

Remediation of the western Lower Tip element of the Tip was carried out by Hydrock between September 2014 and March 2015. This involved the excavation of waste fill down to the underlying peat in most areas and the removal of free oils by either skimming from water in excavations or the draining of oils from excavated soils.

The waste fill was found to contain a mix of anthropogenic material including, barrels, pipes and hoses, laboratory glassware, timber and asbestos containing material including gaskets, rope, and fire blanket. Metal waste including barrels, pipes and steel girders were left to drain of free phase hydrocarbons before removal off site for recycling.

The waste was found to have an average thickness of between 3 and 4 m, although the base of waste fill was unconfirmed at depths of 7 m bgl in the south eastern corner of the Lower Tip. The waste was found to directly overlie soft brown fibrous peat which was shallower in the northern part of the Lower Tip (approximately 1.5 m bgl) compared to the south (approximately 5 m bgl). The waste fill in the Lower Tip is bound to the north by the ash bund. Perched water in the waste material was recorded at broadly the same level as in the Crymlyn Bog to the north and the Coed Darcy wetlands to the south, at approximately 3.5 m below the surface of the waste.

The extent of the turnover works was confined to the north by the ash bund which could not be excavated due to instability and the potential for ingress of water from the Crymlyn Bog. A series of sumps were installed along the northern boundary in the ash bund to allow any residual free phase hydrocarbons to be recovered. These sumps have remained in place and have been monitored on a monthly basis.

The remediation aimed to prevent oil product and residual impact on the Crymlyn Bog and the remediated lagoons (to the south), and to collect and remove all free product and the bulk sources of oil from the Lower Tip. The total oil recovery is not known but is conservatively estimated at 50,000 litres.

It was considered at the time that with the bulk sources of oil removed from the Lower Tip, residual oil present in the ash bund would drain out into the peripheral trench over time. This assumption appears supported by the findings of the peripheral trench completion report and Englobe's recent audit, and this work therefore had the effect of reducing the reliance on the peripheral trench along the western portion of the northern boundary.

Further details of these works are included in the PJA's Lower Tip Works technical note included as Appendix C.

2.7.3.8 2020 Central and Eastern Tip Trial Pits.

On 28th March 2022, 12 trial pits (TP1-12) were excavated in the central and eastern Tip area by PJA.

All trial pits were excavated to a depth of between 4 m bgl and a maximum of 5.5 m bgl. The majority of trial pits were terminated at around 4 m bgl due to instability of the pit, some due to groundwater or oil ingress, two pits contained or were suspected to contain barrels of bitumen.

All the pits contained made ground. The presence of oil was noted in a third of the pits. One pit was terminated at 3.5 m bgl on encountering natural peat.

2.7.3.9 2011 - 2022 On-going Oil Recovery

2011 to 2018: Oil recovery by Hydrock from the peripheral trench, boreholes with the Central Tip area and a number of oil recovery trenches. Over this period approximately 1,050,000 litres of oil were recovered.

2019 to date: Oil monitoring and recovery from the peripheral trenches, sumps and boreholes by Geo-environmental Applications Ltd (GAL) and overseen and reported by PJA. In excess of 80% of the recovered oil now comes from a central 200 m length of the peripheral trench along the northern boundary of the upper Central and Eastern Tip area.

It has been estimated that in total some 1.8 million litres of oil has been recovered from the Tip since 2008.

2.7.4 Monitoring Since Landfill Closure

There has been a history of monitoring programmes pertaining to the landfill since its closure in 1999. The following sections summarise the monitoring that has been undertaken to date.

2.7.4.1 URS 1999 - 2005

Following the development of the Remedial Action Plan in 2000, a routine programme of groundwater monitoring (both for quality and the identification of LNAPL) was conducted every March and September by URS at selected wells across the wider site area, including a subset of those in the Tip.

The dipping round typically comprised measurement of the depth to product and groundwater using an air/ oil/water interface probe. In the original sampling round in March 2000, a total of eight surface water locations, six bog wells, eight deep well and five shallow wells were analysed from within the Tip, for one or more of DRO/GRO, BTEX, Natural Attenuation Parameters and PAHs.

In September 2005 this was reduced to seven surface water, four shallow well and two bog wells for DRO analysis, one shallow well for PAH analysis and two surface water and one shallow well for GRO/BTEX analysis within the Tip. The results were routinely reported to the Environment Agency according to the 2006 URS BP Llandarcy Remedial Action Plan, Tip Closure and Completion Strategy.

As appropriate, this data has been reviewed and utilised within surrender risk assessments within this report and is referenced accordingly in those sections.

2.7.5 Atkins 2008 - 2013

2.7.5.1 Groundwater

Prior to the production of Atkins 2015 Closure and Aftercare Monitoring Plan preliminary limited groundwater monitoring was undertaken by Atkins between May 2008 and November 2010. The

groundwater monitoring was undertaken to determine water quality and groundwater levels, as presented in the 2013 Atkins Environmental Setting and Installation Design (ESID) Report, the monitoring locations are shown in Appendix B of that report (ESID Drawing).

Samples of the groundwater were taken in May and October 2008, April and November 2009, May and November 2010. Samples were taken from 5 locations within the Tip; MSMW154, MSMW155, MSMW156, MSMW034 and MSMW035.

2.7.5.2 Free Oil

The monitoring between May 2008 and November 2010 also involved periods of free oil product recovery, from selected boreholes within the Central Tip, and from RAP Features 7 and 8.

2.7.5.3 Landfill Gas

Up until the issue of Atkins Landfill Gas Risk Assessment (LfGRA) in June 2013, a number of boreholes within the landfill and surrounding area were monitored monthly using a portable infra-red analyser for % methane by volume, % carbon dioxide by volume, % oxygen by volume and atmospheric pressure, with results reported annually to the Environment Agency.

Periods of gas monitoring were undertaken by Atkins in October/November 2010, April and November/December 2011, January 2012, May 2013, February and April/May 2013 and April/May 2014. 21 gas wells were monitored within the landfill, some which had both deep and shallow installations sampled. Monitoring locations are shown on Drawing 5041216/RAP/DWWG/1513 from the Atkins ESID report.

As appropriate, this data has been reviewed and utilised within surrender risk assessments within this report and is referenced accordingly in those sections.

2.7.5.4 2018 Onward Monthly Monitoring

Since 2018, a programme of monthly monitoring has been undertaken at the Tip (the monitoring locations are shown on the PJA Drawing 04020-A-SK201-P2 in Appendix A). The monitoring has been undertaken in order to satisfy Condition 4.2.2 (a) of the Crymlyn Tip Environmental Permit EPR/AP3990LR and subsequent variations (the Permit), which states:

'4.2.2 A report or reports on the performance of the activities over the previous year shall be submitted to the Environment Agency [now Natural Resources Wales] by 31 January (or other date agreed in writing by [NRW] each year. The report(s) shall include as a minimum: a) A review of the results of the monitoring and assessment carried out in accordance with this permit against the relevant assumptions, parameters and results in the risk assessments submitted in relation to this site and any agreed amendments thereto'.

Between January 2018 and March 2019 Atkins undertook the monthly monitoring programme. Since April 2019 PJA took over the responsibility for monitoring and reporting the findings with Geoenvironmental Applications Ltd undertaking the monitoring onsite overseen by PJA. The findings of the monitoring are included in monthly monitoring reports and annual reports, with the 2021 Annual report being the most recently available at the time of writing.

The monthly monitoring includes:

- Monthly surface and groundwater sampling with laboratory testing
- Monthly groundwater level monitoring
- Monthly LNAPL and DNAPL monitoring
- Ground Gas Monitoring

As appropriate, this data has been reviewed and utilised within surrender risk assessments within this report and is referenced accordingly in those sections.

2.7.5.5 Groundwater and Surface Water

Groundwater is monitored from 27 monitoring locations and 13 sumps within the permit boundary. Surface water is monitored from six locations outside the permit boundary. Monitoring locations are shown on the D1870/23/5289/04 in Appendix A.

The monthly surface and groundwater analysis suite includes pH, ammonia, ammoniacal nitrogen, chloride, dissolved and total metals, hardness, total petroleum hydrocarbons criteria working group (TPH-CWG), BTEX compounds, MTBE and polycyclic aromatic hydrocarbons (PAHs).

2.7.5.6 Landfill Gas

Ground gas monitoring is from ten locations within the landfill permit boundary and three locations outside the permit area, the monitoring is for % methane by volume, % carbon dioxide by volume, % oxygen by volume and atmospheric pressure using a GA5000 gas analyser.

2.7.6 Residual NAPL Extent

Works to control free phase oil were required as part of the Section 106 Agreement for the Coed Darcy development. Specific RAP items relating to the Tip included:

Active collection of oil from within the tip by a system which hydraulically effects the free product until asymptotic conditions are demonstrated.

Installation of permanent measures to prevent free phase migration:

- At the western margins of the tip adjacent the Crymlyn Bog - Peripheral Trench
- Adjacent Crymlyn Bog lagoon - Central Trench
- Up flow of the tip to prevent residual oil migration onto the licensed area

These elements of the RAP works have been completed as detailed in Section 2.6.3. The collection of residual oily free phase product from a number of locations is on-going and is currently collected on a regular basis and removed from site to a licensed facility for disposal or recycling. Monitoring and recovery of NAPL has been carried out by PJA and GAL since 2019 and records of these works are included within Appendix D. Review of the data collected as part of these works have indicated:

- It is not considered that there is a significant presence of Dense Non-Aqueous Phase Liquid (DNAPL) warranting any further action;
- LNAPL thicknesses vary monthly and seasonally, as would be expected, with a generally inverse relationship to groundwater levels;
- Two main hotspots are apparent; an area to the east of the bisecting trench, centred on CBH13 and an area further to the east within the Tip, centred on CBH32, CBH36 and CBH39;
- Since the commencement of LNAPL recovery works under the supervision of PJA in 2020, LNAPL thicknesses have reduced in these hotspot areas, as indicated from the monthly monitoring records.

2.8 Englobe 2022 Investigation

2.8.1 Introduction

As discussed in the previous sections, there is substantial information and data available for the permit area based upon past site investigations, draft closure plans, risk assessments and on-going permit compliance monitoring. This data has been utilised within this Restoration Implementation Plan

However, some immediate data gaps existed and therefore a range of site works were undertaken by Englobe through October to December 2022. The site investigation works undertaken are

described in full in Englobe’s Factual Site Investigation Report, R1870/22/5262, Appendix I and Englobe’s Stockpile Report, C1870-KS-SM-11.22.001, Appendix J and are summarised in the following sections.

2.8.2 Geotechnical Boreholes

13 No. boreholes were drilled by Geotechnical Engineering Ltd between October and November 2022 in order to gather further data, principally from the periphery of the landfill area where data gaps existed.

The data required included groundwater levels to the south and south east of the Tip, groundwater levels from the periphery of the landfill and the underlying geology in these locations.

On-site geotechnical testing was undertaken during drilling works from specific boreholes and samples were retrieved to allow specific geotechnical and chemical analysis. Geotechnical testing including moisture content, organic matter, particle size distribution (PSD), compaction, shear strength, liquid and plastic limit and bulk density was undertaken on selected samples to provide data for the stability and hydrogeological risk assessments.

A total of 142 soil samples were retrieved from varying depths during the drilling works and 83 of them were subject to various laboratory geotechnical analysis. In-situ geotechnical testing was undertaken where appropriate.

A total of 16 soil samples were submitted for laboratory chemical analysis.

Following the drilling works, each location was installed with groundwater/ground gas standpipes comprising HDPE slotted and plain pipework, as directed by the supervising engineer, depending on the required response zone. The borehole was then backfilled with 2-6 mm filter pack (graded washed gravel) to 0.1 m above the top of the response zone and bentonite pellets from the top of the gravel up to 0.5 m below ground level. The boreholes were completed with rubber bung and gas tap and headworks were constructed comprising flush steel secure covers concreted in place. The installed boreholes have been surveyed to record their co-ordinates. Selected groundwater monitoring boreholes have also been subject to permeability testing.

The geology encountered during this phase of investigation appears to be consistent with previous findings.

Table 2 below summarises the ground conditions encountered during the site investigation. Further details are provided in the Factual Site Investigation Report in Appendix I.

Table 2 - Summary of Ground Conditions

Description of Strata	Thickness (m)	Maximum Depth to Base (m bgl)
Northern Ash Bund (ENBH01 to ENBH05)		
Made Ground: Variable content including clay, silt, sand, gravel, ash, slag, clinker and brick	Varying from approx. 2.7 m toward the west decreasing to 0.6 m toward the east	2.7
Made Ground: Loose to very loose black sandy angular to subangular gravel of ash with occasional slag cobble	Varying from approx. 4.5 m toward the west increasing to 13.2 m toward the east	14.1
Superficial Geology: Yellow brown fibrous peat	Varying from approx. 2.75 m toward the west and 1.3 m toward the east	15.4

Description of Strata	Thickness (m)	Maximum Depth to Base (m bgl)
Superficial Geology: Soft to firm grey clay, sometimes sandy or gravelly	Varying from approx. 1.45 m toward the west and 0.2 m toward the east	16.6
Superficial Geology: Clayey sandy gravels and cobbles of mudstone and sandstone	Not proven	Not proven
Western, Southern and Eastern Perimeter (ENBH06a to ENBH11)		
Made Ground: Variable content including clay, sand gravel, ash, clinker, brick, concrete, bitumen, cobbles (of brick, slag, concrete, sandstone)	Varying between 1.1 and 7 m	7
Superficial Geology: Yellow brown fibrous peat	Varying between 2.4 m and at least 3 m	Not proven, at least 10 m
Superficial Geology: Firm grey clay, sand, gravel	Not proven	Not proven

Visual and olfactory observation of contamination were recorded during the site investigation. Observations ranged from slight to strong hydrocarbon odours and oily sheens/residues to free oil within the made ground and slight chemical/hydrocarbon odours and black staining within the peat. Further details are provided within the Factual Site Investigation report in Appendix I.

2.8.3 Groundwater Monitoring

11 No. of the boreholes were installed to allow groundwater monitoring. The installed boreholes have been surveyed to record their co-ordinates and levels and have been subject to monitoring to record groundwater elevations and presence of NAPL.

2.8.4 Stockpile Testing

A number of historic stores of treated material are present on the Tip, (these are shown in the drawings within the Stockpile Report in Appendix J). These stockpiles (7 No. in total) have been identified as potential restoration layer materials for the Tip and were therefore investigated to provide an initial indication of their chemical suitability for re-use, within the construction proposals for the Tip.

In addition, materials primarily of glass waste stockpiled at the former Glasstech Recycling Ltd site within St. Modwen's land (offsite to the southeast of the site, situated on Tank Farm road) have been identified as possible materials for the re-profiling of the Tip, subject to processing. These stockpiles were investigated to provide initial indication of their chemical suitability for re-use on site. The following sections summarise the investigation, the works are reported in Englobe's Stockpile Report, C1870-KS-SM-11.22.001 Appendix J.

2.8.5 Crymlyn Tip Stockpiles

The previously treated material, formerly known as stockpiles 162 - 167 and stockpile 171 were re-named as stockpile SPE-1 to SPE-7 respectively. Stockpiles SPE-1 to SPE-7 are estimated to total 25,830 m³.

Between 1st and 3rd of November 2022 following vegetation clearance, 21 trial pits were excavated by Englobe into the stockpiles SPE-2 to SPE-7 shown on Drawing D1870/SP/A in Appendix J. The stockpile SPE-1 was inaccessible due to the extent of overgrowth present.

Representative composite samples of the stockpiled material were taken from pit arisings, which were collected using stainless steel tools or by hand and placed in laboratory supplied containers. The samples were stored in cool boxes with ice packs until courier transport to the laboratory and analysed for various analysis suites to provide initial indication of suitability of their re-use, the analysis suites are summarised as follows;

- Standard Suite: Loss on ignition (LOI), moisture content, stone content, phenols, PAH (EPA 16), TPH (CWG), cyanide (total, complex, free), thiocyanate, elemental sulphur, sulphate, chloride, ammonium, PCB (7 congeners) metals, asbestos screen and ID.
- WAC Analysis (inert solid and single stage 10:1).
- Asbestos quantification if required.
- PFAS.
- SVOCs.
- VOCs.
- SVOC TICs (Tentatively Identified Compounds).
- VOC TICs.

The analysis results are included in the stockpile report in Appendix J.

For each sample the location was recorded, photographs of the sample materials taken, and a description of the material logged. The logs and photographs of each sample are in appended to the stockpile report in Appendix J.

Most materials sampled from stockpiles SPE-2 to SPE-6 comprised brown silt with frequent wood chip and inclusions of various building materials, occasional waste materials and gravel. Olfactory evidence of contamination ranged from 'no odour' to 'moderate hydrocarbon odours'.

Materials from stockpile SPE-7 were wet, dark grey silts with frequent wood chip and occasional cobble and boulders with olfactory evidence of contamination from strong to very strong hydrocarbon odours recorded.

2.8.6 Glasstech Stockpiles

Stockpiles identified as potentially suitable for use as part of the construction proposals for re-profiling of the Tip were Stockpile GT-1 'unprocessed materials' and Stockpile GT-3 '<20 mm screened materials' (shown on Drawing D1870/SP/B in Appendix J) at the former Glasstech Recycling Ltd site. Stockpile GT- 1 is estimated at approximately 30,306 tonnes, Stockpile GT-3 is estimated at approximately 400 tonnes.

On 4th of November 2022, 10 samples of stockpile material at the former Glasstech Recycling Ltd site were obtained by hand from SP-GT 1 'unprocessed' material and SP-GT 3 '<20 mm screened' material. Samples were taken across accessible areas of the stockpiles. Samples representative of the sample locations were collected using stainless steel tools and placed in laboratory supplied containers. The samples were stored in cool boxes with ice packs until courier transport to the laboratory. Samples were analysed for various suites of determinands to provide initial indication of suitability of their re-use, the analysis suites are summarised as follows;

- Standard Suite: LOI, moisture content, stone content, phenols, PAH (EPA 16), TPH (CWG), cyanide (total, complex, free), thiocyanate, elemental sulphur, sulphate, chloride, ammonium, PCB (7 congeners) metals, asbestos screen and ID.
- WAC Analysis (inert solid and single stage 10:1).
- Asbestos quantification if required.
- SVOCs.
- VOCs.

The materials encountered were described as follows; SP-GT-1: mixed broken glass of various sizes and thickness with abundant waste plastic, occasional other waste materials, sometimes with silt/soil-like coating, SP-GT-3: Screened mixed broken glass generally of <20 mm size, with occasional fragments of plastic with silt/soil coating. Aside from the inclusion of household waste (mostly plastic) materials there was no other visual or olfactory evidence of contamination.

For each sample the location was recorded, photographs of the sample materials taken, and a description of the material logged. The logs and photographs of each sample are appended to the stockpile report in Appendix J.

2.8.7 Landfill Gas Monitoring

In order to provide additional data for the landfill gas assessment, (summarised in Section 7.3 and included in Appendix I), two of the boreholes drilled during this site investigation were installed to allow additional ground gas/vapour monitoring to cover one location in the north and one in the south of the periphery of the Tip, these locations are shown on Drawing D1870/23/5289/15 in Appendix A.

Ground Gas Solutions Ltd (GGS), landfill gas specialists, attended the site during December 2022 to undertake an initial programme of works. The objectives of this site work were as follows:

- To undertake site reconnaissance, to identify any further relevant issues.
- To assess the presence, condition and ongoing suitability of any pre-existing landfill gas monitoring infrastructure.
- To undertake real-time comparison of observed methane concentrations using both a GA5000 infra-red (IR) gas analyser and a methane-specific tuneable diode laser (TDL) gas analyser.
- To collect landfill gas samples from selected wells for subsequent laboratory analysis to identify absolute methane and Total Volatile Organic Compound (TVOC) concentrations using flame ionisation detection (FID) gas chromatography (GC) and mass spectrometry (MS) for comparison with results gathered in the field.
- To survey the Area 2 (see Appendix I for definition) surface for any significant sources of methane and/or TVOC emissions (and if detected, to seek to quantify their relative flux at the time of surveying).
- To deploy continuous monitoring equipment within select monitoring wells to provide improved information of equilibrium gas concentrations and potential driving mechanisms at a select number of key locations.



3 Detailed Quantitative Risk Assessments and Landfill Gas Assessment

3.1 Introduction

Detailed Quantitative Risk Assessment (DQRA) has been undertaken to provide technical assessments of available soil, groundwater and vapour chemistry data with respect to potential risks to human health and the wider environment. Standalone reports for these assessments are provided within Appendices E, F and G. They have been written in accordance with the UK Government's Land Contamination Risk Management guidance (LCRM), focussing on the assessment of potential statutory risk under Part 2A of the Environmental Protection Act 1990 as enacted by the Environment Act 1995 (Part 2A). LCRM defines possible receptors under Part 2A to include human health, controlled waters, organisms and ecosystems. The report uses the term "wider environment" to encapsulate those potential receptors not associated with human health.

The purpose of the DQRA is to provide supporting technical evidence to assist with restoration design and performance criteria for the reuse of site-won materials and restoration validation/verification works. The risk assessment approach considers a public open space end use for the site.

The DQRA provides a conceptual site model together with detailed pollutant linkage assessments. A description of the data collection and assessments is provided together with a preliminary risk assessment of source-pathway-receptor linkages and generic quantitative risk assessment.

The assessments and modelling outputs have been used as the technical basis for deriving restoration target values (RTVs). These detailed assessments are presented within each risk assessment report in the appendix, with a summary of the findings presented within the following sub-sections.

