Kerdiffstown Landfill Remediation Project

Kildare County Council

Environmental Impact Assessment Report (EIAR) Volume 4 of 4: Appendices (Part 1)

32EW5604 DOC 0056 | Final

August 2017

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Appendix A4.1 Road and New Site Access Design Technical Note

Technical Note

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Client	Kildare County Council
Project Name	**Kerdiffstown Landfill Remediation Project**
Subject	**Road and New Site Access Design Technical Note**
Date issued	10 March 2017

Introduction

The purpose of this Technical Note is to outline the design criteria applied to the provision of an at-grade roundabout on L2005 Kerdiffstown Road, and identify the likely benefits and disbenefits. Discussion of design criteria applied for a new adjacent footpath and cycleways provision is also undertaken to facilitate future public access to the end-use of the site, comprising a multi-use public park with sports facilities.

1.1 Background

The site is currently closed with only KCC personnel accessing the site to undertake day to day management, and security guards attend on shifts to provide 24 hour security to the site. Intermittent access is required from visitors or road tankers, accessing the site to extract and remove leachate from the site.

The current access requires crossing of the L2005, Kerdiffstown Road, which is circa 5.4m wide, with a speed limit of 60kph. No footpaths exist alongside this road adjacent to the site currently.

1.2 Proposed Project

Remediation of the site is proposed, which will require importation of a significant quantity of materials. These materials will be brought to site in Heavy Goods Vehicles (HGVs). An outline project safety review indicated that the current traffic flow, with sight line restrictions combined with the access arrangements to the site presented a hazard to all road users. With the possibility of HGVs passing the current carriageway width was also identified as a constraint. There is also likely to be an increase in road users, and with the current road configuration the possibility of congestion due to vehicles crossing Kerdiffstown Road in order to access the site.

In the Operational Phase road tankers may continue to require access in instances when on site management systems are offline for maintenance. It is anticipated that the end-use of the proposed Project as a public park with multi-use sports pitches will also generate traffic to access the park, though largely cars.

Taking cognisance of the above to enable safe access for the short-medium and long-term, improvements were to be considered. A new road alignment is required from the existing roundabout to the access road of Kerdiffstown Landfill site to accommodate the increased use of HGVs on Kerdiffstown Road. As well as the new road layout, provisions are to be made for an increase in pedestrian and cycle movement which will be incorporated by the introduction of a new shared use cycleway/footway adjacent to the new road layout.

Road and Junction Design

1.3 Existing Constraints

As shown in Figure 1 the section of Johnstown Road between the existing roundabout and the entrance to Kerdiffstown Landfill site is heavily constrained. The existing carriageway is approximately 5.4m wide and located between Mike Brown Caravans site and two residential properties to the east and four residential properties to the west.

Figure 1: Existing Constraints at Kerdiffstown Landfill Site Access Location

1.4 Design

A number of options were considered for the reconfiguration of the access. However, on balance it was considered that a roundabout offered the most practical access arrangements.

The new road access arrangements are shown on the following drawings:

- 32EW5604-00-029 New Site Access Proposed Road Layout
- 32EW5604-00-030 New Site Access Proposed Pedestrian Access and Cycleway
- 32EW5604-00-031 Site Access Design Profiles

This technical note should be read in conjunction with the above drawings.

1.5 Engineering Standards

The roundabout has been designed in accordance with the National Road Authority Design Manual for Roads and Bridges (NRA DMRB) (DN-GEO-TD16 Geometric Design of Roundabouts). The geometric design parameters for all other roads are set out in the Design Manual for Urban Roads and Streets (DMURS) (Section 4.4.6 Alignment and Curvature). A summary of the desirable minimum standards for a 60kph and 30kph Design Speed is shown below in Table 1.

Location	Design Speed (kph)	Horizontal Curvature (Radius, m)	Vertical Curvature (K Value)		Stopping Sight Distance (m)
		Desirable Minimum Radius	Desirable Minimum Crest	Desirable Minimum Sag	Desirable Minimum
Johnstown Road	60	136 (Super-elevation of 2.5%) 178 (Adverse Camber of 2.5%)	8.2	9.2	65
Landfill Access Road	30	26 (Adverse Camber of 2.5%)	N/A	2.3	24

Table 1: KLRP Geometric Parameters

1.6 Design Alignment

1.6.1 Kerdiffstown Roundabout

The ‘Kerdiffstown Roundabout’ is a three-arm compact roundabout and is located approximately 40 metres south of the existing minor priority junction into Kerdiffstown Landfill site and has an Inscribed Circle Diameter (ICD) of 32 metres. The roundabout connects Johnstown Road east and west arms as well as the site access road.