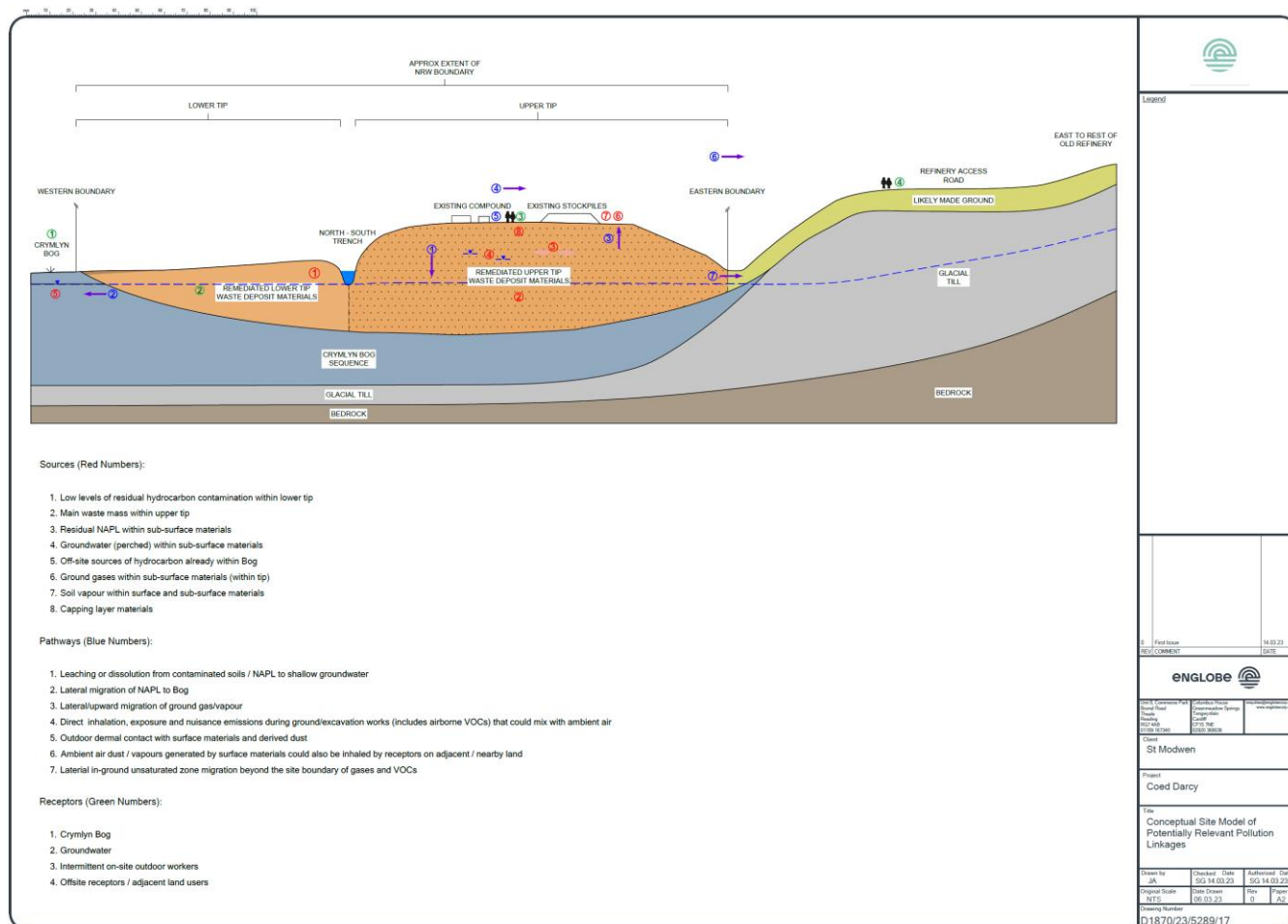
3.2 Conceptual Model

In line with best practice, a conceptual site model (CSM) has been derived to assess potential interaction between the ground and groundwater conditions beneath the site with either human health or the wider environment (groundwater within aquifers and local surface watercourses and the ecosystems they support).

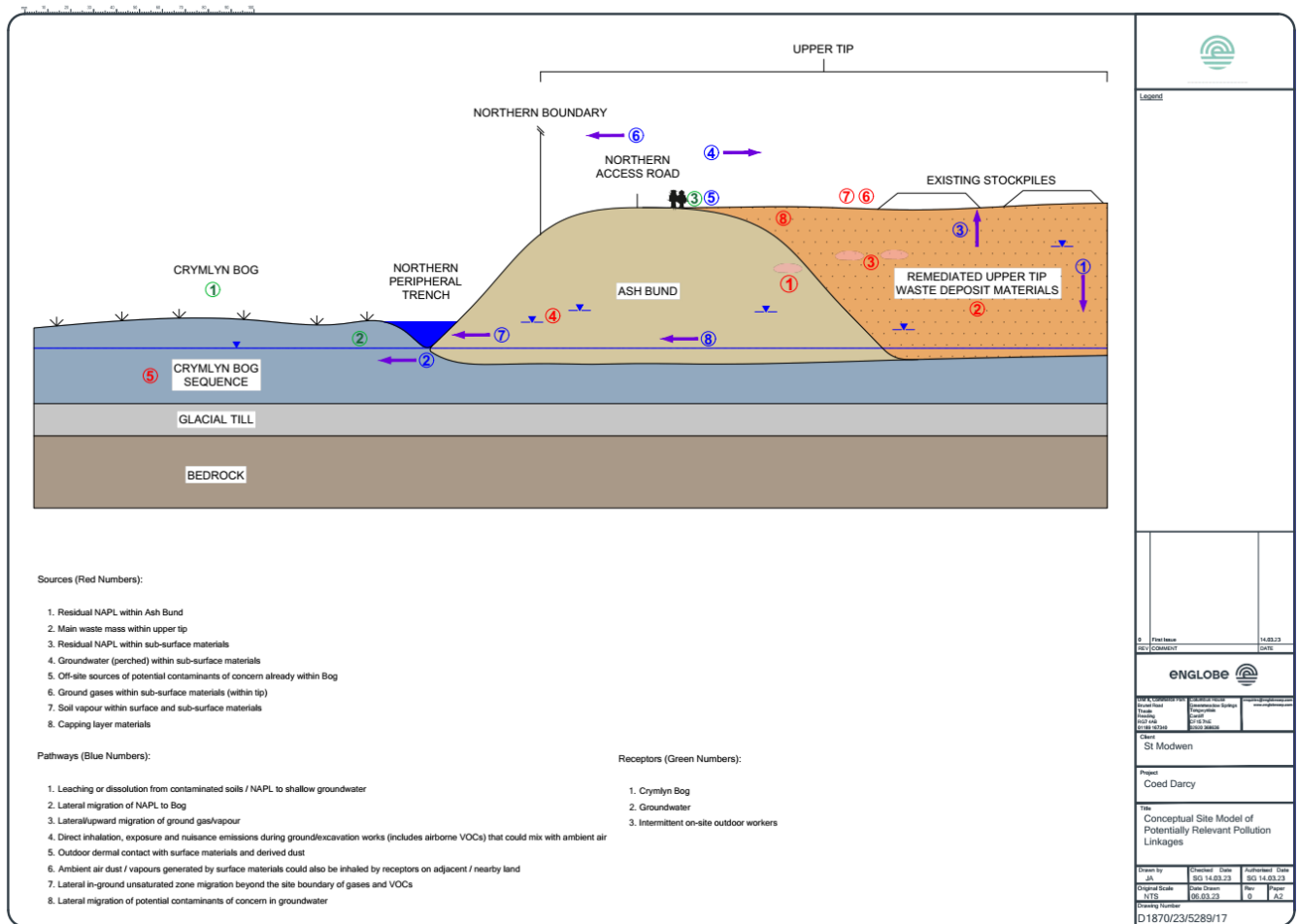
The DQRA identifies the source areas of contamination, the associated CoCs and discussion around the interaction of pathways with potential receptors.

Pictorial cross-sections east-west and north-south are presented below.

Graphic 3 - Conceptual Model East-West



Graphic 4 - Conceptual Model North-South



3.3 DQRA Process for Controlled Waters

A DQRA for controlled waters, otherwise known as a Hydrogeological Risk Assessment (HRA) or Controlled Waters Risk Assessment (CW-RA), has been undertaken and is included as Appendix E.

This assessment has considered risk to controlled waters from residual impactation of potential contaminants at the Crymlyn Tip via dissolved phase migration in the groundwater and has derived site assessment criteria for groundwater. Although additional works are being designed to improve conditions further, the present study considers existing conditions without these works.

The assessment has included numerical modelling of the groundwater system in the vicinity of the site. This modelling was undertaken to assist in development of the conceptual model with respect to the groundwater pathway and in order to allow predictions to be made as to the likely degree of dilution and attenuation of potential contaminants and their likely fate in the groundwater system. As such it assists in the quantification of the risks to controlled waters that may be associated with migration of any potential contaminants remaining on site and allows the development of defensible site-specific assessment criteria that are protective to controlled waters. The numerical modelling will also be used in design assessments for the proposed improvement works.

3.4 Initial Conceptual Model of Groundwater Flow

3.4.1 Topographical Setting and Surface Water Features

The tip site lies on the eastern edge of the Crymlyn Bog and has been constructed by placement of fill and waste materials over part of the former bog area. In particular, a bund was formed along the northern edge of the tip and wastes placed to the south. Ground levels rise to the east and south to areas that were formerly utilised by the refinery. The bog area to the north and west is typically at about 8 to 10 m AOD. Ground levels on the overall site area drop from about 20 m AOD in the north east to about 10 m AOD in the west.

Figure 1, Appendix E shows the site's topographic setting with some topographic contours and surface water features highlighted for clarity.

Surface water features in the vicinity of the site are illustrated in Figure 2 of Appendix E (selected topographic contours have been highlighted for clarity). Current surface water features are shown in light blue. Former streams, which have been traced from historical mapping and shown as dashed blue lines in Figure 2, Appendix E, and the Glan Y Wern / Tennant Canal, which passes through the central bog area, is shown as dark blue.

3.4.2 Ground Conditions

Various phases of ground investigation have been undertaken on site and recently Englobe have undertaken some additional investigation works, including installation of further boreholes and wells and groundwater monitoring.

Mapping published by the British Geological Survey (BGS) shows the site to be underlain by solid strata of the Pennant Sandstone Formation of Carboniferous Age. The bedrock is overlain by glacial deposits that include clay till and granular fluvioglacial strata, which are generally represented by gravels. The glacial strata are overlain by the bog sediments that generally comprise soft clays overlain by peat.

Figure 3a, Appendix E shows an extract from the published geological map of the areas surrounding the site and Fig 3b, Appendix E shows a detail for the site area. Although mapped across most of the lower site area, intrusive investigation has indicated that peat is locally absent from some parts of the site area.

Made Ground comprising tipped material from the refinery operations and some excavated peat, appears to have been placed straight over the original ground profile, with no attempt to remove the existing peat, soft clays or vegetation.

3.4.3 Anticipated Pattern of Near Surface Groundwater Flow

Based on the site's topographic setting, the direction of near surface groundwater flow below the site could be expected to be to the west in the eastern site area and to the north in the south. Within the central northern site area, the predominant flow direction would be expected to be to the north west, becoming more westerly in the western area, with discharge into the adjoining bog area and eventual discharge to a series of streams and drainage ditches within the bog, including the Glan Y Wern / Tennant Canal. Previous experience from studies for sites adjoining other areas of the Crymlyn bog have suggested that the canal water level is generally in continuity with the groundwater and that groundwater usually discharges to the canal.

3.4.4 Hydrogeology and Potential Controlled Waters Receptors

The Peat and by inference other bog sequence deposits are considered to be Unproductive Strata. The underlying Glacial Till is considered to be an 'Undifferentiated' Secondary Aquifer. The Fluvioglacial strata, present but not mapped in the area, would generally be considered a Secondary 'A' Aquifer. The Pennant Formation is also considered to be a Secondary 'A' Aquifer. There are a number of surface water ditches and drains within the Crymlyn Bog area and as noted

above, groundwater likely discharges to the Glan Y Wern / Tennant Canal. The drainage ditches to the north of the site appear to drain southwards and are discontinuous, presumably discharging water drained from upstream to the bog.

The Crymlyn Bog is a designated Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC), Ramsar Site and a National Nature Reserve (NNR).

3.5 Measured Groundwater Conditions on Site

3.5.1 Groundwater Conditions

Data on groundwater levels within the site area are available from monitoring undertaken during two main periods; firstly from 1998 to 2003 and reported by URS and more recent from 2020 to 2022 and reported by PJA.

Inferred contours of groundwater level for each monitoring date for the 1998 to 2003 data are included in Addendum 1 of Appendix E, and similar plots for the 2020 to 2022 data are included in Addendum 2 of Appendix E. Data from some monitoring points that relate to wells that apparently reflect locally perched conditions within or on shallow clay layers have been omitted for these plots.

Note that for all contour plots the permit boundary is shown as a green line and the 'site' boundary as a red line.

Figures 4a and 4b of Appendix E show inferred contours of groundwater level based on average levels at each monitoring point for the periods 1998 to 2003 and 2020 to 2022, respectively. Average values have been used as no single dataset includes monitoring of all standpipes and the intention is to illustrate general trends. As noted above, contours for each individual dataset are included in Addenda 1 and 2, Appendix E.

The two data sets show reasonably consistent conditions although both data sets have only limited data in the southern and eastern site areas and several of the individual dates have no data at all in the eastern site area. Where sufficient data are available, they show relatively high groundwater levels in the east with a generally westerly flow direction. This becomes more northerly in the central site area and then more westerly in the extreme west. This is generally consistent with the anticipated directions of near surface groundwater flow inferred from the site's topographic location and discussed above.

Superimposed on this general pattern are local groundwater highs within the north central site area that are thought most likely to be related to the heterogeneity of the wastes in this area but could also potentially be partly due to changes in character of the bog sequence strata underlying the relevant areas. The local high levels imply that locally the vertical conductivity of the wastes is so low that infiltration is being restricted from migrating vertically downwards through the unsaturated zone. This could be due to locally higher clay content in the wastes or LNAPL presence reducing the effective hydraulic conductivity. There are also occasional areas of locally low groundwater level. These could be due to heterogeneity in the wastes but could also be due to locally higher vertical conductivity in the underlying bog sequence.

Some of the local highs and lows on some monitoring visits could also be the result of product recovery activities that may have been ongoing at the time.

Figures 5a and 5b of Appendix E show plots of measured water level vs date for the two main datasets, respectively. All available data are included in these plots. As noted in relevant monitoring reports, the main influence appears to be seasonal with highest levels generally in the period December to January and lowest September to November. Although there are some anomalies that generally relate to surface water levels in sumps or wells that appear to be reflecting perched conditions, most locations show only relatively small fluctuations and levels tend to rise and fall in unison, suggesting that the overall direction of groundwater flow is not changing markedly with the season.

For some monitoring well locations shallow and deep response zones were installed. Levels in the two are generally similar. Figure 6 of Appendix E shows a plot of measured water level in the deep installation vs the level in the shallow installation for the 1998 to 2003 data, for which more data

are available. Generally, water levels in the deep standpipes either increase and decrease at a similar rate to the shallow levels or, more commonly, shallow levels increase more rapidly than the deep. This suggests that the fluctuations are due to changes in local infiltration, resulting in greater fluctuation in the shallow levels than the deeper.

There are two exceptions to this general pattern; MSMW027, where deep water levels appear to reduce as shallow levels rise and MSMW035, where deep levels appear to fluctuate more than shallow but move in the same direction. The reason for these apparent anomalies is not clear. MSMW027 is in the extreme western end of the site, close to the bog. MSMW035 is in the north eastern site area, also close to the bog but also close to the higher ground. Figure 7 of Appendix E shows contours of the ratio of deep to shallow water level for the average of all readings. That is, for contour values greater than unity deeper levels exceed shallow. Near the bog, deeper data generally show higher levels than shallow whereas within the tip area the reverse is the case. This general pattern could be explained by an upward flow within the deeper bedrock and glacial strata as groundwater discharges to the bog and a downward flow within the tip area, where recharge is occurring. It also suggests that although the deeper and shallow groundwater levels are similar, that the bog sediment clays are acting as at least a partial aquiclude. The upward gradient of groundwater potential along the northern site boundary suggests that there is little potential for any dissolved phase contaminants, which may be emanating from the northern site boundary in near surface groundwater, to flow downwards into the underlying glacial or bedrock aquifers.

3.6 Previous Controlled Water Risk Assessments

URS Corporation Ltd (2006) undertook a detailed controlled waters risk assessment that concluded that no organic or inorganic contaminants posed any significant risk to controlled waters. Based on analysis undertaken it was concluded that the effects of contaminated groundwater discharge from the licensed area are unlikely to extend very far into the bog.

3.7 Hydrogeological Risk Assessment

3.7.1 Dissolved Phase

A new hydrogeological risk assessment (HRA) has been prepared based on the site's current status and in accordance with current regulatory guidance adopted by NRW; <https://www.gov.uk/government/collections/groundwater-protection>. This HRA also considers the pre-existing site data. The hydrogeological assessment and the assessment of risk from dissolved phase is included in Appendix E.

The 2022 HRA considered risk to controlled waters from residual impactation of potential contaminants at the Crymlyn Tip via dissolved phase migration in the groundwater, and derived site assessment criteria for groundwater. The HRA considered the site in its current state with existing conditions and without the works proposed in this report.

As noted in previous sections, the history of site usage has resulted in impactation of the ground at the site with some potential contaminants, in particular petroleum hydrocarbons. This has resulted from waste deposition prior to, and after the landfill becoming a regulated facility in 1977. As presented in Section 5, various programmes of remediation have been undertaken since around 1999, and in particular the RAP Works since 2010. This has been supplemented by various monitoring programmes, updated as a result of earlier IP1 assessments and closure plans.

The assessment has included numerical modelling of the groundwater system in the vicinity of the site. This modelling was undertaken to assist in development of the conceptual model with respect to the groundwater pathway, and in order to allow predictions to be made as to the likely degree of dilution and attenuation of potential contaminants and their likely fate in the groundwater system. As such it assists in the quantification of the risks to controlled waters that may be associated with migration of any potential contaminants remaining on site and allows the development of defensible site-specific assessment criteria that are protective of controlled waters.

The dissolved phase HRA concludes that groundwater emanating from the permit area is flowing generally northwards from the eastern and central site area and north westwards from the western site area, in both cases with discharge to the Crymlyn Bog. Local groundwater highs within the permit area can be assumed to be due to relatively low vertical hydraulic conductivity in those areas, potentially partly due to presence of LNAPL within the pore spaces. There is evidence of an upward gradient in groundwater potential along the northern site boundary, which suggests that the bog sequence clays are at least a partial aquiclude and that there is little potential for any dissolved phase contaminants that may be present in the near surface groundwater to migrate downwards into the bedrock or glacial aquifers. In an early site investigation in the 1990s by Golder Associates, they observed evidence for two at least partially separate groundwater units, one in the peat and one in the underlying fluvioglacial deposits. Golder observed that these two geological units were separated by a thin (approximately 1.5 m) clay layer which also appears to at least partially separate the groundwater units. Golder noted evidence of an upward hydraulic gradient from the glacial deposits to the peat. Even if such potential exists, there is no obvious sensitive receptor within the deeper aquifer other than the Crymlyn Bog itself, which is covered by this assessment.

Some concentrations of potential contaminants above compliance criteria in water samples are present within the central part of the permit area, which is historically where wastes have been placed and remain. However, most areas of elevated concentrations are of limited lateral extent and do not extend as far as the northern site boundary. For organics, measured conditions are likely to overestimate the true dissolved phase concentration owing to the presence of NAPL. Based on the first five months of 2022 monitoring, only the following substances represent potential contaminants of concern with respect to potential dissolved phase off-site migration:

- Aromatic TPH Fractions C10 and higher.
- Aliphatic TPH Fraction C12-C16.
- PAH Compounds, except Naphthalene.
- Ammonium.

Site assessment criteria have been derived for the potential contaminants of concern using the Environment Agency's Remedial Target Methodology for two arbitrary compliance points downstream of the site. The high organic content levels of the bog sediments result in very high retardation factors in relation to migration of organic contaminants. For the majority of principal organic contaminants of concern, assessment criteria exceed solubility even for an assumed distance to compliance of just 10 m.

For the other potential contaminants of concern, the report proposes completion criteria for permit surrender based upon this risk assessment, and a reasonable initial conclusion, based on these criteria, is that no significant future impact of the bog area will result from dissolved phase migration of these substances. This initial conclusion is based on an assumed 50 m point of compliance and with comparison to the highest average concentration over any 220 m length of the downstream boundary of the permit area, which is the source width assumed in RTM analysis. On this basis key compounds such as Ammoniacal Nitrogen and Benzene appear compliant, but a further aftercare monitoring programme is proposed.

3.7.2 Free Oils

As a result of the sites history, residual oils analogous to that within the Tip are considered highly likely to be present within the site and in the downgradient Crymlyn Bog dating from pre-1977.

The condition of the land during the life of the permit, and particularly since the landfill closed, has been substantially improved through the completed RAP Works and voluntary remediation. The focus on removal of oils from the Tip has resulted in in excess of 1,800,000 litres of oil being recovered since 2008.

The remediation of the Lower Tip has limited the operational extent of the Peripheral Trench to the Upper Tip, and within that length, recovery is predominantly from two discrete locations, most likely as

a result of the product recovery works within the main Upper Tip fill since 2010, which were validated as reaching an asymptotic point within the main waste mass. It is considered that there are no on-going sources of NAPL and the remaining NAPL is residual.

While there remains some oil emissions from the site, it is a demonstrably improved situation. However, free oils from the ash bund currently captured by the peripheral trench may represent an ongoing risk of free oils leaving the site.

3.7.3 Groundwater Completion Criteria

Site assessment criteria were derived in the HRA for two arbitrary assumed distances to compliance; 10 m and 50 m. In addition to the principal contaminants of concern, assessment criteria have been derived for other substances detected in groundwater in the permit area.

The proposed completion criteria for groundwater with respect to controlled waters have been adopted as Restoration Target Values as part of the Remediation Implementation Plan. They are included in section 3.17.1 'Groundwater RTVs'. Note that some of the derived assessment criteria exceed the likely solubility of some compounds. In such cases, the relevant substances may be assumed to be insufficiently leachable to pose any risk to controlled water. These factors should be considered in the overall assessment.

It is proposed that the initial completion criteria (adopted as RTVs for the Remediation Implementation Plan) are based on an assumed 50 m point of compliance and determined as the highest average concentration over any 220 m length of the downstream boundary of the permit area, which is the source width assumed in RTM analysis.

The utilisation of the 50 m point of compliance is considered reasonable in light of both the distance to the Crymlyn Brook and the historical off-site impact. It is proposed that these completion criteria will apply along the boundary of the permit area, which is further detailed in the following Aftercare Monitoring section.

The Closure and Aftercare Monitoring Plan outlines that the proposed aftercare strategy is to allow for the testing for VOCs, SVOCs plus Tentatively Identified Compounds (TICs) and PFAS/PFOS. The strategy includes for a provision to review the HRA should any of these compounds prove to be significant. It should be emphasised that the nature and age of the waste does not indicate that these should be considered contaminants of concern at this stage. VOCs and SVOCs were tested for within soil samples obtained during Englobe's 2022 site investigation (see Appendix I) and no significant concentrations were detected.

3.8 DQRA Process for Human Health

3.8.1 Introduction and Approach

This section will describe the human health risk assessment (HH-RA), which together with the detailed quantitative risk assessment for controlled waters consider the risks that potentially exist and likelihood to be posed by the restored land after completion of the proposed works detailed within later sections of this report. These works include landform reprofiling and provision of final site wide restoration layer.

The purpose of the risk assessment is to provide supporting technical evidence to assist with the regulatory approval of the proposed restoration works within the town and country planning regime.

For the purposes of the HH-RA, the restored land will be considered as an area of 'public open space' (POS) without immediately adjacent residential land use. As mentioned in previous sections of this report, the site includes waste materials within the closed 'Coed Darcy Tip' (currently regulated via an environmental permit).

The HH-RA is provided in full within Appendix F and includes an initial preliminary risk assessment (PRA) to identify relevant pollutant linkages (RPLs) and subsequent more detailed considerations

of published generic assessment criteria and detailed site-specific human health quantitative numerical modelling. The capping & restoration layers will provide a robust cover over underlying materials, including the waste materials.

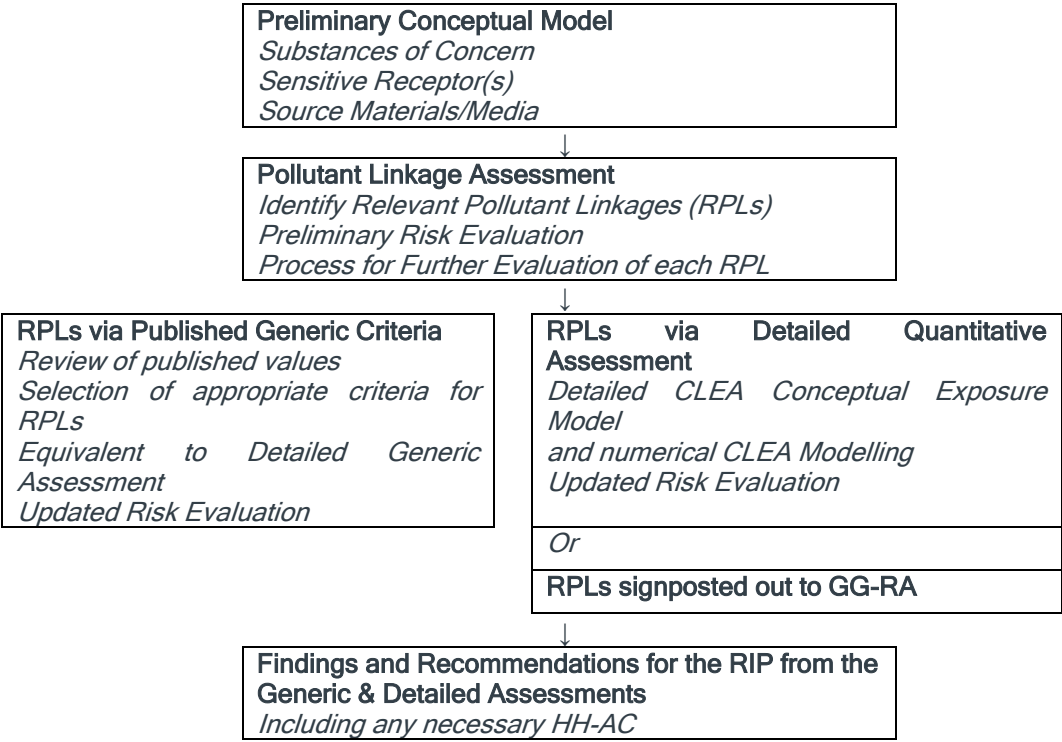
The PRA, combined with the detailed generic/quantitative assessments, have been used as the technical basis for the selection of a range of human health assessment criteria (HH-AC); the HH-AC will then be utilised for the remedial works.

For ground gases, trace gases and vapour-phase volatile organic compound (VOCs), a number of the HH-RA pollutant linkages will be addressed by an appropriate Ground Gas Risk Assessment (GG-RA), which will also include VOCs within 'trace gases'. For selected pollutant linkages, the PRA will signpost out of the HH-RA and refer the reader solely to the GG-RA; for other selected linkages (where the HH-RA may also be subservient to the GG-RA), additional assessment work is provided in the HH-RA to be used alongside the GG-RA.

Non-aqueous phase liquids (NAPLs) are also documented at the site and NAPL sources will be considered in the PRA; lateral NAPL migration will be mitigated by the remedial works.

The PRA is detailed in Section 3.9, with the detailed assessments and HH-AC discussed in Sections 3.13 & 3.14 and presented in the appendices of Appendix F.

In summary, the HH-RA has adopted the following overall approach:



The assessment has been prepared under the umbrella management framework provided by non-statutory UK guidance available online gov.uk ‘*Land Contamination: Risk Management*’ (LCRM). The LCRM guidance is based on the now withdrawn CLR-11 ‘*Model Procedures for the Management of Land Contamination*’.

The HH-RA has been undertaken within the 2009 SR3 CLEA (contaminated land exposure model) framework. The 2009 CLEA methodology has been amended to take into account relevant conceptual model updates outlined in documents associated with the 2015 LQM/CIEH Suitable for Use Levels (S4ULs), the Phase 1 & 2 2014/21 Category 4 Screening Levels (C4SL) and CLEA model v1.071 with associated handbook Version 1.05. Additional human health guidance for the assessment of VOC-vapour/gas risks has been drawn from guidance provided by the EA, British Standards, SoBRA, CL:AIRE, CIRIA, CIEH and other world-wide sources; selected technical references are provided in Appendix F.

The risk assessment should only be used by competent persons for its intended purpose, and it is beyond the scope of this report to present a detailed summary of the risk assessment methodologies, supporting documents and their technical basis. The risk assessment was finalised in December 2022 and should be read in the light of any subsequent changes in legislation, statutory requirements, statutory & non-statutory guidance, relevant research, and industry practices.

Selected technical and literature references are provided in Appendix F.

3.9 Preliminary Conceptual Model

The preliminary conceptual model considers contaminants & hazards in source media and their associated exposure/migration pathways through which the contaminants/hazards could impact upon sensitive human health receptors relevant to the restored land. The conceptual model has then been used to identify the plausible relevant pollutant linkages (RPLs).

The pollutant linkage assessment process (LCRM ‘*S-P-R assessment*’) considers the following components:

Receptors Identify sensitive human health receptor(s)

- Sources** Identify source media and contaminant ‘substances of concern’
- Pathways** Identify plausible migration/exposure pathways linking sources to receptor(s)
- Note-1: the general term contaminant used to cover LCRM ‘source, contaminant and pollutant’*
- Note-2: ‘relevant pollutant linkage’ is used in favour of LCRM term ‘contaminant linkage’*

3.10 Human Health Sensitive Receptors

The PRA considers the following potentially sensitive receptors for the restored land:

Receptors on the Restored Land

- Intermittent Outdoor Worker

There is no planned commercial use of the restored land and there are no plans for permanent site buildings; any outdoor working is likely to be infrequent, probably similar to warden, security and grounds-keeper type roles.

In the absence of a specific scenario for this use, a CLEA-type commercial land use based around intermittent to full-time outdoor working could be adopted.

The outdoor worker excludes groundworkers. Specific risks to groundworkers would be addressed by separate risk assessments and method statements under HS&E obligations.

- Use by Public

Final arrangements for formal public access to the restored land are to be finalised.

A C4SL land use for public open space for public parks (POS-2) will be adopted.

Receptors on Adjacent/Nearby Land to South and East

- Users and occupiers of adjacent/nearby land to the south and east.

Immediately adjacent land to the south and east is proposed to be POS type land use.

The nearby land will be assumed to potentially include future commercial, residential and POS type land uses.

CLEA/C4SL type commercial, residential and POS land uses could be adopted.

Receptors on Adjacent/Nearby Land to North and West

- There are no users of potential concern on adjacent/nearby land to north & west.

To the north and west is an extensive natural habitat area known as Crymlyn Bog.

There are no plausible human health receptors of concern associated with the Crymlyn Bog area. No known public rights of way cross the area.

3.11 Substances of Concern

The substances of concern considered by the assessment are detailed in Table 3.

Table 3 - Substances & Hazards of Potential Concern

Potential Substances of Concern	Non-Volatile or Insufficiently Volatile	Sufficiently Volatile
Total petroleum hydrocarbons Risk banded TPH fractions	Aliphatic & Aromatic C16-C35 fractions are insufficiently volatile	Aliphatic C5-C16 fractions Aromatic C8-C16 fractions (see below)
Benzene, toluene ethylbenzene, xylene isomers (BTEX)	-	BTEX Benzene is solely aromatic C5-6 Toluene is solely aromatic C7-8

Potential Substances of Concern	Non-Volatile or Insufficiently Volatile	Sufficiently Volatile
		<i>Ethylbenzene/Xylenes in Aromatic C8-10</i>
16-PAHs	15-PAHs are considered insufficiently volatile	Naphthalene <i>also in Aromatic 10-12</i>
Phenols	-	Phenols <i>Note: phenol could be taken as Insufficiently-volatile</i>
Other Speciated VOC/SVOC	Speciated SVOCs Typically, insufficiently volatile	Speciated VOCs
Arsenic, cadmium, chromium, copper, inorganic lead, mercury, nickel, selenium, vanadium and zinc	Non-volatile (inorganic species)	-
Easily liberatable cyanide and total cyanide	Non-volatile	-
Asbestos/ACMs	Non-volatile	-
Soil pH (as a soil hazard)	Non-volatile	-
Notes: The rationale with respect to sufficiently volatility is summarised in Appendix B of the HHRA, itself in Appendix F of this report.		
Other Potential Hazards of Concern		
Ground Gases: methane, carbon dioxide, carbon monoxide & H ₂ S. Depleted oxygen		
Trace Gases / VOCs Vapours		

Note-1: Benzene and toluene have their own aromatic C5-C7 & C7-C8 fractions (i.e. there are no other substances in these fractions); ethylbenzene & xylene isomers, 16-PAHs and other PAHs will also be detected within the aromatic C8 to C12+ fractions. It is important to ensure that potential 'double accounting' issues are considered when interpreting TPH/BTEX/PAH results.

Note-2: All banded/speciated GC/MS TPH testing methodologies inherently use Equivalent Carbon (EC) numbers based on boiling point. The carbon banding terminology (e.g. Aromatic C12-C16) used in the assessment is based on EC banding and can be used with all banded TPH testing results, irrespective of whether the testing is compliant with the TPH-CWG methodology.

3.12 Source Materials

The following restored land source materials/layers ('source media') are considered by the preliminary conceptual model:

At Surface / Near Surface (*Surface Materials*)

- Restoration Layer Materials.
- Capping Layer Materials.

Deeper Layers (*Sub-Surface Materials*)

- Capping Layer Materials.
- Waste Deposit Materials.
- Non-Waste Materials.
- Natural Soil Materials.

Liquid, Gas and Vapour Sources/Hazards (*Non-Soil Materials/Hazards*)

- NAPL within sub-surface materials.
- Groundwater (GW) within sub-surface materials.
- Soil Vapour (SVap) within surface materials.

- Soil Vapour (SVap) within sub-surface materials.
- Ground Gases within sub-surface materials.

3.13 Human Health Exposure Pathways

The relevant/plausible exposure pathways for the adopted human health receptors are provided below and are drawn from the standard CLEA/C4SL conceptual models:

For Surface Materials

- Ingestion of surface materials and derived dusts.
- Outdoor dermal contact with surface materials and derived dusts.
- Outdoor inhalation of respirable airborne dusts derived from surface materials.
- Outdoor inhalation of VOC vapours generated by sufficiently volatile substances diffusing out from surface layer materials and mixing with ambient air.
- Ambient air dust/vapours generated by surface materials could also be inhaled by receptors on adjacent/nearby land after lateral advection and dispersion/dilution.
- Includes SVap sources within surface materials.

For Sub-Surface Materials (including relevant Non-Soil Materials)

- Vertical soil VOC vapour and ground/trace gas migration and mixing with ambient air; soil VOC vapours and ground/trace gases generated by sub-surface source materials, with migration up and through the Surface Materials. Followed by subsequent inhalation by receptors on the restored land; the ambient air vapours/trace/gases could also then be inhaled by receptors on adjacent/nearby land after lateral advection and dispersion/dilution.
- Lateral in-ground unsaturated zone migration (beyond the site boundary) of soil VOC vapours and ground/trace gases generated by sub-surface source materials. Subsequent diffusion to surface and inhalation by receptors on adjacent/nearby land.
- Includes NAPL, GW, SVap and Ground gas sources within sub-surface materials.

The controlled waters risk assessment has established that groundwater flow is northwards towards Crymlyn Bog. Given the absence of plausible human health receptors within the Crymlyn Bog habitat area, the PRA has not needed to consider human health pathways associated with northerly groundwater flow. The PRA has also not needed to consider human health pathways associated with potential lateral NAPL migration as this will be mitigated by the remedial works.

3.14 Preliminary Linkage Assessment and Risk Evaluation

A pollutant linkage assessment has been undertaken to characterise the RPLs and includes the following elements:

Receptors → Sources → Plausible Pathways → Identified Human Health RPLs

Table 4 and Table 5 summarise the sources, the identified RPLs, the preliminary risk evaluation & assessment (PRA) and the recommended next step for each identified RPL.

In summary, the recommendations for the five RPLs identified by the PRA (RPL-1 to RPL-5) are as follows:

RPL-1 for Surface Materials

- The risks will be addressed via a generic assessment using UK published generic criteria for relevant/applicable land uses(s).

RPL-2 for VOC Vapours associated with Sub-Surface Materials

- The risks will be addressed via a detailed CLEA quantitative risk assessment.

RPLs 3 to 5 for Ground Gas & Trace Gases associated with Sub-Surface Materials

- The risks posed by these RPLs are addressed in the GG-RA.
- These RPLs are not considered further by the HH-RA.
- Please refer to the GG-RA for the risk assessments for these RPLs.

Notes

Note-1: the substances of concern are detailed in Table 3.

Note-2: the human health RPLs requiring detailed CLEA assessment relate to vapour inhalation pathways and the detailed assessment only need to consider sufficiently volatile substances of concern. The rationale with respect to sufficiently volatility is summarised in Appendix F.

Note-3: the risk classification matrix is provided in Table 6.

Table 4 - Receptors on Restored Land: RPLs and Preliminary Risk Evaluation

Source Materials Averaging Areas	RPL Ref	Human Health Pathways	Consequence	Likelihood	Preliminary Risk Evaluation	RPL of Concern?	Recommended Approach for RPL to address Level of Concern
Surface Materials (Including SVap)	RPL-1	Soil/soil-dust ingestion Outdoor dermal contact Outdoor dust inhalation Outdoor vapour inhalation	Medium	Likely	Moderate Risk	Of concern	Address RPL via a generic risk assessment using UK published generic criteria
Vapours from: Sub-Surface Materials Non-Soil Materials (NAPL & GW)	RPL-2	Outdoor vapour inhalation	Mild	Likely	Low to Moderate	Of concern	Address RPL via a detailed CLEA quantitative risk assessment
Ground/Trace Gases from: Sub-Surface Materials (Non-Soil Hazard)	RPL-3	Outdoor inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via the GG-RA

Table 5 - Receptors on Adjacent/Nearby Land: RPLs and Preliminary Risk Evaluation

Source Materials Averaging Areas	RPL Ref	Human Health Pathways	Consequence	Likelihood	Preliminary Risk Evaluation	RPL of Concern?	Recommended Approach for RPL to address Level of Concern
Vertical Migration							
Dusts/Vapours from: Surface Materials	Via RPL-1	Advection/dispersion, then Outdoor dust inhalation Outdoor vapour inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via a generic risk assessment using UK published generic criteria
Vapours from: Sub-Surface Materials Non-Soil Materials (NAPL & GW)	Via RPL-2	Advection/dispersion, then Outdoor vapour inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via a detailed CLEA quantitative risk assessment
Ground/Trace Gases from: Sub-Surface Materials (Non-Soil Hazard)	Via RPL-3	Advection/dispersion, then Outdoor inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via the GG-RA
Lateral Migration							
Surface Materials	No RPLs	No plausible pathways	-	-	No Risk	No concern	No further Risk Assessment Required
Vapours from : Sub-Surface Materials	RPL-4	Lateral in-ground migration then, migration to surface	Minor	Likely	Low Risk	Limited concern	Address RPLs via the GG-RA

Source Materials Averaging Areas	RPL Ref	Human Health Pathways	Consequence	Likelihood	Preliminary Risk Evaluation	RPL of Concern?	Recommended Approach for RPL to address Level of Concern
<i>Non-Soil Materials (NAPL & GW)</i>		and vapour inhalation					
Ground/Trace Gases from: <i>Sub-Surface Materials (Non-Soil Hazard)</i>	RPL-5	Lateral in-ground migration, then, migration to surface/near-surface to pose hazard	Mild	Likely	Low to Moderate	Of concern	

Table 6 - Qualitative Risk Classification Matrix

Probability (likelihood)	Consequence			
	Minor	Mild	Medium	Severe
High likelihood	Low risk	Moderate risk	High risk	Very High Risk
Likely	Low risk	Low to moderate risk	Moderate risk	High risk
Low likelihood	Very low risk	Low risk	Low to moderate risk	Moderate risk
Unlikely	Very low risk	Very low risk	Low risk	Low to moderate risk
No Pollutant Linkage	No potential risk			

3.15 Further Assessments and Recommendations

The generic and detailed assessments and the findings for RPL-1 and RPL-2 are provided in Appendix F.

Recommendations for RPL-1

The proposed HH-AC for consideration of surface materials with respect to the risks posed by RPL-1 are presented in Appendix F (Addendum A, Table A1).

If the surface materials are suitably validated to chemical specification criteria that include appropriate consideration of the HH-RA, then the human health risks posed by RPL-1 for the restored land should be very low and can be considered to be acceptable.

Should other speciated VOC/SVOC or inorganic substances of potential concern be encountered in surface materials during the RIP works, then the RIP can draw upon appropriate criteria (or surrogate/proxy criteria) drawn from the S4UL/C4SL/EIC references.

Addendum A of that report also includes further advisory commentary on the use of the RPL-1 HH-AC.

Recommendations for RPL-2

The detailed assessment concluded that the substances of concern in sub-surface materials pose a very low risk via RPL-2 and that the level of risk can be considered to be acceptable.

As such, it is not considered necessary for the RIP to provide soil, soil-vapour, groundwater or NAPL HH-AC for the sub-surface materials with respect to RPL-2.

3.16 Gas Assessment

3.16.1 Introduction

Ground Gas Solutions Limited (GGS) was commissioned by Englobe to provide an initial landfill gas assessment for the Crymlyn Tip landfill at the Coed Darcy site with respect to permit surrender (which is covered in the Closure and Aftercare Monitoring Plan Report, submitted to NRW). The following text summarises the findings of the initial LfGRA conducted by GGS and the monitoring proposed as part of the Closure and Aftercare Monitoring Plan, as this data has relevance to the remediation and future development of the site.

This gas assessment provides an initial assessment of the current gas regime based upon historical data and additional data collected by Englobe and GGS. The full assessment is provided in Appendix G.

Englobe in conjunction with specialists GGS have undertaken a detailed review of available evidence on landfill gas behaviour at the site in conjunction with a limited programme of contemporary monitoring at the site.

Englobe and GGS consider that it is highly unlikely that significant ongoing typical landfill gas generation is ongoing at the site. However, there are significantly elevated gas concentrations present within the site due to significant historical hydrocarbon contamination, underlying peat deposits, offsite gas sources and the general made ground character of the site and the wider area.

Based on the above, it has been considered by the Closure and Aftercare Monitoring Plan that the site represents a credible candidate for permit surrender based on consideration of the landfill gas issues only (other matters are being considered within the other IP1 assessments and the IP2 Closure Plan). Further, based on the variable gas conditions present within and surrounding the site, it is considered that NRW landfill gas completion scenario 3 presents the only viable route towards an acceptable surrender argument due to the elevated gas concentrations present.

As such, it is considered that the site requires a monitoring network compliant with NRW's guidance on landfill permit surrender (and general landfill monitoring guidance). Such a network is detailed within the full assessment in Appendix G. It is noted that this network outlines a 'standard' monitoring network based on guidance requirements. Englobe consider a more limited network is appropriate in light of the age of the landfill, the pre-existing land condition prior to the site becoming a landfill, and the extent of monitoring since 2011. This monitoring network along with proposed Restoration Target Values (RTV) is presented in Section 6.



4 Restoration Options Appraisal

4.1 General Approach

Englobe have undertaken an extensive assessment of the site's historical usage, its present condition and existing pollutant linkages. This section of the report will consider the proposed after-use of the site and an appraisal of the restoration options, which may be required in conjunction with, as well as outside of, any Permit compliance and closure requirements. The restoration options have been selected based on Englobe's experience and the constraints and objectives specific to this site. The considered techniques are viable within the current UK market and regulatory framework.

An assessment of the feasibility of the various options and consideration of the waste hierarchy will determine the Best Practicable Technique (BPT) for any restoration works deemed to be necessary at the Crymlyn Tip to render the site suitable for a public open space end use.

The Waste Hierarchy forms part of the Waste Framework Directive and is a tool used in the evaluation processes that protects the environment alongside resource energy consumption from most favourable to least favourable actions. The hierarchy establishes preferred program priorities based on sustainability. Therefore, sustainable waste management cannot be solved only with technical solutions, but an integrated approach is necessary. A diagram showing the five stages of the waste hierarchy is shown in Graphic 4.

Graphic 4 - The 5 Steps of the Waste Hierarchy



Where prevention or re-use are deemed unsuitable, solutions to enable the recycling or recovery of materials will take precedence to the least preferred approach of landfill disposal.

It is important to note that this report is provided on the basis of restoration works beyond that required by or included with the CAMP for the permit surrender. Where appropriate, this report will refer to works covered by the Permit and included in the CAMP. It should therefore be recognised that this RIP draft dependent upon the final permit requirements.

4.2 Constraints to the Restoration Works

4.2.1 Environmental Constraints

The site is known to have a number of constraints that are required to be considered and mitigated in order to allow proposed restoration activities to be undertaken. Identified constraints to restoration activities are as follows:

Existing known and unknown wastes within the landfill and the associated health, safety, and environmental risks

- The presence of the Crymlyn Bog adjacent to the landfill
- The presence of ecological receptors at the landfill, such as newts
- The risk of nutrient release and the associated adverse impacts to the Crymlyn Bog and associated ecology

4.2.2 Security

The wider Coed Darcy Urban Village site is monitored by full time security and access to the site is restricted. During the proposed works the Principal Contractor will have responsibility to appropriately secure the tip area under the Construction (Design and Management) Regulations 2015 and any associated planning requirements.

4.3 Proposed After Use of Site

The proposed after use of the land within the permit boundary and its periphery is for public open space (POS). There are currently no plans in place to build structures, roadways or infrastructure within the area; however, there is a requirement for vehicular/pedestrian access to key monitoring locations during the closure and aftercare management phases. Any future development works is assumed to require planning permission and the historical reports together with as-built drawings and health and safety file following restoration works should therefore be consulted. In the longer term, it is not envisaged that there will be any vegetation produced for human consumption or use

and that the area will not be used for grazing. It is intended that a restoration layer will be constructed as part of the construction proposals within the CAMP and associated CQA requirements of the Environmental Permit's Improvement Programme. For completeness, these construction proposals are re-produced within this report. It is assumed that natural regeneration of vegetation will occur and expand in a natural state. No planting or ecological plans are included within the scope of this report.

The surface water bodies outside of the permit area will remain and form part of the drainage system for the wider Coed Darcy development. Note: the drainage system forming the ponds already provides a direct hydraulic linkage to the Crymlyn Bog via a licensed discharge. Access to the licensed discharge points is available outside of the permit boundary.

The land immediately to the north and west of the site will remain as Crymlyn Bog Site of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC), National Nature Reserve (NNR) and Ramsar Site. The land to the south and east of the permit boundary is proposed to be a mix of open spaces and residential areas.

4.4 Restoration Options

4.4.1 Summary of Restoration Options Appraisal

Based upon the findings of the risk assessments, Englobe have carried out an Options Appraisal of the identified restoration actions based on the site's final end-use, as described within the previous sections. A summary of the restoration options appraisal is provided in Table 7 - Summary of Restoration Options Appraisal .

Table 7 - Summary of Restoration Options Appraisal

Restoration Option	Comments on Feasibility
Excavate and dispose of waste from the tip to alternative locations	It is unlikely that alternative or suitable facilities are available or would have the capacity to accept any significant quantities of waste from this site. Significant risks to health, safety and the wider environment could be created by any large disturbance or movements of waste. It is therefore considered impractical as well as unnecessary to excavate or dispose of any waste from the tip.
Install vertical cut-off barrier wall	Sub-surface vertical barrier walls, using a cement/bentonite slurry, are often constructed to prevent contamination of ground water and soils by landfill leachate. Hydraulic conductivity and depth of the barrier wall are critical factors to contaminant migration.
NAPL Recovery	Recovery of NAPL is expected to be required in the areas of significant residual free oil product. NAPL recovery is traditionally implemented from larger diameter (>100 mm diameter) recovery boreholes, interception trenches or sumps. The NAPL recovery design should take into account the properties of the recoverable fluid, the conductivity of the ground and associated radius of influence. Various techniques are also available to maximise the recoverability of NAPL.
Re-profiling of waste materials	It is deemed necessary to re-profile the waste landform, in order to improve the long-term stability and reduce risks associated with instability. This is a feasible option as long as the nature of the waste materials being re-profiled were sufficiently understood and any associated risks mitigated or at least suitably controlled.
Restoration Layer	A restoration layer is a suitable option to mitigate risks from direct exposure or potential fugitive emissions from underlying waste materials at the site. A Construction Quality Assurance plan would be required to establish the suitable procedures for construction and verification purposes.
Install drainage systems	Drainage systems could help with the management of surface water run-off and potentially divert water infiltration away from waste materials. Modelling of flow rates and impacts on receiving water bodies would be required.

4.5 Installation of an Oil Containment Wall

The installation of a low permeability vertical oil containment wall has been considered, to act as a physical barrier to reduce potential movement of residual mobile contamination as free oils currently captured by the peripheral trench represent an ongoing risk. Dissolved phase migration will still be possible, but in the context of the lack of basal liner of the existing landfill and the findings of the DQRA, it is considered a reasonable solution.

Consideration has been given to the use of sheet piles and also various mixtures such as soil/cement, soil/bentonite and cement/bentonite slurry. Additives can also be used to improve hardening, such as granulated ground blast furnace slag cement.

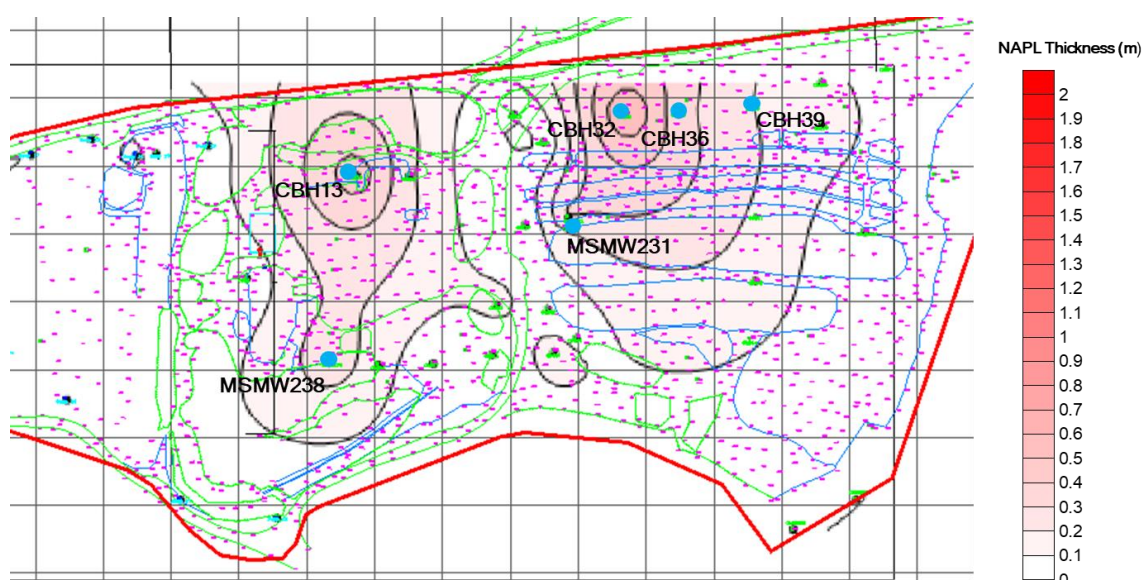
Sub-surface vertical barrier walls are often constructed to prevent contamination of ground water and soils by landfill leachate. Research into the sustainability of vertical barriers for environmental containment (JC Evans et al, 2020) has found that sheet pile walls had the highest negative environmental impact mainly derived from the manufacture of the steel. The lowest environmental impact was associated with a soil/bentonite mix, due to the relatively low impacts associated with bentonite and higher impacts associated with the production of cement.

4.6 LNAPL recovery

Monitoring and recovery of LNAPL has been carried out by GAL under the supervision of PJA since 2019. Review of the data collected as part of these works have indicated:

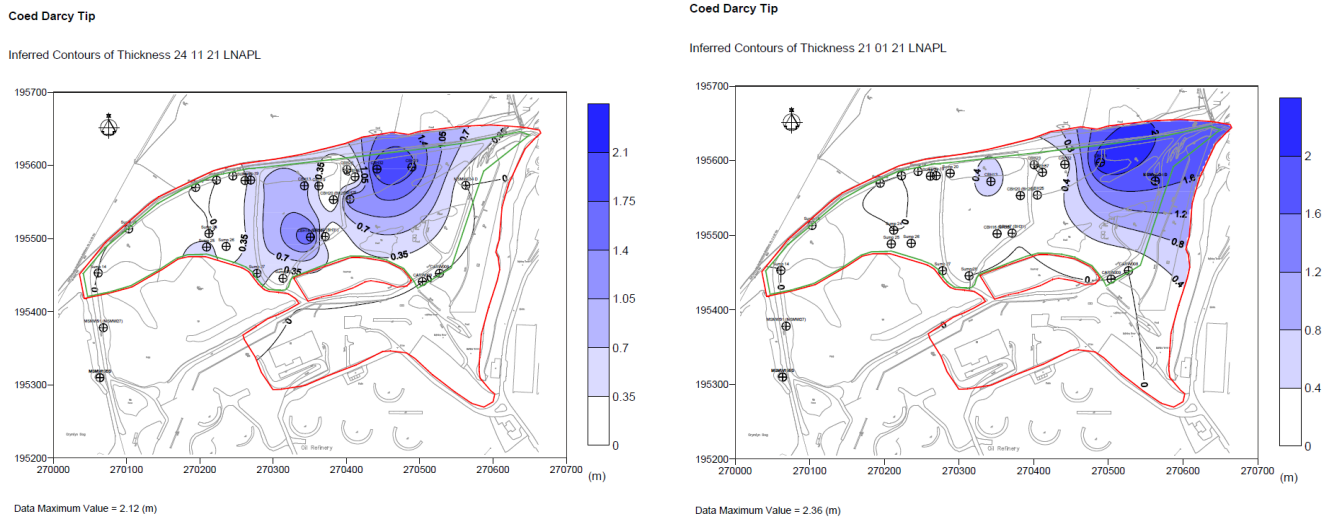
- LNAPL thicknesses vary monthly and seasonally, as would be expected, with a generally inverse relationship to groundwater levels;
- Two main hotspots are apparent; an area to the east of the bisecting trench, extending from MSMW238 in the south to CBH13 in the north, hereafter referred to as Hotspot 1; and an area further to the east within the tip, extending from MSMW231 in the south to CBH32, CBH36 and CBH39 to the north, hereafter referred to as Hotspot 2 (see Graphic 5);
- Since the commencement of LNAPL recovery works by GAL in 2019, LNAPL thicknesses have on average reduced in these hotspot areas, as indicated from average and maximum LNAPL thickness plots from monthly monitoring records in 2021 to 2022

The average LNAPL thickness plots for 2022 is presented in Graphic 5 - Mean LNAPL Thicknesses Recorded in 2022.



Graphic 5 - Mean LNAPL Thicknesses Recorded in 2022

Maximum NAPL thicknesses during this period are illustrated below:

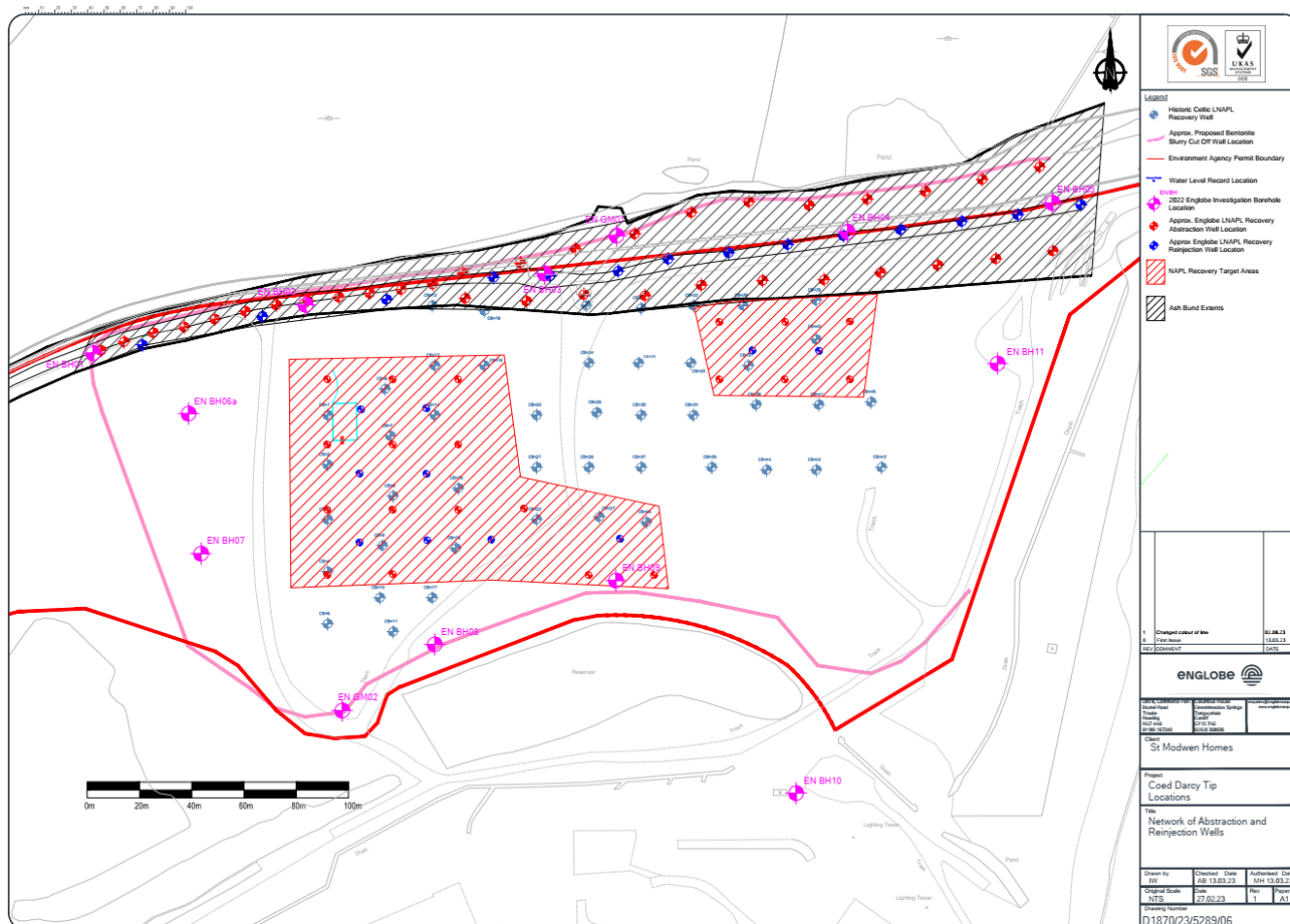


Graphic 6 - The two maximum NAPL thickness plots during period 2019 - 2022

It is considered prudent that a final phase of LNAPL recovery works is undertaken as a conservative measure which could be implemented during other restoration activities and to compliment the barrier wall construction. A betterment strategy of focused high intensity LNAPL recovery is considered feasible and necessary to reduce the mass of mobile LNAPL present both within the body of the Crymlyn Tip and the previously un-remediated Ash Bund. NAPL recovery is traditionally implemented from larger diameter (>100 mm diameter) recovery boreholes, interception trenches or sumps. The NAPL recovery design should take into account the properties of the recoverable fluid, the conductivity of the ground and associated radius of influence. Various techniques are also available to maximise the recoverability of NAPL, such as intermittent re-injection wells.

4.6.1 Schematic Layout of Potential LNAPL Recovery Option

A schematic of the potential works is provided in Graphic 7 for information and described further within Section 5.7 Finalised details are currently envisaged to be submitted via a new full planning application.



Graphic 7 - Approximate Schematic of Planned Restoration Works (Provided for Information)

The above graphic, provided for information, gives the currently anticipated extent of the restoration activities comprising the installation of a barrier cut-off wall, NAPL abstraction/recovery.

This figure shows that the ash bund has not been subject to substantive remediation works with the previous remediation phases having targeted the landfill mass itself. This, when combined with the evidence gathered from Englobe's 2022 SI, (Appendix I), points to the ash bund being both source and pathway. As shown by the figure, a substantial number of recovery (red) and re-injection (dark blue) locations are proposed and should serve to significantly reduce NAPL within this source zone. The barrier cut-off wall, shown as the pink line, is seen as an extra line of security and to fully ensure that the aesthetic and management issues with the peripheral trench can be removed.

Given that the ash bund: has not been subject to previous remediation works; has evidence of significant LNAPL impact; lies directly adjacent to the northern peripheral trench; and has relatively high permeability (in the order of 1×10^{-4} m/s from borehole logs and permeability testing) amenable and economic recovery methods are considered to be applicable and necessary.

4.7 Site Stability and Final Landform (Permit)

4.7.1 Introduction and Preliminary Assessment

The reprofiling of the Tip will be undertaken as part of the compliance with Permit and in accordance with an agreed permit Construction and CQA Plan. For full details reference should be made the CAMP.

The final landform should take account of the existing ground profile in conjunction with the location of waste materials and their stability, so that future instability risks associated with upward,

lateral or downward movement of the ground are minimised. In addition, the health, safety, and environmental risks associated with the current landform should also be considered. A preliminary assessment of the current landform and potential risks and instability issues has been carried out as follows.

The only significant slope area is along the northern boundary of the tip, where a steep sided 'ash' bund was originally constructed to contain the wastes. Currently the top of northern ash bund is between approximately 1 m (towards the west) and 12 m (towards the east) above the level of the Crymlyn bog and has a gradient of between approximately 1:2 (45 degrees) and 1:3 (33 degrees) along its northern face. It is assumed that the ash bund's gradient was a result of the materials' natural angle of repose which was formed during the tipping processes to create the ash bund containment feature. The stability of the bund is likely to be dominated by the geotechnical properties of the ash bund and the bog sediments, the underlying natural superficial material and bedrock being relatively much more competent than the bog sediments.

An approximate 4 to 6 m wide access track has been formed along the top of the bund, which has been used as a vehicular and pedestrian access route during the operation of the tip and to facilitate Permit compliance requirements. A chain-link fence is present along the northern shoulder of the bund as a health and safety feature to prevent access to and minimise risk of falls and injury associated with the slope. An additional vehicular access track leading down to the Crymlyn bog (to the north) is present approximately halfway along the bund. Scrub vegetation and trees have established themselves along the northern shoulder and slope of the bund.

4.7.2 Site Stability / Landform Options Appraisal

An option to reduce potential health and safety risks, together with potential risks of landslip or future material movement, is the reduction of the angle along the northern perimeter bund to a shallower gradient. This would require the removal of existing vegetation, including semi-mature to mature trees which have established themselves along the bund, in order to facilitate the necessary earthworks. The material to be excavated predominantly comprises loose to very loose ash which appears to have been stable in the short to medium term, with no evidence of landslip or instability. The presence of established vegetation and limitations on access are likely to have contributed to its stability and re-establishment of vegetation and tree-cover should be considered to further mitigate future risks.

The re-use of the ash bund material to re-profile other areas of the tip should be considered as long as the material can be demonstrated to be suitable for its intended use, both chemically and geotechnically. It is noted that the depth of the ash bund to be re-profiled will be above the level of groundwater, and based upon boreholes, also above any significant contamination. The full stability assessment, included within Appendix H, concludes that deep failure through the peat/soft clay is likely the critical failure mode. A safe angle of 1:4 (22.5 degrees) has been calculated for the northern ash bund. Elsewhere within the site, there is a mixture of terrain gradients which on the whole would appear to be stable in the current landform but would need to be re-assessed should they be subject to change.

4.8 Restoration Layer

The capping / restoration layers for the Tip will be undertaken as part of the compliance with Permit and in accordance with an agreed permit Construction and CQA Plan. For full details reference should be made to the CAMP.

The human health risk assessment (HH-RA) detailed within Section 3 considered that a minimum thickness of 1.1 m of restoration material be placed across the entirety of the permit area. It is also considered that the restoration materials could be formed from existing materials from the wider Coed Darcy development site, subject to them being suitable for their intended use from both a geotechnical and chemical suitability aspect. It is recognised that the CL:AIRE Definition of Waste (Development Industry) Code of Practice, 2011 (DoWCoP) could be implemented to control this re-use of material to ensure the appropriate safeguards are in place; and to record and validate the material used. Alternatively, the DoWCoP could be used to bring suitable materials in from an

alternative site under the 'Direct Transfer' route, or otherwise would need to be delivered to site from primary material sources.

It is considered prudent to consider the need for a high visibility membrane layer so that any future maintenance or construction works will have a clear and visible guide to show the start of underlying waste materials.

The proposed chemical criteria for the restoration layer have been adopted from the human health risk assessment, which comprises the details provided within Table 19.

4.9 Alternative Disposal of Waste

Crymlyn Tip is a closed landfill, which will not receive any additional or future waste deposits and any disturbance is required to consider current permit compliance and protection of human health and the wider environment as a minimum. Based on the composition and extent of the waste materials within the tip and the risk assessments undertaken to date, it is considered impractical as well as unnecessary to excavate or dispose of any waste from the tip.

It is also unlikely that alternative or suitable facilities are present or would have the capacity to accept any significant quantities of waste from this site. Significant risks to health, safety and the wider environment could be created by any large disturbance or movements of waste.

Disturbances of the underlying waste materials should be minimised as far as practicable; however, it is acknowledged that cut/fill requirements are required as part of these restoration plans, although these are designed to minimise any cut into the waste body.



5 Restoration Strategy

5.1 Introduction

Based on the restoration options appraisal, Englobe has determined the Best Practicable Technique (BPT) for the restoration to render the site suitable for a public open space end use is as follows:

- Targeted NAPL recovery within areas of identified significant residual NAPL. There are hotspots recording a significant thickness of LNAPL within the body of the tip itself, in addition to evidence of abundant smear zone LNAPL impact encountered within the Ash Bund during recent site investigation works carried out by Englobe. Given that the Ash Bund:
 - i. Has not been subject to previous remediation works;
 - ii. Has evidence of significant LNAPL impact;
 - iii. Lies directly adjacent to the northern peripheral trench; and
 - iv. Has relatively high permeability (expected in the order of 1×10^{-4} m/s from borehole logs) making it amenable to economic recovery methods.

Englobe propose to focus LNAPL recovery work on the Ash Bund and remaining Crymlyn Tip hotspots. Recovered NAPL would be subject to off-site disposal to appropriately licenced facilities. Treated waters would be subject to on-site re-injection under appropriate regulatory agreement;

- Installation of a low permeability vertical barrier cut-off wall, to act as a physical barrier to reduce potential movement of residual mobile contamination. Consideration has been given to the use of cement/bentonite slurry with potential addition of ground granulated blast furnace slag. The critical factors assessed include the permeability requirements, construction requirements and associated risks. Conductivity testing and sufficient modelling has been undertaken in the first instance to understand the impact on the groundwater regime;
- Reprofiting works associated with the construction of a temporary working platform during the construction of the barrier wall; and subsequent re-profiling to provide a suitable landform to minimise risks of potential future instability. Re-profiling works would require cut/fill and are likely to require a degree of re-consolidation following earthworks;
- Re-use of materials in line with Permit and/or DoWCoP to re-profile the site to a stable landform;

- Placement of restoration layers above landfill to mitigate potential risks to human health associated with direct exposure and fugitive emissions; and
- Disposal of ‘unsuitable for treatment’ material off-site to appropriately licensed facilities.
- Monitoring infrastructure to confirm compliance with dissolved phase and ground gas RTVs.

5.2 Preliminary Works

The following preliminary works will be undertaken as required:

- Submission of Planning Application for restoration works and associated stakeholder engagement;
- Regulatory engagement and agreement of this Restoration Implementation Plan;
- NRW Permit deployment to cover restoration treatment activities;
- Production of a final materials management plan (MMP) in compliance with CL:AIRE Definition of Waste: Development Industry Code of Practice (DoWCoP) and declaration by Qualified Person, and;
- Preparation of a Construction Phase Plan, to include QHSE documentation, in line with CDM regulations.

5.3 Initial Site Set-up, Welfare Compound and Pedestrian/Vehicular Access Routes

In order to complete the works, Englobe will establish a site compound area and temporary welfare cabins to include office, canteen, decontamination unit / changing room, toilets, stores and a parking area. The welfare will be powered by an on-site ‘silenced’ generator which will only run during operational hours and therefore turned off at night. It is proposed that the site compound includes provision for nightly plant and equipment storage and includes CCTV coverage supported by out of hours surveillance and call out response. It is not anticipated that floodlighting will be required; however, several motion sensor low power security lights will be established around the welfare compound to aid security and safety.

Primary access to the compound will be via a designated vehicle route from the Darcy Business Park access gates off the B4290 and will include a booking in system with the site security gate. Provision for site team car parking will be made at the primary access area and also at the site compound area. Traffic management during the project will be controlled and continually reviewed to manage the traffic movements on-site and the access/egress arrangements.

Segregated pedestrian routes using fencing and signage will be established to keep vehicles and pedestrians separated.

5.4 Re-profiling

The reprofiling of the Tip will be undertaken as part of the compliance with Permit and in accordance with an agreed permit Construction and CQA Plan. For full details reference should be made the CAMP.

Re-profiling works of the Crymlyn Tip area have been considered to minimise long term potential instability risks.

An angle of between 22.5 degrees or 1:4 (vertical:horizontal) or 25% grade is considered to be appropriate in terms of safeguarding future landslip risk and offers a pragmatic solution in terms of minimising cut/fill requirements and future safety concerns regarding the steep banking.

A shallower gradient along the northern area would require a cut and fill exercise, which could be undertaken by reforming the ash materials to create a slightly re-profiled area to the south and particularly the south east. The aim of the re-profiling would be to create a natural landform pattern comprising a mounded or convex shape to provide drainage relief and encourage the dispersal of rainwater to the existing drainage features surrounding the tip area.

There would also be, to a lesser extent, reprofiling of the Lower Tip area, in order to produce a gradient to facilitate drainage.

Drawing D1858/23/5289/07 provides a plan view of the proposed base of restoration soils levels to reduce the northern boundary gradients to 1 in 4 and reprofile the Tip more generally to achieve a suitable landform and acceptable gradients.

Drawing D1858/23/5289/09 provides the location of drawing cross sections, which are provided on Drawings D1858/23/5289/010 and D1858/23/5289/011a and 11b.

D1858/23/5289/013 shows the cut and fill requirements to achieve the proposed base of restoration layer levels.

The greatest differences between the top of the restoration layer and the current ground level, in terms of increased height, occur at:

- The interface of the Upper and Lower Tip (including the 'Santander' Trench).
- The northern central area of the Upper Tip in order to create the predominant southerly slope.
- The depression to the east of the Upper Tip.

The stability and settlement assessments take into account these changes.

The greatest differences between the top of the restoration layer and the current ground level, in terms of decreased height, occurs at the ash bund along the northern boundary of the Upper Tip.

In order to achieve this reprofiling, it is currently calculated that a cut of 23,200 m³ is required and a fill of 56,980 m³. Therefore, an import/fill requirement of 33,780 m³ is needed to complete the reprofiling to base of cap.

Given that these materials will sit below the cap / restoration layer, it is intended that stockpile SP7 (which has been assessed as part of the Closure and Aftercare Monitoring Plan) will form part of this reprofiling fill (c. 15,000 m³), and approximately 8,200 m³ will be generated by temporary platform works. The remainder will be sourced from the wider Coed Darcy site in accordance with DoW CoP. This may include in the order of 10,580 m³ of the glass Glasstech waste (discussed in the Closure and Aftercare Monitoring Plan). This waste is suitable fill for two specific areas of the reprofiling required - the 'Santander' Trench, and part of the low eastern area. We believe there is a necessity for this fill, and the Glasstech material, being granular and moderately geotechnically competent, is considered geochemically suitable.

Once this reprofiling is complete, the existing capping soils and any additional soils placed during the reprofiling works will form a physical separation between the waste within the Tip and restoration soils. A marker layer of geotextile material will be placed prior to the placement of restoration soils.

5.5 Temporary Construction Platform

A 10 m wide temporary construction working platform will be required for plant to construct the proposed barrier wall. The stability of plant is fundamentally dependent upon the provision of a suitable and sufficient working platform, which must be properly designed and installed to a recognised standard. Details of the plant to be used and bearing pressures will be required, in

order to appropriately design the working platform in advance of the works. A geotextile membrane will be required beneath approximately 0.5 m of granular platform material to contribute to the stability of the platform.

In order to provide a minimum head of slurry, it is essential that the working platform is 1.5 m above groundwater level. The consequence of not creating this differential head is a risk of trench collapse and potential presence of unwanted inclusions into the cement bentonite wall which may compromise its ability to cut-off groundwater. The level of the temporary platform has therefore been designed to be 1.5 m above the maximum measured groundwater levels. The temporary platform alignment and proposed levels are shown on Drawing D1870/23/5289/05, Appendix A.

5.6 Oil Containment Wall

5.6.1 Wall Design

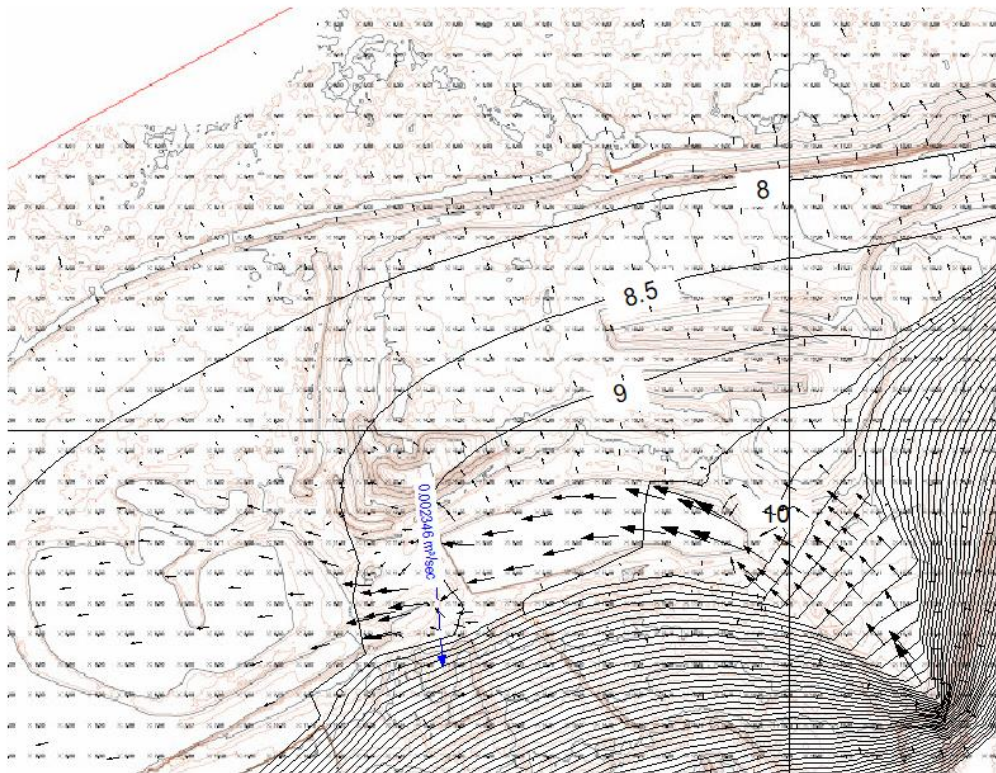
In order to complete the design of the oil containment wall critical factors requiring assessment include the groundwater regime, hydraulic conductivity of underlying soils, the required depth of the barrier wall, permeability requirements, interaction between wall materials and residual contamination, construction requirements and associated risks.

Conductivity testing and sufficient modelling has been undertaken in the first instance to understand the impact on the groundwater regime. Installations within each of the new Englobe boreholes were screened within the natural strata beneath the proposed line of the wall. This enabled conductivity testing to be undertaken and an assessment of the ability for groundwaters to pass beneath the wall.

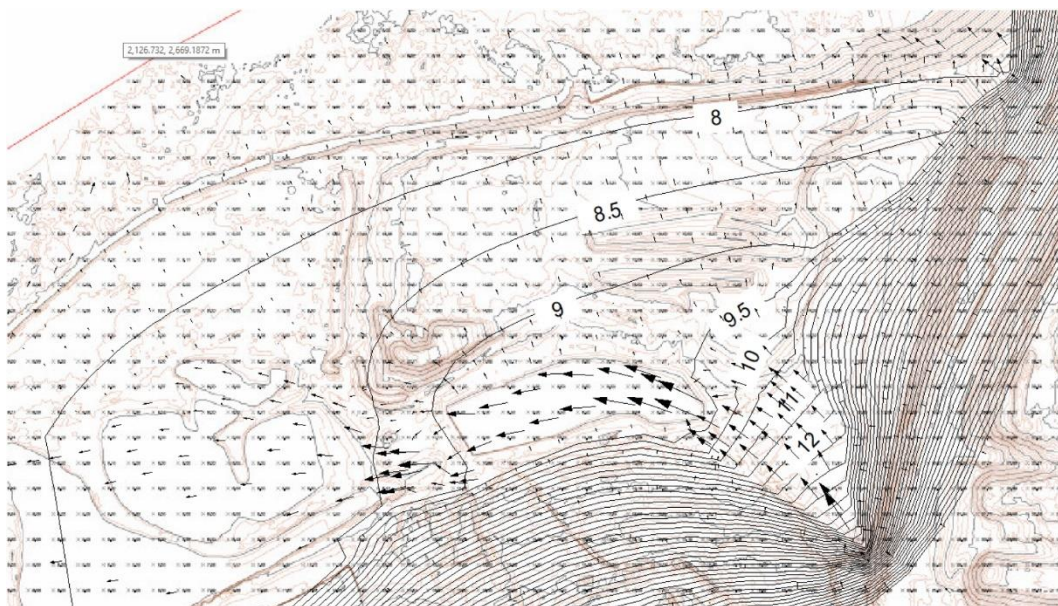
Graphic 8 - Mean Conductivity of Natural Stata Below the Tip

BHID	K Value (m/s)			
	Value 1	Value 2	Value 3	Mean
ENBH1	5.60E-04	6.10E-04	-	5.85E-04
ENBH2	1.90 E-05	2.20 E-05	-	2.05 E-05
ENBH3	5.00E-04	5.50E-04	-	5.25E-04
ENBH4	5.40 E-05	5.30 E-05	-	5.35 E-05
ENBH5	1.60 E-05	2.20 E-05	2.30 E-05	2.03 E-05
ENBH6	4.60E-04	3.50E-04	-	4.05E-04
ENBH7	1.10E-06	9.90E-07	-	1.05E-06
ENBH8	8.90E-07	1.10E-06	-	9.95E-07
ENBH9	1.60E-05	2.10E-05	-	1.85E-05
ENBH11	1.80E-05	-	-	1.80E-05

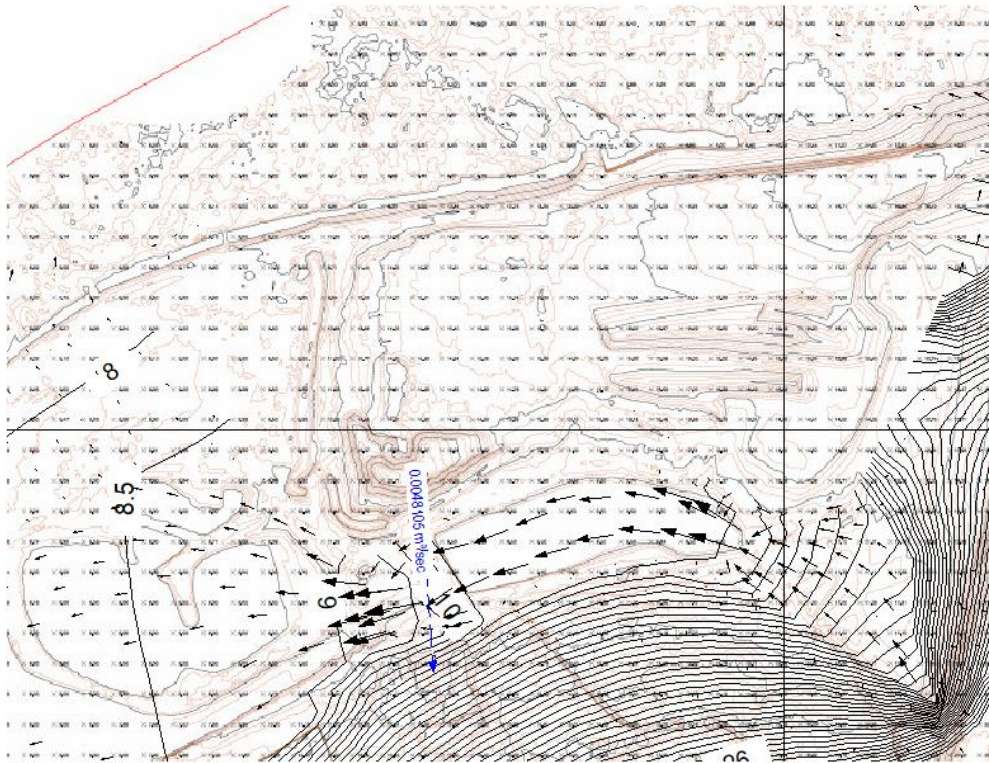
Graphic 9 illustrates the modelled groundwater flow with no barrier in place, Graphic 10 illustrates flow with a partial barrier wall in place and Graphic 11 with a total barrier in place, Graphic 12 shows modelled groundwater flow with no cut off and no infiltration within a capped area.



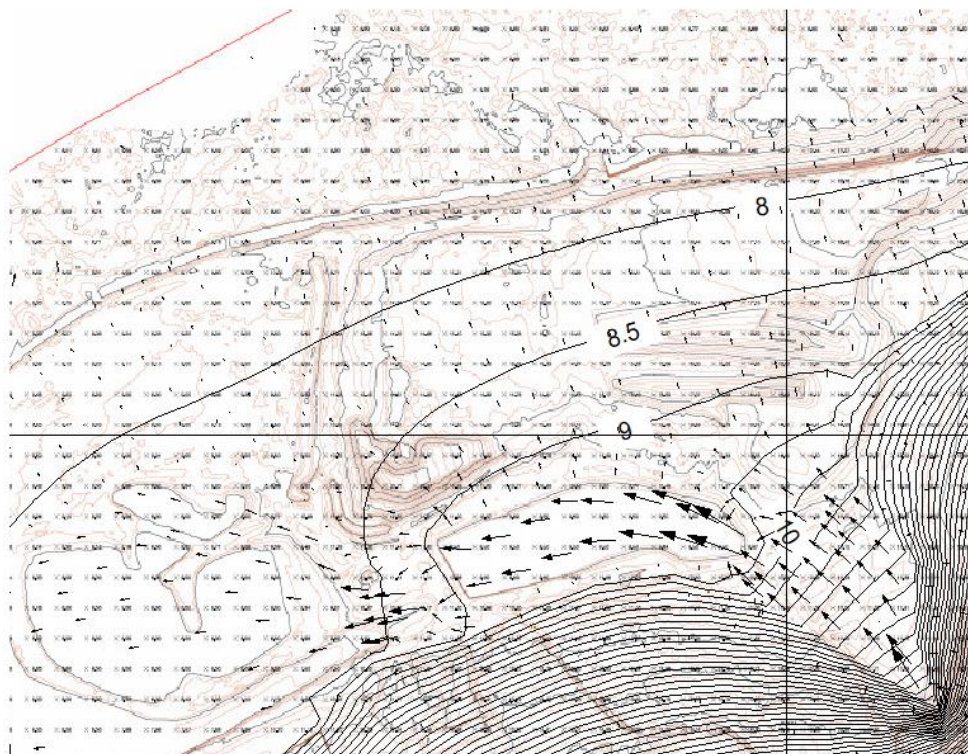
Graphic 9 - Modelled Groundwater Flow with No Barrier



Graphic 10 - Modelled Groundwater Flow with Partial Barrier

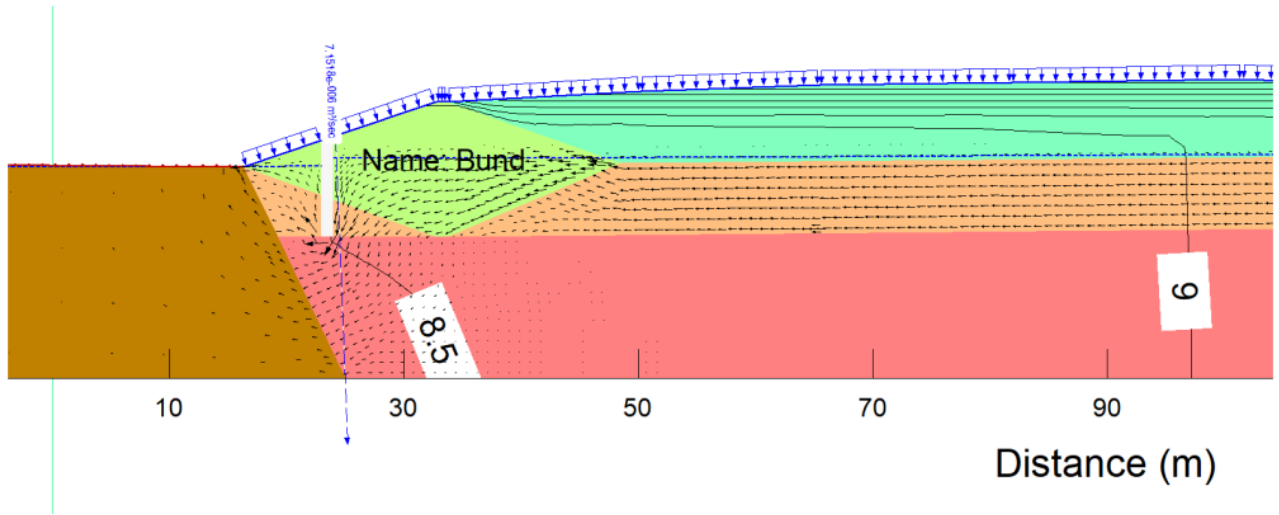


Graphic 11 - Modelled Groundwater Flow with a Total Barrier

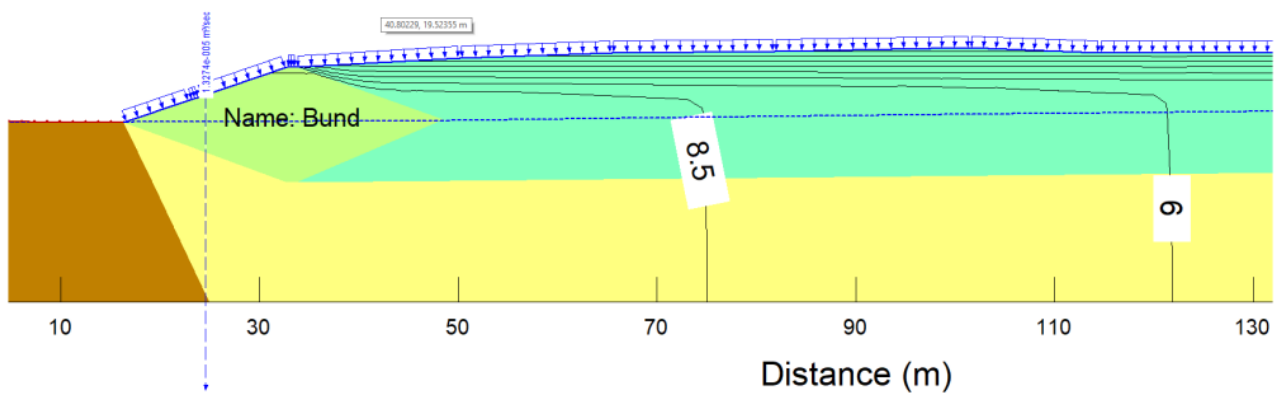


Graphic 12 - Modelled Groundwater with no barrier, no infiltration and capped

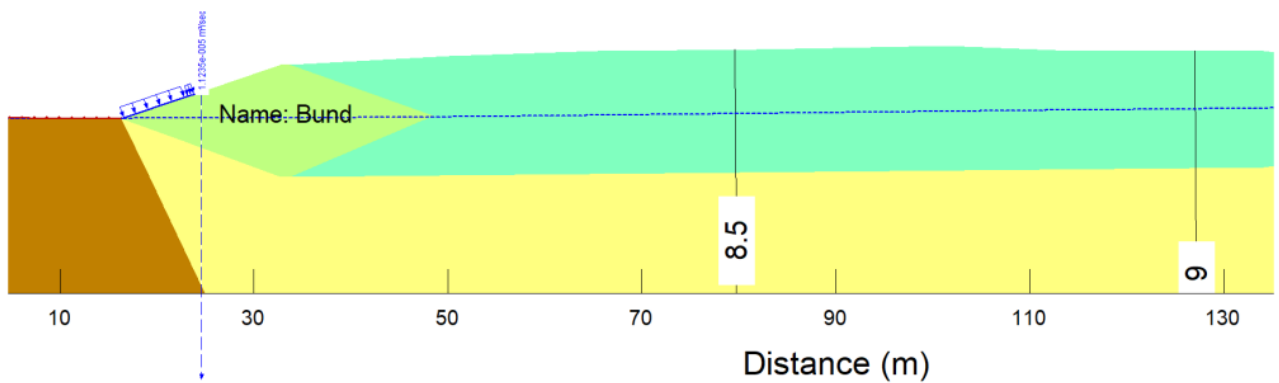
The following cross section, Graphic 13, illustrates the modelled groundwater flow associated with a partial barrier cut-off wall as illustrated by Graphic 10, Graphic 14 and 15 provide other modelled scenarios for comparison. Graphic 16 shows Effect of conductivity below the wall on Flow and Water Level.



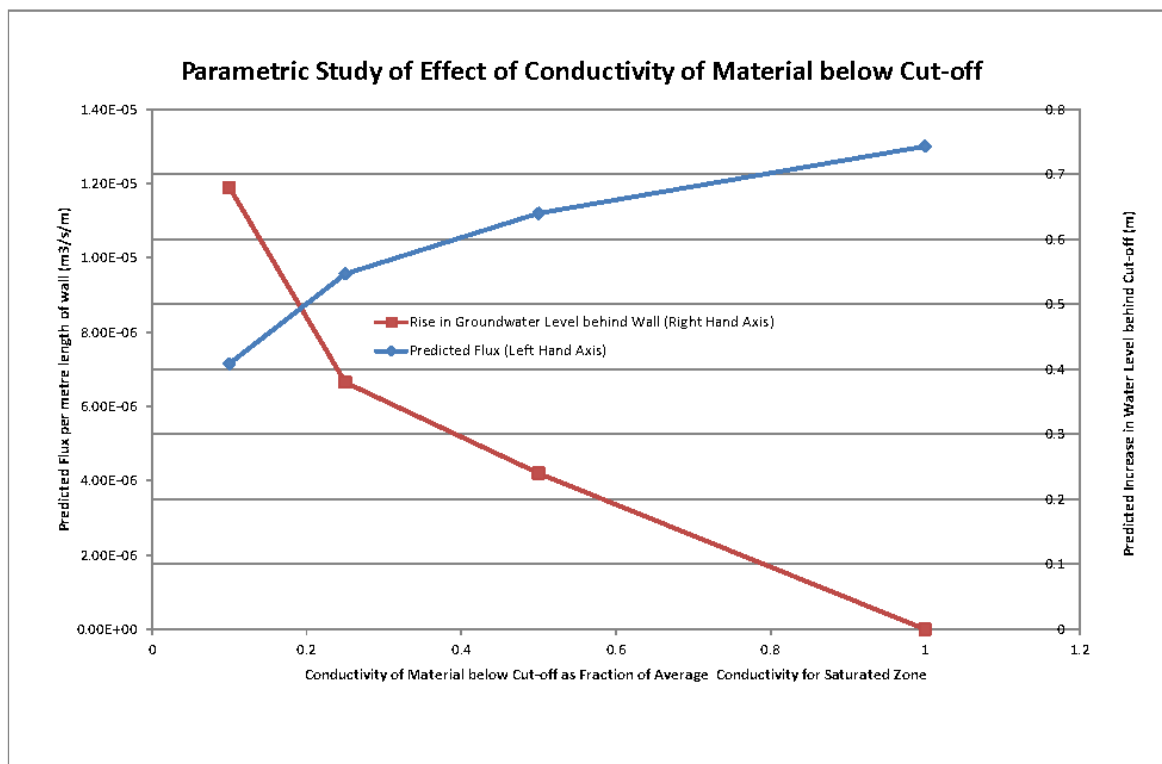
Graphic 13 - Modelled Cross-Section of Groundwater Flow with a Partial Barrier



Graphic 14 - Modelled Cross-Section of Groundwater Flow with no Barrier (base case)



Graphic 15 - Modelled Cross-Section of no Infiltration in Capped Area



Graphic 16 - Effect of k below wall on Flow and Water Level

The depth of the base of the barrier wall has been designed to take into account fluctuations in the local groundwater levels, the underlying geology and associated hydraulic conductivity and the effect of groundwater flow on the barrier.

It is calculated that the underlying natural strata provides sufficient conductivity to allow sufficient groundwater flow. A conductivity of the underlying natural strata of 10% of the saturated zone above will result in a calculated rise behind the barrier of 70 cm. This therefore does not impact the efficacy of the oil containment barrier.

As discussed below, for the wall to achieve the objective of oil containment, it does not need to extend fully down to the natural ground (at approximately 2 m AOD). The deepest base of wall is calculated at 4 m AOD, and this therefore provides approximately 2 m of higher conductivity material for groundwater to flow through. The barrier typically will provide a 2 m 'gap' between base of wall and the natural peat/clays, hence increasing the conservatism of the calculations shown in the above Graphics.

Subsequently, Englobe have undertaken falling head tests on wells installed within the underlying natural ground, presented in Graphic 8, the calculations shown in Graphic's 9 - 16 will be revised with this site data (and this report updated should the results indicate any significant variance).

The extent of LNAPL sources and potential maximum thickness is also required to be considered in the wall design. In general, the base of the wall has been designed to allow continuity of groundwater flow so as not to allow groundwater levels to 'mound up' or significantly raise due to the presence of the barrier, however, it also needs to be deep enough to ensure NAPL cannot move beneath the wall. Contouring of the apparent LNAPL thickness has been undertaken to approximate the thickest credible LNAPL layer. The maximum thickness of LNAPL recorded within the last three years of monitoring has been 2.36 m (21st January 2021). The base of the wall has therefore been designed to be set at the lowest anticipated water level minus the thickest credible LNAPL.

The base of the barrier wall is therefore designed to be installed to a depth of between 4 m and 7 m AOD, (the variance due to variances in groundwater levels). This depth sits above the underlying peat and clay and as such will allow sufficient groundwater flow beneath, but also is

The level of the top of the barrier wall has been designed to be at least 1.5 m above the highest groundwater level to allow for potential future changes in groundwater level and prevent ‘over-topping’ of the barrier. The proposed location and level of the barrier wall is illustrated on drawing D1870/23/5289/05, Appendix A, and shown in Graphic 17 below:



While there are no definitive design lives for such a wall, the construction utilising a cement / bentonite clay slurry will result in a barrier that should maintain its efficacy for a very substantial period of time.

5.6.2 Wall Construction Methodology

- GGBS less than 10%
- CEM 1 less than 10%

- Bentonite greater than 10%
- Water greater than 80%

The slurry wall mix design would be undertaken in accordance with the ICE/CIRIA/BRE “Specification for the Construction of Slurry Trench Cut-Off Walls”, 1999. In accordance with the ICE Specification the slurry design mix would target a minimum unconfined compressive strength (UCS) of 100 kPa at 28 days. The slurry would be designed to have a maximum permeability of 1×10^{-9} m/s.

The cement bentonite slurry will be prepared on-site with a slurry batching plant incorporating a high shear mixer to ensure product quality and uniformity. The bentonite is mixed with water in a high shear colloidal mixer to ensure adequate hydration of the bentonite before a second stage of the process can begin. The cement and GGBS are then introduced into the high shear mixer. The mixed cement bentonite slurry is then discharged into agitation tanks for temporary storage prior to delivery to the trench. The cement bentonite slurry will be pumped from the batching plant to the location of the slurry wall installation. The slurry that is added to the excavation will restrict collapse by providing support to the side walls.

The trench would be excavated to the required depth utilising a long-reach tracked excavator. Excavated material would be side cast to a safe position adjacent to the trench. If necessary, this material would be loaded and transported to suitable stockpile location. The cement bentonite slurry will be pumped into the trench and allowed to set to form the required low permeability barrier.

Sufficient grout volume greater than the theoretical trench volume will be produced to allow for any wastage, overbreak and filtration into surrounding ground. Collection of slurry in U100 samples will be undertaken for quality assurance testing, typically every 200 m² of slurry wall or each day (whichever is the lesser). Further laboratory testing will be undertaken to determine the unconfined compressive strength and the permeability of the cement bentonite cut-off wall. In accordance with the ICE Specification for the Construction of Slurry Trench Cut-Off Walls, 1999, we have allowed for two tests of each parameter for every 1,000 m² of wall constructed to be tested.

Where day production joints are required, these will be formed by cutting into the end face of the previous day’s excavation by a minimum of 500 mm to ensure no permeable “window” is left within the wall structure.

Following the installation of the cement bentonite wall, the top will be covered with either a suitable clay or concrete in order to prevent the grout from desiccating, whilst exposed and before the restoration layers are in place.

5.7 NAPL Recovery Works

5.7.1 Objective of NAPL Recovery Works

The NAPL recovery works are being carried out as a risk averse measure to compliment the barrier wall design and construction. Part of the purpose of the NAPL recovery is to confirm the maximum thickness of NAPL is consistent with the maximum thickness used in the design of the wall. A betterment strategy of focused high intensity LNAPL recovery is proposed for a six-month period to reduce the mass of mobile LNAPL present both within the body of the Crymlyn Tip (Hotspots 1 and 2) and the previously un-remediated Ash Bund.

5.7.2 NAPL Recovery Works Design

Englobe propose to install a network of abstraction and reinjection wells in three key areas; the Ash Bund, Hotspot 1 and Hotspot 2, as illustrated in Drawing D1870/23/5289/06, Appendix A the drawing is an indicative layout, the final layout will take into account the final slope and wall platform locations.

Abstraction wells will contain intrinsically safe pneumatically operated total fluids pumps, designed to recover both LNAPL and groundwater. Each cluster of four abstraction wells will be paired with a

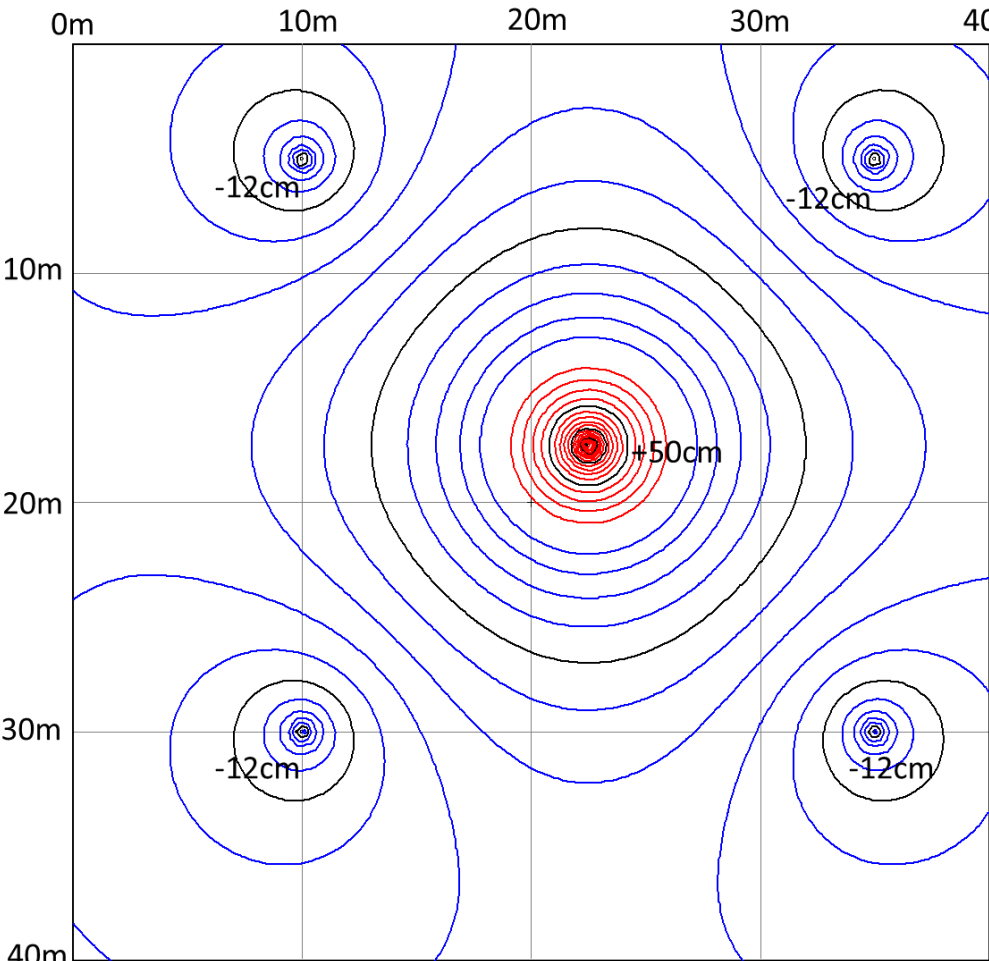
central reinjection well, with the objective of creating a steepened hydraulic gradient, thereby increasing pore velocity and creating a flushing effect of LNAPL towards the abstraction wells. The induced groundwater contours have been modelled using MLU modelling software, inputting hydraulic conductivity values inferred from borehole logs from Englobe’s recent site investigation works. Based on the induced hydraulic gradient and abstraction well spacing of 25 m, the groundwater pore velocity is increased from 0.005 m/s under steady state conditions to 0.05 m/s, which in Englobe’s experience, will increase LNAPL recovery rate, compared with traditional LNAPL skimming methods. Induced groundwater contours under pumping and re-injection conditions are illustrated in Graphic 18.

Groups of abstraction well clusters will be operated on a timer, so that the active zones will operate on a cyclical basis. This will result in regular rise and fall of the induced groundwater level within the hotspot zones, enhancing the flushing of LNAPL from pore spaces.

The abstracted liquids will be treated above ground by passage through an oil-water separator, prior to reinjection into the zone of origin. Groundwater mass balance using this method will therefore be net zero.

Given that the Made Ground within the tip is variable in nature and therefore hydraulic conductivity, it is likely that some wells or areas within Hotspot 1 and Hotspot 2 will not have sufficient hydraulic conductivity to carry out the total fluids pump and treat method. Where significant LNAPL thickness is recorded in these areas, LNAPL skimming will be carried out using low-flow rate pneumatic skimming pumps, with recovered liquids returned to the central oil-water separator.

As it is anticipated that off-site removal of recovered LNAPL will be required on at least a monthly frequency; Englobe will install LNAPL skimming infrastructure to facilitate regular or continuous LNAPL removal.



Graphic 18 - Induced Groundwater Contours in an Abstraction Cluster

The LNAPL recovery system will comprise a containerised compressor system to supply the zoned networks of pneumatic total fluids pumps and LNAPL skimming pumps. The compressor system will be controlled by a programmable logic controller (PLC) to enable:

- Control / cessation of system operation based on input from critical safety devices;
- Control of individual timers for recovery from each zone, allowing for LNAPL recovery optimisation;
- Telemetry to notify nominated Englobe personnel via SMS of any system event requiring attention, plus visualisation of key system parameters via 4G router and associated online portal.
- Each individual intrinsically safe (ATEX rated) pneumatic pump will be equipped with an air isolation valve to enable pump removal for maintenance and to allow monitoring of conditions within the recovery well. The pumps will be secured to an anchor point to allow adjustment of pump height to ensure successful capture of LNAPL with groundwater fluctuation.

Recovered liquids from the pneumatic pumps will enter a header main leading to an oil-water separator (OWS). The OWS will comprise a steel tank with multiple baffles to ensure effective gravity separation of LNAPL prior to discharge. An oil-skimmer will be installed on the separator to continuously drain captured LNAPL into the associated oil storage tank.

Following oil-water separation, treated water will be conveyed via a discharge pump to the network of reinjection wells. Automated control valves will ensure that treated water is discharged only into the active abstraction clusters.

All tanks will be contained within a bund of 110% capacity of the largest tank. Each tank, as well as the bund, will be equipped with high level sensors acting to shut down relevant elements of the system to immediately cease further inflow.

5.7.3 System Monitoring and Optimisation

The LNAPL recovery system will be monitored regularly during both commissioning and operation to ensure appropriate recording of system performance parameters, including all information required to enable optimisation of LNAPL recovery rates. The parameters to be monitored are listed in Table 8 - **System Monitoring Parameters** below.

Table 8 - System Monitoring Parameters

Parameter	Location	Frequency	
		Commissioning	Operation
Pneumatic pump discharge rate	Pump discharge sample valve	3 times per week	Weekly
Pneumatic pump water/LNAPL ratio	Pump discharge sample valve	2 times per week	Weekly
Pneumatic pump inlet air pressure	Pump air inlet pressure gauge	2 times per week	Weekly
Recovery well LNAPL level / thickness	Recovery well	3 times per week	Weekly
Recovery well groundwater level	Recovery well	Daily	Weekly
Recovery well depth to base	Recovery well	Twice in total	Monthly
Compressor system outlet air pressure	Compressor system cabin	Daily spot check / continuous monitoring	Weekly spot check / continuous monitoring
Cumulative volume of reinjected water	Water treatment system water meter	Daily spot check / continuous monitoring	Weekly spot check / continuous monitoring

Parameter	Location	Frequency	
		Commissioning	Operation
Cumulative re-injection volume per zone	Reinjection zone inlet branch water meter	Daily	Weekly
LNAPL level within LNAPL recovery tank	LNAPL recovery tank	Daily	Weekly
Total volume of recovered LNAPL	LNAPL recovery tank	Daily	Weekly

Certain parameters can be read in real-time and displayed / logged by the programmable logic controller (PLC), whereas others will require manual spot checks; as summarised in the above table. Real-time monitoring ensures that the air delivery and treated water reinjection systems are functioning as required, whilst alarm set-points can be programmed to trigger Short Message Service (SMS) alarms to promptly alert operators of a problem.

Water level and LNAPL monitoring will ensure that recovery effort is focussed on the most productive wells, and regular adjustment of pump positions may be required to ensure that LNAPL is being adequately captured with any change in water levels.

5.8 Restoration Layer

The capping / restoration layer for the Tip will be undertaken as part of the compliance with Permit and in accordance with an agreed permit Construction and CQA Plan. For full details reference should be made the CAMP.

Following cut/fill re-profiling works to achieve the final landform and the completion of the wall installation and NAPL recovery, a final restoration layer would be constructed.

Drawing D1858/23/5289/08 provides a plan view of the proposed final landform (top of restoration soils). Drawing D1858/23/5289/09 provides the location of drawing cross sections, which are provided on Drawings D1858/23/5289/010 and D1858/23/5289/011a and 11b. Drawing D1858/23/5289/014 provides the final general gradients across the Tip.

It is proposed that the restoration layer is 1.1 m thick on the Upper Tip and 0.5 m on the Lower Tip, resulting in a total volume requirement of 77,250 m³. This material will be required to meet the appropriate chemical criteria as set out in Section 6. Currently it is anticipated that stockpiles SP1 to SP6 (see Appendix J) will be suitable and represent approximately 12,700 m³. The remaining volume will be sourced from the wider Coed Darcy site in accordance with DoWCoP. Materials will be tested at a frequency of 1 per 500 m³, however the final frequency will be determined once the source material is determined.

Both the identified stockpiles and any further imported materials will be controlled via an agreed Materials Management Plan which will ensure all materials are tracked, suitable for use, and will confirm the necessity for the material. At this stage, we believe that the CAMP CQA Plan, will demonstrate that the materials, and the estimated quantities, will be genuinely “recovered” and replace the use of otherwise imported virgin materials.

The final construction designs and methods will form part of the Permit’s Construction Plan; however, they are anticipated to take into account the sequence and scope of these restoration works. This will include the interaction with the barrier wall and NAPL works, and the protection of longer-term monitoring infrastructure. Table 10 provides a summary of the anticipated areas and volumes.

Table 9 - Summary of Anticipated Areas and Volumes

Description	Area/Volume
Lower Tip Capping Area (including north batter)	15,723 m ²
Upper Tip Capping Area (including north batter)	61,929 m ²
Total Tip Capping Area	77,652 m ²

Description	Area/Volume
Area of Ash Bund Northern Toe (Perimeter Drain) to be Capped	880 m ²
Restoration Soils Volume (500 mm across Lower Tip)	7,862 m ³
Restoration Soils Volume (1,100mm across Upper Tip)	68,122 m ³
Restoration Soils Volume (Bund North Toe/Perimeter Drain)	1,270 m ³
Total Volume of Restoration Soils Required	77,254 m ³

A recent investigation of the stockpiled materials on-site has been undertaken and a copy of the report is included within Appendix J. In summary, a volume of approximately 10,830 m³ is available from stockpiles SPE-1 to SPE-6, which is suitable material for use in the restoration layer, would leave an approximate shortfall of 66,424 m³.

In lieu of suitable availability of on-site materials, sources of suitable off-site materials would be required to make up any shortfall. It is considered that the suitability and placement of the capping and restoration layers would be undertaken in-line with the CL:AIRE, DoWCoP, 2011 and associated materials management plan.



6 Restoration Verification Approach

6.1 Proposed Restoration Targets

Based on the risk assessments and options appraisal, Restoration Target Values (RTVs) using professional judgement based on the range of available modelling outputs, published criteria and meeting the project objectives, or other verification criteria, have been selected.

It is noted that RTVs should be used carefully when comparing with site data and their use should appropriately take into account adopted sampling strategies. Such criteria are typically compared to average or representative source/averaging-area concentrations, rather than maximum or isolated elevated/peak levels. If representative concentrations are significantly above an adopted criterion, then this would normally trigger further appropriate actions, such as additional investigation/verification, risk assessment or further/continuing remediation/mitigation.

Analytical results are to be analysed and compared to the remedial targets in line with CL:AIRE Guidance¹. Results will be deemed acceptable if the UCL Mean concentration of the results for each source area meet or are lower than the relevant remedial targets.

6.1.1 Groundwater RTVs

These values are based on an assumed 50 m point of compliance and determined as the highest average concentration over any 220 m length of the downstream boundary of the permit area, which is the source width assumed in RTM analysis. The utilisation of the 50 m point of compliance is considered reasonable in light of both the distance to the Crymlyn Brook and the historical off-site impact. It is proposed that these completion criteria will apply along the boundary of the permit area. The proposed validation monitoring locations are discussed later in this section.

¹ Guidance on Comparing Soil Contamination Data with a Critical Concentration, CL:AIRE, May 2008.

Table 10 - RTM Assessment Criteria - Level 3 Groundwater

Substance	RTM Assessment Criteria Level 3 Groundwater (mg/l) 2 = 50m Compliance
Benzene	0.079
Toluene	11
Ethylbenzene	120
m-Xylene	ES(320)
o-Xylene	140
p-Xylene	180
Benzo[b]fluoranthene	ES(>10,000)
Benzo[k]fluoranthene	ES(>10,000)
Benzo[ghi]perylene	ES(>10,000)
Benzo[a]pyrene HH2015	ES(>10,000)
Fluoranthene HH 2015	ES(>10,000)
Indeno[123-cd]pyrene	ES(>10,000)
Naphthalene	ES(>10,000)
Anthracene	ES(>10,000)
TPH Aliphatic C5-C6	ES(>10,000)
TPH Aliphatic C6-C8	ES(>10,000)
TPH Aliphatic C8-C10	ES(>10,000)
TPH Aliphatic C10-C12	ES(>10,000)
TPH Aliphatic C12-C16	ES(>10,000)
TPH Aromatic C8-C10	ES(>10,000)
TPH Aromatic C10-C12	ES(>10,000)
TPH Aromatic C12-C16	ES(>10,000)
TPH Aromatic C16-C21	ES(>10,000)
TPH Aromatic C21-C35	ES(>10,000)
Arsenic	0.05
Cadmium	0.00025
Copper	0.049
Chromium	0.02
Lead	0.0072
Mercury	0.00005
Nickel	0.034
Selenium	0.01
Zinc	0.079
Vanadium	0.02
Ammoniacal Nitrogen as N	1.5
Chloride	250

ES = Target Exceeds
Solubility

6.1.2 Human Health RTVs

The proposed human health RTVs are presented below for the 1.1 m restoration layer soils in order to be protective of human health in accordance with the risk assessment outcomes.

Table 11 - Proposed Human Health RTVs in mg/kg

Substance	Reference Criteria		Proposed HH-AC
	POS-2: Parks	Commercial Use	
Arsenic	170	640	170
Cadmium	560	190	190
Chromium (as III)	33,000	8,600	8,600
Copper	44,000	68,000	10,000 (reduced from 25,000) ⁽¹⁾
Lead (inorganic)	1,300	2,300	1,300
Mercury (inorganic)	240	1,100	240
Nickel	800	980	800
Selenium	1,800	12,000	1,800
Vanadium	5,000	9,000	5,000
Zinc	170,000	730,000	10,000 (reduced from 170,000) ⁽¹⁾
Easily Liberatable Cyanide	100 (SoBRA Acute)	100 (SoBRA Acute)	24
Asbestos/ACM in Soil	-	-	No visible ACM, plus: Not identified at Stage-1 OR $\leq 0.001\%$ at Stage-2 With allowance for sporadic $<0.005\%$ w/w
Sum TPH Fractions	Hazard Quotient ≤ 1	Hazard Quotient ≤ 1	Consider Sum-TPH value in RIP based on Hazard Quotient ≤ 1 and TPH composition in surface materials.
Aliphatic TPH C5-6	3,200	95,000	3,200 ⁽²⁾
Aliphatic TPH C6-8	7,800	150,000	7,800 ⁽²⁾
Aliphatic TPH C8-10	2,000	14,000	2,000 ⁽²⁾
Aliphatic TPH C10-12	9,700	21,000	9,700 ⁽²⁾
Aliphatic TPH C12-16	59,000	25,000	10,000 (reduced from 25,000) ^(1,2)
Aliphatic TPH C16-35	160,000	450,000	10,000 (reduced from 160,000) ^(1,2)
Aliphatic TPH C35-44	160,000	450,000	10,000 (reduced from 160,000) ^(1,2)
Aromatic TPH C8-10	3,500	7,200	3,500 ⁽²⁾
Aromatic TPH C10-12	16,000	9,200	9,200 ⁽²⁾
Aromatic TPH C12-16	36,000	10,000	10,000 ⁽²⁾
Aromatic TPH C16-21	28,000	7,600	7,600 ⁽²⁾
Aromatic TPH C21-35	28,000	7,800	7,800 ⁽²⁾
Aromatic TPH C35-44	28,000	7,800	7,800 ⁽²⁾
TPH C44-70	28,000	7,800	7,800 ⁽²⁾
Sum 16-PAHs	-	-	<i>The RIP could use an additional Sum-16 value to help simplify the PAH criteria</i>
Naphthalene	190	1,200	190
Acenaphthylene	83,000	29,000	1,000 (reduced from 29,000) ⁽¹⁾
Acenaphthene	84,000	29,000	1,000 (reduced from 29,000) ⁽¹⁾
Fluorene	63,000	20,000	1,000 (reduced from 20,000) ⁽¹⁾
Phenanthrene	2,000	6,200	1,000 (reduced from 2,000) ⁽¹⁾
Anthracene	520,000	150,000	1,000 (reduced from 150,000) ⁽¹⁾
Fluoranthene	23,000	6,300	1,000 (reduced from 6,300) ⁽¹⁾
Pyrene	54,000	15,000	1,000 (reduced from 15,000) ⁽¹⁾
Benzo(a)anthracene	77 Via BaP (C4SL)	21 Via BaP (C4SL)	21 ⁽³⁾
Chrysene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Benzo(a)pyrene			
Indeno(1,2,3-cd)pyrene			
Dibenz(a,h)anthracene			

Substance	Reference Criteria		Proposed HH-AC
	POS-2: Parks	Commercial Use	
Benzo(ghi)perylene			
Total Phenols	440	440	440
Other VOC/SVOC/Inorganics	S4UL/C4SL/EIC	S4UL/C4SL/EIC	If required, the RIP can use other S4UL/C4SL/EIC values
Soil pH (as skin irritant)	5 to 9	5 to 9	Within normal soil range 5 to 9 ⁽⁴⁾
Notes: (1) reduced down to prevent excessive contaminant loadings; (2) where practicable, the speciated TPH fraction criteria should be used in conjunction with a sum-TPH value; use the 'unreduced' criteria number in the calculation; (3) C4SL (marker for 8 genotoxic PAHs), do not sum the 8-PAH, only compare against BaP; (4) applies to soils and not applicable in the case of crushed aggregates and concrete.			

6.1.3 Ground Gas RTVs

The monitoring data assessed by GGS in the LfGRA (Appendix G) was used to produce completion criteria as a route to surrender of the permit. The completion criteria are to be applied based on waste-derived gas generation and therefore borehole flow rates remaining low (i.e., below 70 l/hr) at all locations during each monitoring episode over 24 consecutive months.

The completion criteria have been adopted as Restoration Target Values in the context of the Remediation Implementation Plan. These are tabulated below.

Table 12 - Ground Gas RTVs

Gas/Parameter	RTV
CH ₄ %	>5% v/v
CO ₂ %	>10% v/v
BH Flow (Max)	<70l/hr
Qhgs/GSV	<0.7/0.7

It is noted that the risk to human health from trace gases is not considered significant by either the HH-RA or the LfGRA. However, trace gases, by measurement of TVOCs, will be monitored as part of the gas verification programme.

6.1.4 Containment Wall

There will be a requirement to retrieve and test U100 samples for unconfined compressive strength and permeability. The testing frequency should be undertaken on a 1 per 200 m² of barrier wall or each day (whichever is less).

Full verification criteria will be established and agreed with St Modwen and the regulators as part of detailed planning works. However, in accordance with the ICE Specification the slurry design mix would target a minimum unconfined compressive strength (UCS) of 100 kPa at 28 days. The slurry would be designed to have a maximum permeability of 1x10⁻⁹ m/s. In accordance with the ICE Specification for the Construction of Slurry Trench Cut-Off Walls, 1999, we have allowed for two tests of each parameter for every 1,000 m² of wall constructed to be tested.

There will also be detailed records during the construction and as-built drawings to verify construction to the final designs.

6.1.5 LNAPL Recovery Targets

- The data collected during system operation will be used to verify the works against the proposed criteria:
- Total volume of recovered LNAPL;
 - ≥90% system uptime during the recovery works; and
 - Confirmation that the design assumptions of the oil containment wall are valid and that maximum NAPL thickness will not exceed a thickness that may result in NAPL loss beneath the wall.

6.2 Verification and Monitoring Plan

6.2.1 Introduction

- In general, the aim of the verification test plan is to provide a regime of testing to demonstrate the following:
- that residual contaminants meet the remedial criteria (adopted RTVs) and do not pose an unacceptable risk to human health or the wider environment;
 - that restoration works have been correctly undertaken;
 - that materials have been appropriately treated and that remedial criteria have been achieved;
 - that only appropriate materials have been imported to site; and
 - that site originating materials are suitable for re-use.

6.2.2 Ground Gas and Groundwater Monitoring Infrastructure

The current monitoring network, which comprises the locations detailed in PJA Drawing 04020-A-SK201-P2 in Appendix A, are concentrated within the site’s central area along with a number of peripheral locations.

Several of these locations may be suitable for use within a monitoring network, and there is inherent value in providing long term continuity within datasets where possible, however it must be recognised that many of these locations are over 20 years old, and many have been designed and/or used for purposes other than groundwater and gas monitoring. As such, Englobe have developed what we consider to be a monitoring network compliant with the requirements of permit surrender as stated in NRW guidance.

Although developed as part of the closure plan the monitoring data will be relevant to the future redevelopment of the site to also confirm compliance with the proposed remedial targets. The proposed monitoring locations for both groundwater and ground gases are summarised in Table 13 below:

Table 13 - Monitoring Locations

Site Area	No. of required locations	Requirements	Purpose and Notes
Western Lower Tip area	4	Full waste depth	Combined gas and groundwater monitoring
Lower Tip, southern perimeter	3	Screened depth to at least 1 m below min. annual GW level	Combined gas and groundwater monitoring (MSMW091 may be reusable, if fit for purpose)

Site Area	No. of required locations	Requirements	Purpose and Notes
Lower Tip, northern perimeter	4	Screened depth to at least 1 m below min. annual GW level/surrounding topography	Combined gas and groundwater monitoring
Central Upper Tip, Central area	4	Full waste depth	Combined gas and groundwater monitoring (Avoid re-using wells previously used for liquid extraction or if heavily soiled)
Central Upper Tip, southern perimeter	2	Screened depth to at least 1 m below min. annual GW level	Combined gas and groundwater monitoring (ENBH1-5 not fit for re-use. ENBH6-11 may not be fit for re use depending on their screened horizons)
Central Upper Tip, northern perimeter	2	Screened depth to at least 1 m below min. annual GW level/surrounding topography	Combined gas and groundwater monitoring (ENBH1-5 not fit for re-use. ENBH6-11 may not be fit for re use depending on their screened horizons)
Upper Tip eastern area	6	Full waste depth	Combined gas and groundwater monitoring (Dependant on access and topography)
Upper Tip eastern area, southern perimeter	2	Screened depth to at least 1 m below min. annual GW level	Combined gas and groundwater monitoring (CARW009 may be reusable, if fit for purpose)
Upper Tip eastern area, northern perimeter	3	Screened depth to at least 1 m below min. annual GW level/surrounding topography	Combined gas and groundwater monitoring (CARW008/CARW009 may be reusable, if fit for purpose)
Upper Tip eastern area, eastern perimeter	2	Screened depth to at least 1 m below min. annual GW level	Combined gas and groundwater monitoring (CARW002 - CARW008 may be reusable, if fit for purpose. Dependant on access and topography)
Total combined gas and groundwater locations	32		

An illustrative plan indicating the broad spatial outline of such a monitoring network is shown on Drawing D1870/23/5289/12 in Appendix A.

It is considered that this monitoring infrastructure and the strategies in 6.2.3 and 6.2.4 would be installed and commenced on completion of the containment wall installation and Tip reprofiling. However, there are permit and planning consideration that may make initiation of these strategies necessary prior to any other works.

6.2.3 Landfill Gas Monitoring Strategy

Scenario 3 completion criteria for landfill gas assumes that methane is present at greater than 5% v/v and that carbon dioxide is present at greater than 10% v/v. These criteria are compatible with the site's existing recent monitoring results.

Furthermore, scenario 3 requires that calculated whole-site hazardous gas flow rate (Q_{hgs}) is lower than 0.7 l/hr (a situation commensurate with CS2 according to BS8485:2015+A1:2019) and that the maximum recorded borehole flow rate is lower than 70 l/hr. Although not stated, Englobe understand this to relate to 'steady-state' flow rates (as in BS8485) rather than peak results (which may be subject to exaggeration and distortion due to well geometry and dynamics).

Finally, NRW's guidance requires that a dataset satisfying each of the above two criteria be gathered across the entire site (full waste depth and spatial extent) over a minimum of 24 datasets across two consecutive years.

As noted, continuous monitoring may be used to supplement (or, by agreement, to reduce) the monitoring period. Englobe recommend that such use of continuous monitoring will be considered once the overall pattern of gas monitoring results is realised.

Taking account of the above requirements and considering a balance between upfront costs and robust data requirements, the following monitoring strategy presented in Table 14 below is proposed in conjunction with the 32 gas monitoring locations detailed in Section 6.2.2.

Table 14 - Proposed Landfill Gas Monitoring Strategy

Period	Activities
Preliminary data collection phase	
Pre-commencement	Final detailed design of monitoring network, (locations, target depths, screened horizons, headworks, etc) Mobilisation and installation Position surveying and as-built drawings
Months 1 - 3	Initial periodic monitoring period
Preliminary data review	Assess initial data for critical issues (e.g. significant positive steady state flow, evidence of offsite migration etc.). Revise monitoring network and undertake targeted investigation, where necessary
Months 3 - 6	Continue periodic monitoring period
Data review	Complete preliminary data assessment
Main data collection phase	
Months 7 - 24	Routine periodic data collection with brief monthly review
Data progress review	Month 13, 19 and 25
Month 25	Verification Report

Landfill gas monitoring will be monthly and will include:

- CH₄
- CO₂
- O₂
- CO
- H₂S
- TVOC

- Atmospheric pressure
- Temperature
- Max. steady flow rate

6.2.4 Groundwater Monitoring Strategy

Section 6.2.2 summarises the proposed groundwater monitoring and sampling locations for the verification phase. Monitoring is proposed to be from all wells, however it is the 18 wells at the perimeter of permit area which are applicable to the HRA and the RTVs. It is therefore proposed that the 18 perimeter wells will be utilised for comparison with the RTVs and the wells in the waste mass will be utilised for further source characterisation. This further characterisation relates to VOCs, SVOCs and PFAS/PFOS. The Table below provides the proposed monitoring strategy for groundwater.

Table 15 - Proposed Groundwater Monitoring Strategy

Period	Activities
Preliminary data collection phase	
Pre-commencement	Final detailed design of monitoring network, (locations, target depths, screened horizons, headworks, etc). Mobilisation and installation. Position surveying and as-built drawings.
Months 1 - 3	Initial periodic monitoring period.
Preliminary data review	Assess initial data for critical issues (e.g. significant trends or exceedances and data for VOC, SVOC, TICs & PFAS/PFOS). Revise monitoring network and undertake targeted investigation, where necessary. Review HRA as necessary.
Months 3 - 6	Continue periodic monitoring period.
Data review	Complete preliminary data assessment.
Main data collection phase	
Months 7 - 24	Routine periodic data collection with brief monthly review.
Data progress review	Month 13, 19 and 25.
Month 25	Verification Report.

Groundwater monitoring will be undertaken monthly. Groundwater will be monitored for groundwater level and the presence/absence of LNAPL using an interface meter. Depths to groundwater and LNAPL will be measured relative to top of well casing and relative to ground level. The interface meter will be decontaminated between each use using wipes or clean water. The measurements will be recorded in the field and records saved on Englobe's server at the earliest opportunity.

Samples of groundwater will be collected into laboratory supplied containers using a peristaltic pump. Samples will be collected under the following protocol;

- Prior to sampling, a maximum of three well volumes of groundwater to be purged using dedicated equipment.
- Purged waters will be fed directly into storage containers prior to disposal. In accordance with Englobe personnel assessment, the appropriate purging equipment will be chosen. Available purging equipment to include Waterra tubing, peristaltic pumps and bailers. The purged waters are to be disposed in accordance to site regulations and Waste Management (Duty of Care) Regulations.
- Following recharge of the well, sample(s) are to be retrieved using dedicated equipment or peristaltic pump.

- Purging will cease once the in-situ parameters have stabilised (i.e. when three successive readings are within +/- 0.1 pH, +/-3 % conductivity, +/-10 mv redox and +/- 10 % DO measured by multi-parameter probe or when a maximum of three well volumes have been removed as Englobe standard practice.
- The flow of water should be reduced to a steady trickle (around 0.5-1 l/min to reduce drawdown), with bottles held at an oblique angle with water running down the inside wall of the container.
- Samples for VOC analysis should be filled so that no air remains in the container (tip vial upside-down to check for air bubbles).
- The water samples selected for storage or laboratory analysis are to be placed in laboratory supplied containers appropriate for the sample and proposed analysis.
- The samples should be labelled with sample ID, date, location and project number.
- The samples are to be stored on site prior to shipment to the laboratory in the laboratory supplied transportation boxes with supplied ice packs.
- Field blanks are to be supplied by the laboratory and returned with the samples.
- Visual characteristics, which include the presence or absence of any free product or sheens to be noted and all samples handled appropriately.

Groundwater samples will be analysed for the following laboratory analysis suite;

- pH;
- Ammoniacal Nitrogen as N;
- Chloride;
- Dissolved and total metals (arsenic, boron, cadmium, chromium, copper, lead, nickel, selenium, vanadium, zinc);
- Hardness;
- Total Petroleum Hydrocarbons Criteria Working Group (TPH CWG);
- BTEX Compounds (benzene, toluene, ethylbenzene and xylenes);
- VOCs (10 No. total locations in waste mass and downgradient boundary for first 3 months. Further monitoring subject to review);
- SVOCs (10 No. total locations in waste mass and downgradient boundary for first 3 months. Further monitoring subject to review);
- PFAS/PFOS (10 No. total locations in waste mass and downgradient boundary for first 3 months. Further monitoring subject to review);
- MTBE (methyl tertiary butyl ether); and
- Polycyclic Aromatic Hydrocarbons (PAH).

6.2.5 Restoration Layer

Materials will be tested at a frequency of 1 per 500 m³, however the final frequency will be determined once the source materials are confirmed. Representative sampling will be undertaken in line with Englobe standard operating procedures, using sub-sampling methods and techniques such as cone and quartering. Samples will be sent for solid chemical analysis and results compared against the RTVs in Table 11.

In addition to the chemical testing, there will be full construction records and surveys at all stages of the reprofiling and capping works, with verification records on a 10 m x 10 m grid basis. As-built drawings will be produced for the reprofiled Tip and restoration layer in order to record and confirm final gradients and elevations are as per the final designs. The Permit Construction Plan should also be referenced for further detail on the restoration layer verification and aftercare monitoring.

6.3 Record Keeping

Throughout the works extensive records will be maintained including (but not limited to) the following:

- A full and detailed description of the works completed;
- Site Diaries, visitors, inductions etc.;
- All progress meeting minutes and key correspondence;
- Records of local community liaison / letter drops etc.;
- Environmental monitoring records (including noise, dust, odour and surface/ground water monitoring);
- Materials Tracking Records;
- Details of unforeseen contamination encountered during the works and subsequent remedial actions;
- Materials / Waste import / export records (including full Duty of Care documentation);
- Groundwater quality monitoring data and laboratory analytical certificates;
- Relevant approvals from NRW and NPTBC;
- Laboratory certificates for soil and groundwater analysis (for environmental and geotechnical testing purposes);
- The extent and location of all restoration works, including 'As Built' engineering plans showing update topographic surveys, location of validation sampling, backfilled soils, obstructions etc.;
- Records of all soil treatment (including volumes and validation testing analytical results);
- Records of post restoration groundwater monitoring;
- A photographic record; and
- Records of all environmental monitoring.

6.4 Verification Reporting

A verification report will be prepared on completion of the restoration works. The report will contain details of the installation of the barrier wall, NAPL recovery works, reprofiling works carried out, materials management aspects including details of the volumes of material excavated, treatment activities, disposal activities and material re-use on-site. Photographs of the works, environmental monitoring data and certificates of the laboratory verification testing for chemical and geotechnical properties of all materials will also be included.

The verification report shall be completed in accordance with current regulatory guidance and best practice.



7 Environmental Management Plan

The records required to be made by this permit include:

- That they are retained, unless otherwise agreed by CNC-NRW, for at least six years from the date when the records were made, or in the case of the following records until permit surrender:
 - Off-site environmental effects;
 - Matters which affect the condition of the land or groundwater;
 - The results of groundwater monitoring;
 - Sub-surface landfill gas monitoring;
 - Leachate levels, quality and quantities;
 - Landfill gas generation and collection;
 - Waste types and quantities;
 - The location of hazardous waste deposits; and
 - The specification and as built drawings of the basal, sidewall and capping engineering systems.
- The operator shall keep on site all records, plans and the management system required to be maintained by the permit, unless otherwise agreed by CNC-NRW.

As part of the permit reporting requirements, the operator shall send a report or reports on the performance of the activities over the previous year and include as a minimum:

- A review of the results of the monitoring and assessment carried out in accordance with the permit against the relevant assumptions, parameters and results in the risk assessments submitted;
- The topographical surveys required (other than those submitted as part of a CQA validation report;

- An assessment of the settlement behaviour of the landfill body based on difference between the most recent topographical survey and previous annual topo surveys for the areas of the landfill which did not receive waste between the surveys.

Within 28 days of the end of the reporting period the operator shall submit reports of the monitoring and assessment carried out in accordance with the agreed closure and aftercare management plan.

In order to address and manage the identified risks, it is proposed that the following environmental management, mitigation and monitoring measures are employed during the works. The proposed methods below also reflect the environmental management, monitoring and mitigation measures that will be presented and discussed with the NRW-CNC as part of Englobe's Environmental Permit deployment (EPR/AP3195FG). A Section 61 consent application for construction noise will also be submitted to NPTBC.

The proposed working hours will be restricted to Monday to Friday 08:00 - 18:00 hrs. Where Saturday working is required; this will be restricted to 08:00 - 13:00 hrs. No works will be undertaken on Sundays or Public Holidays without prior consent of St Modwen and NPTBC.

7.1 Pollution Prevention

Safeguards will be implemented to minimise risks of pollution associated with the proposed remediation activities as follows:

- Fuel required for the welfare and plant/equipment will be stored within secure (lockable), double bunded (minimum of 110% capacity) storage tanks with sufficient absorbents available;
- Refuelling will take place within a designated hardstand area, by trained and competent personnel;
- Oils and chemicals necessary for the works will be stored within a secure COSHH stores;
- Englobe shall restrict the movement of plant and position haul routes away from any sensitive boundaries and minimise the works required in these areas;
- Materials will be temporarily stored within designated areas with bunds and covers being used to contain and prevent cross contamination and nuisance emissions;
- Treatment activities will be positioned as far away from sensitive receptors as reasonably practicable;
- Plant and machinery will be maintained in good working order and where available will be less than 3 years old;
- Wheel washing facilities will be available to cleanse the wheels of vehicles leaving site to prevent mud/debris leaving the site; and
- Licensed waste carriers will be used for all waste transfers off-site and appropriately licensed facilities will be used with waste duty of care documentation retained on-site throughout the duration of works and records included within the verification report.



8 Proposed Air Quality Control and Monitoring Approach

Emphasis will be placed on the prevention and control at source rather than mitigation following release and site operations will be conducted to reduce environmental impacts to a practical minimum. Based on the project requirements Englobe will ensure any emissions are controlled.

The monitoring programme, which details the recommended frequency of monitoring, is commensurate with the sensitivity of the site and local land use will be undertaken in accordance with the requirements of the restoration designs presented within this report.

8.1 Control and Monitoring of Dust

Englobe's management of the site will ensure that dust will not migrate across site boundaries or affect adjacent land uses. Dust control measures will be in place prior to works commencement to prevent dust affecting users of the properties adjacent to the site, general public outside the site and project staff. Dust-netting may be deployed on the restoration area boundaries where works are to be undertaken and immediately adjacent areas of excavation and materials management/segregation where required.

Englobe will carry out environmental monitoring of dust continuously prior to and during the works on a visual basis. In addition, daily airborne particulate matter monitoring using a hand-held direct reading instrument and weekly deposition rate quantification measured using frisbee type gauges deployed around the site boundary with particular attention to adjacent stakeholder properties.

The dust collected from the frisbee type gauges will be measured on a fortnightly basis during the works with analysis undertaken on a 5-working day turn around.

Should significant dust generation be identified, additional chemical analysis of the dust may be implemented. The threshold levels deemed appropriate for the works shall be based on other similar site agreements of 200 mg/m²/day for airborne particulate matter (PM10) and Englobe work to the latest LAQM guidance when the works commence (190ug/m³ over a 1-hour period) and pro rata to a shorter period for averaging purposes of 15 minutes at each monitoring location. Should

these thresholds be approached or exceeded, the works on-site and contingency measures deployed will be reviewed with the aim of mitigating dust to below the threshold levels.

8.2 Control and Monitoring of Odours/ Vapours and Gases

Englobe will take responsibility for control of odours and vapours and will provide a method statement detailing how these will be minimised for restoration works (involving oil/ hydrocarbons). It is considered, based on Englobe's proposed methodology, to include controlled excavation and storage of contaminated material within designated areas, makes the potential for odour generation low. However, based on previous experience a pro-active approach will be taken to include monitoring and mitigation (odour suppressant) as/where required.

8.3 Vapours and Gases

A method statement detailing how odours and vapours will be minimised for restoration works during the handling of contaminated materials will be available as part of Englobe's safety, health and environmental management plan.

Based on the known site contaminants and surrounding stakeholders, works will be progressed in a manner where practicable to minimise open excavations for extended periods, minimise contaminated material stockpile volumes and remove, where encountered, free NAPL and perched water within excavations with appropriate controlled on-site storage prior to off-site disposal. In addition, odour suppression equipment shall be made available which may include fixed boundary dispersal and mobile rotary atomiser systems to allow deployment and movement based on encountered conditions and contamination.

Mobile treatment plant for soils and waters will be under the strict control of Englobe and are unlikely to create significant emissions of vapours and gases during normal operations.

Englobe will be responsible for the environmental monitoring of VOCs in ambient air within Englobe work areas. Monitoring will be undertaken at a minimum of once per day, during working hours for the duration of site works. Monitoring will be undertaken prior to main works in order to determine baseline levels. A Photo Ionisation Detection meter (PID meter) will be kept on site for this purpose.

Monitoring will be carried out once a day for a duration of at least 15 minutes. Monitoring will be carried out with a PID meter fitted with a 10.6 eV lamp calibrated for total VOCs, to assess vapours quantitatively. The 15-minute average for each location and maximum concentration will be recorded, together with the time that the monitoring was carried out.

During periods where the intermittent monitoring is not being carried out, a PID meter will be located at a dust monitoring station or other location downwind of current works areas and set to log the average vapour concentration (time weighted average) at that location. Once again, the average vapour concentration at that location and maximum concentration will be recorded, together with the time that the monitoring was carried out.

Englobe will be responsible for daily calibration of any PID meter used on site. The site Engineer will record all monitoring information in electronic format (table format) on a weekly basis.

The threshold levels for vapour monitoring set out in EH40/2005 (Health and Safety Executive Workplace Exposure Limits) and subsequent amendments will be observed during the works. However, in practice, a maximum limit for the time weighted average concentration of 1 ppm will be set for vapours. If ambient levels on site approach or exceed this concentration, works on-site and contingency measures deployed will be reviewed with the aim of mitigating vapour levels to below the threshold levels.

Englobe will also monitor personnel most at risk from odours/ vapours and gases whilst on site and will provide sufficient personal monitoring instruments to do this. Typically, this will include excavation operators, banksmen, operatives carrying out hand excavation works and plant operators carrying out bulk excavation in the contaminated areas/ removal of gasworks structures.

For personal monitoring, PID meters will be placed on the operative and set to record the average vapour concentration (time weighted average). The average vapour concentration and maximum concentration will be recorded, together with the time that the monitoring was carried out.

These procedures will be reviewed during the work and potentially revised for activities deemed to be higher risk. All monitoring data shall be recorded as per Englobe environmental permit requirements.

8.4 Odour

Odour monitoring (olfactory sniff test) will be undertaken daily at the edge of the works zone and at the most relevant site boundary to offsite receptors, dependent on work locations and weather conditions. The FIDOL factors will be recorded which are represented as follows:

Frequency	How often an individual is exposed to odour
Intensity	The individual's perception of the strength of the odour
Duration	The overall duration that individuals are exposed to an odour over time
Odour unpleasantness	Odour unpleasantness describes the character of an odour as it relates to the 'hedonic tone', and will be measured on a standard none-point scale
Location	The location of odour and nature of human activities on the vicinity of an odour source, including receptor characteristics

Odour intensity will be measured and recorded on a 0-5 scale where:

- 0 - No detectable odour
- 1 - Faint odour (barely detectable, need to stand still and inhale facing into the wind);
- 2 - Moderate odour (distinct odour detected while standing still);
- 3 - Moderately strong odour (detectable while walking & breathing normally, possibly offensive);
- 4 - Strong odour (bearable, but offensive odour);
- 5 - Very strong odour (very offensive, possibly causing nausea).

The trigger criteria are as follows:

- **Action Levels** shall be set at 3 or above for intensity at which point odour reduction measures should be put in place. This includes covering of stockpiles, limiting area of open excavations and deodorising sprays.
- **Stop Work Levels** shall be set at 4 or above for intensity at which point works will cease until the odour problem can be rectified.

Remedial actions and mitigation measures shall be documented, and odour monitoring undertaken again to ensure that the remedial measures have achieved the appropriate level of improvement.

If monitored odours are considered to exceed the action levels, records of sensitivity of the location will also be made as follow:

Table 16 - Location Sensitivity

High Sensitivity Receptor	Surrounding land use where: Users can reasonably expect enjoyment of a high level of amenity; and People would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land. Examples may include residential dwellings, hospitals, schools/education and tourist/cultural.
Medium Sensitivity Receptor	Surrounding land use where: Users would expect a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or People wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land. Examples may include places of work, commercial/retail premises and playing/recreational fields.
Low Sensitivity Receptor	Surrounding land use where: The enjoyment of amenity would not reasonably be expected; or There is transient exposure, where the people would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land. Examples may include industrial use, farms, footpaths and roads.

The suggested descriptor for magnitude of odour effects is illustrated within Table 17. Where the overall effect is greater than 'slight adverse', the effect is likely to be considered significant.

Table 17 - Suggested Descriptor for Magnitude of Odour Effects

		Receptor Sensitivity		
Relative Odour Exposure (Impact)		Low	Medium	High
	Very large	Moderate adverse	Substantial adverse	Substantial adverse
	Large	Slight adverse	Moderate adverse	Substantial adverse
	Medium	Negligible	Slight adverse	Moderate adverse
	Small	Negligible	Negligible	Slight adverse
	Negligible	Negligible	Negligible	Negligible

Appropriate PPE and RPE will be made available for use by workers if odours exceed action levels. PPE and RPE shall be assessed under separate works and requirements presented within the Englobe safety health and environment report.

Englobe will proactively deploy odour management measures in addition to the controls detailed above as part of works. These shall be set in advance in areas of known contamination and could be relocated based on nature of contamination and odour assessment. It is proposed that both fixed and mobile odour suppression units shall be used to include fixed fence line atomisers and mobile atomisers. Englobe would, based on an assessment of odours, also look to deploy odour neutralising and masking agents via both mobile and fixed atomiser systems.

8.5 Monitoring/ Control of Noise and Vibration

Best practicable means of noise control will be applied during the restoration works to minimise noise (including vibration) at neighbouring residential properties and other sensitive receptors arising from the site activities. Excavations will proceed carefully and as quietly as possible. Several 360 degree excavators, together with dumptrucks will be utilised to excavate and transport

the materials and bladed dozers will be used to re-profile and grade the final levels. Although a hydraulic breaking hammer will be mobilised to site, It is not envisaged that significant hardstand (concrete/brickwork) will be required to be broken out during these restoration works. It is anticipated that below ground obstructions requiring removal will be limited to remnant hard materials associated with deposited waste.

Englobe shall complete works in accordance with a submitted Section 61 document and deploy mitigation measures as required. Mitigation and planning shall include the following:

- The working hours will be restricted to Monday to Friday 08:00 - 18:00 hrs. Where Saturday working is required; this will be restricted to 08:00 - 13:00 hrs. No works will be undertaken on Sundays or Public Holidays without prior consent of St Modwen and NPTBC.;
- Englobe shall position treatment activities as far away from sensitive receptors as reasonably practicable;
- Englobe shall restrict the movement of plant and position haul routes away from any sensitive boundaries and minimise the works required in these areas;
- Englobe shall select plant and machinery in good working order and less than 3 years old and, where available, use quiet and low vibration equipment; and
- Vehicles and plant will be maintained in a good and effective working order and operated in a manner to minimise noise emissions.

Englobe shall review phasing and operations to limit the overlap and duration of highest noise and vibration level activities.

Noise monitoring shall be carried out by Englobe daily at the designated environmental monitoring points as per the works progression and phasing. These points shall be confirmed during the daily site briefings and confirmation of works areas. Noise monitoring shall be carried out using a calibrated and certified Decibel Noise Meter.

If Englobe operations produce and record unacceptable noise and vibration levels then additional measures including further acoustic shielding/enclosures, works re-phasing and assessment of operational hours shall be completed.

All monitoring data shall be available and provided to the Client's team as part of both weekly and monthly reporting with additional information to support remedial measures in the event of a complaint or continued exceedance of action levels.

8.6 Asbestos Monitoring

- Based upon the ground investigation and laboratory testing undertaken at the site Englobe do not anticipate widespread or significant asbestos containing soils during excavation works at site.
- Background, reassurance, asbestos air monitoring shall be undertaken on a weekly basis during excavation works and cover operational areas and key identified receptors. Asbestos reassurance monitoring shall be completed by a specialist 3rd party sub-contractor with all results provided on day of testing to allow a proactive and immediate review and response based on any identified elevated concentrations. The monitoring shall include occupational health monitoring of site staff, general works area monitoring and boundary monitoring targeting the most applicable potential receptors based on atmospheric conditions. Specific asbestos air monitoring shall be undertaken in works areas and the site boundary in the event previously unidentified or asbestos materials of a different nature are recorded.
- A watching brief for asbestos in soils shall be undertaken by environmental monitoring staff and all other staff during the works. An asbestos watching brief and discovery strategy shall be formulated, agreed and distributed to all identified stakeholders. Any watching brief and associated further review of PPE and RPE shall be presented and updated as part of Englobe site-specific safety health and environmental report. Asbestos monitoring data shall be presented as part of both the weekly and monthly report submissions and immediately should

levels dictate an immediate suspension or change to works, working methodologies, controls, PPE or RPE.

- It is noted that the controls detailed for dust mitigation will also serve to mitigate any potential asbestos generation based on the current data and current low risk level



9 Construction Phase Health and Safety / Environment Plan

Accredited with ISO 9001, 14001 and 45,001 and awarded ROSPA Gold for the 7th year running. Englobe are highly experienced in managing health safety and the environment aspect of project delivery with a proven track record

In addition to the regular daily, weekly and monthly health and safety auditing undertaken by the site team, Englobe also welcome regular health and safety/auditing visits from St Modwen and other interested parties. Any observations received from these parties will be welcomed and where required enacted upon at the earliest reasonable opportunity.

9.1 Identified Higher Risk Activities and Hazards

Table 18 below identifies and summarises several considered and higher risk hazards and proposed mitigation measures associated with the on-site works.

Table 18 - Higher Risk Hazards and Proposed Mitigation

Identified Hazard	Risk prior to Mitigation	Mitigation Measures	Risk Following Mitigation Measures
Working near open excavations / excavation stability	High	Experienced, competent, trained and inducted operators and supervisors. Excavation batters are to be formed to prevent serious falls. Safe distances from edges to be maintained. Method statement, in accordance with Temporary Works advice, to be in place for excavations and suitable stand-off put in place to not affect safety.	Low

Identified Hazard	Risk prior to Mitigation	Mitigation Measures	Risk Following Mitigation Measures
		Excavations are not to be left open where possible. Suitable barriers/fencing are to enclose excavation areas. No major excavations to be left open when the site is not manned, e.g., overnight.	
Site Access, Traffic Management and Members of the Public Around the Site Access	High	Traffic Marshal will be employed during periods of significant off-site plant / vehicle movement at site set up and demob. Traffic Management Plan. Consideration will be given to main access routes to and at the site. Wheel cleaning will be used if necessary, to avoid off-site migration of mud with road sweeping as required.	Low
Personnel struck by plant & traffic	High	Segregation of traffic and pedestrians via defined routes and appropriate physical barriers. Site Traffic Management Plan. Flashing beacons on all site plant. Compulsory high visibility PPE. Site induction/ toolbox talks. Competent operators and supervision of plant and equipment.	Low
Risk of trespassers entering site	High	Manned security on-site with regular site patrols. Main site gates are to be kept closed during site operating hours with security controlling site access. All open excavations are to have appropriate barriers/fencing to prevent access. Site security review for the use of cameras.	Low
Striking of buried services (Gas, electric, communications, water, sewer)	Medium	Full services tracing by specialist contractor (GPR, CAT & Genny). Traced confirmation of services in vicinity of works is to be carried out. Vibration monitoring where required as works progress. Permit to dig for all excavations.	Low/very low

Any other significant risks not outlined in Table 18 but recognised in the Significant Risk SHES Table will be addressed primarily through RAMS and temporary works design to ensure the highest of safety standards at the site.

9.2 Permitting and Licensing Requirements

Englobe has been advised by CNC-NRW that the following permit applications may be needed to facilitate the proposed restoration works:

1. Deployment of Englobe Environmental Mobile Plant Permit (EPR/AP3195FG) for the NAPL recovery and associated water treatment works;
2. FORM WRC: Application for a consent to investigate a groundwater source;
3. Application for an environmental permit: Part B6 - new bespoke water discharge activity and groundwater (point source) activity;
4. Abstraction License (water for barrier wall process);

5. Permit for processing of the Glasstech material if required;
6. Tree Felling License; and
7. Greater Crested Newts License.

9.3 Stakeholder Engagement

Englobe is a Social Value Pioneer and proactively look to help out in the community with actions such as community litter picking and community DIY SOS projects. Englobe look forward to supporting St Modwen in any community relations events they feel appropriate for this site.

- Based on any St Modwen requirements, measures will be taken in conjunction with St Modwen with regards to stakeholder engagement. Co-ordinated stakeholder information letter drop detailing outline works and works programme (pre-works, properties adjacent site access etc);
- Pre-works negotiation and agreement of works with the Local Authority Contaminated Land Officer with communication organogram development, pre-works site meeting and project strategy review;
- Designated Englobe point of contact for stakeholder engagement with St Modwen interface to ensure if required co-ordinated and considered responses;
- Monthly progress meeting with non-technical summaries for issue as required; and
- Regular stakeholder progress letter completion (as required).



10 Quality Management Plan and Auditing Construction

10.1 Quality Management Plan and Auditing

Englobe operate to an Integrated Management System (IMS), audited externally, to encompass, ISO 9001:2015 Quality Management System, ISO 14001:2015 Environmental Management System and OHSAS 18001:2007 Health & Safety Management.

Our IMS policy sets the vision for the IMS, is reviewed annually, and can be seen in action throughout the IMS.

Englobe has developed substantive core system procedures: IMS-01 to 15 covering all aspects of our business. This is supported by Quality Procedures, (QP's), most notably in terms of this project:

- **QP-02 (Project Management Procedure).** Amongst other aspects, this includes tightly defined meetings at the Handover, Kick-off, Operational and Close-Out phases of the contract cycle. During the operational period, meetings are both technical and commercial in nature. The Project Manager and Director hold the principal responsibility for co-ordinating risk management within the project team and to ensure these key risk and quality management meetings are held in accordance with QP-02.

In support of the QP's are 19 Standard Operating Procedures, all subject to continuous improvement through Close-Out lessons learnt meetings and internal audits. Additionally, each QP comes with a range of Standard Forms. For QP-02 the key forms to ensure quality and IMS compliance are:

- **SF-01 (Project Management Plan).** A document which is kept updated throughout a project. This document provides a standardised template to record the project management procedures (QP-02), key project risks (carried forward from the tender stage), project roles and responsibilities and what actions to take, or RAMS to formulate, to minimise known risks.
- **SF-02 (Project Risk Register).** Used in-conjunction with SAR-PC-01 to record, monitor and manage all aspects of the project risks, and therefore quality.

Quality Management Objectives

By implementing an effective quality management system, Englobe will ensure that data is of a known and documented quality which will support informed and defensible decision making. This will be key in demonstrating that the works have been completed to the technical and procedural standards as set out in the specifications and comply with the requirements of the regulatory bodies.

Project Quality Management

The quality management approach for this project will ensure quality is planned for both the processes and final product. In order to be successful, this project will meet its quality objectives by utilising the IMS to ensure an integrated quality approach; to define the expected quality standards, implement quality control measures and quality assurance procedures to ensure the overall quality of the remediation works.

Quality Control and Quality Assurance

The following definitions of Quality Control (QC) and Quality Assurance (QA) will be applied to the Project:

Quality Control - measurement, monitoring and documentation of all of the works processes, including the process/operation to ensure the activities will meet the agreed technical specifications set out in this RIP, Scope of Works and other documents; and

Quality Assurance - monitoring and verification that the remedial works are meeting the agreed technical specification, performance objectives and regulatory requirements.

To maintain effective QC, Englobe will establish a set of operational metrics to ensure compliance with the technical specification.

QA and QC objectives are interdependent and Englobe will continually monitor and assess the remediation operations. A consistent performance data set, showing achievement of the remediation criteria / specifications in all respects, provides a high level of confidence in the project performance and aids in stakeholder acceptance.

QA & QC Roles and Responsibilities

The Englobe Project Team will be structured to have the following general responsibilities for the Project QA and QC program:

Project Design & Planning: Responsible for ensuring the overall restoration methodology and implementation complies with the Restoration Implementation Plan.

Quality Assurance: Monitoring and review of the overall remediation and site works processes, including process documentation, validation/verification data,

Quality Control: Ensuring the remediation, earthworks and stabilisation processes adhere to the established design procedures, the collection of consistent and robust data, control and production of process documentation

Quality Assurance Procedures

The Englobe QA process is designed to maintain an overview of project operations with the aim of ensuring that the appropriate QC is in place, that QC is effective and that the technical specification and project program requirements are being met.

One of the principal roles of QA is to establish a decision-making framework in the event of any change, either to the specification or operational process. The general areas that the QA will focus on are:

- **Design** - for example, substantively different sub-surface conditions from those previously encountered.
- **Operational** - processes that are not consistent with the design specification, or effective for the successful delivery to meet the technical specification.

Sampling and analysis - errors in sample collection or geotechnical/laboratory testing (e.g. false negative/positive results).



11 Outline Programme

The programme for the remediation works will be subject to the progress of the planning application and associated planning conditions. In addition, the programme will be dependent on the progression of any required abstraction and/or discharge licenses and environmental permit application.

Applications have been made for:

- Groundwater discharge permits;
- Mobile Treatment Licence deployment;
- Groundwater Abstraction licence.

These applications have been progressed as far as possible without a planning application being in place.