1.6.2 Johnstown Road East Arm

Johnstown Road east arm is 351 metres long and begins at the southern extent of Johnstown Road approximately 20 metres north of the existing roundabout. The alignment ties in on a straight before transitioning into a right hand horizontal curve with adverse camber. The alignment continues through a sweeping left hand horizontal curve with adverse camber and immediately transitioning into a right hand horizontal curve with super-elevation and connecting into the proposed roundabout at the site.

1.6.3 Johnstown Road West Arm

Johnstown Road west arm is 111 metres long and ties into the northern extent of Johnstown Road. The alignment incorporates a left hand horizontal curve with super-elevation and connects into the proposed roundabout at the site.

1.6.4 The Site and Compound Access Roads

The access road to the site ties into the existing access road within the site and is approximately 70 metres long. It connects from a straight road into a right hand horizontal curve with adverse camber before it ties into the proposed roundabout. The access road junction to the new Landfill Infrastructure Compound ties into the site access road at Ch.45m.

The plan and profiles of the at-grade roundabout design are provided in Drawing Numbers 32EW5604-00-029 and 32EW5604-00-031.

Summary

A summary of the key benefits and disbenefits for provision of an at-grade roundabout to access the proposed Project is given in Table 2.

Benefits	Disbenefits
a) Removes safety issue with right turning traffic associated with the minor priority junction; b) Reduced landscape and visual impacts compared to other design options, primarily due to on-line and at-grade design; c) Reduced land-take compared to other options; d) Increased operational performance; e) Reduced impact on residential and commercial property on the east and west of Johnstown Road; and f) Higher standard of engineering design to existing layout.	g) Construction programme risk and time disbenefits compared to minor priority junction; h) Introduction of a roundabout can increase driver stress for divers not accessing landfill site; i) Road lighting required; and j) Localised increase in emissions of pollutants affecting air quality in the vicinity of the roundabout.

Table 2: Summary of Key Benefits and Disbenefits of an at-grade roundabout

Pedestrian and Cycle Access Design

1.7 Existing Constraints

The site is located to the north of Johnstown and east of Sallins along Kerdiffstown Road. The N7 presents a significant severance of non-motorised access from the settled areas of Johnstown and Naas to the south. This is mitigated by the presence of a pedestrian bridge directly south of the proposed project site connecting to Johnstown, and by shared use pathways along the frontage roads both north and south of the N7 and at the roundabouts at N7 Junction 8, as well as links to an underpass further east to Kill. Due to a low parapet design, the pedestrian bridge is unsafe for cyclists, who are required to walk bicycles across.

In the immediate proposed project site vicinity, a footway connects the pedestrian bridge to an uncontrolled crossing at an existing roundabout to the south of the site (north of the N7). The uncontrolled crossing is immediately adjacent to the give way line for the eastern arm of the junction, which does not meet current crossing guidance.

A shared use path on the north side of the existing roundabout provides access eastward to N7 Junction 8, and onwards to an underpass leading to Kill. The path narrows considerably in the westward direction along the existing Kerdiffstown Road and abruptly ends 95 metres north-west of the uncontrolled crossing location. Pedestrians and cyclists at this point must use the existing single lane carriageway, sharing with motorised vehicles. This condition persists until the road (named Church Avenue at this point) connects to the built up areas of Sallins, about 250 metres east of the R407.

There is no existing dedicated pedestrian or cycle access to the site at present. Figure 2 shows the carriageway and footpath cessation to the south-east of the site on Kerdiffstown Road.

Figure 2: Existing Kerdiffstown Road (looking north-west), showing footpath cessation to the right.

1.8 Proposed Pedestrian and Cycle Access Design

1.8.1 General Shared Use Pathway Arrangement

The option taken forward is to reconfigure the access road to the site as a 7m single carriageway, with an additional dedicated shared use cycle and pedestrian space adjacent to connect the existing pedestrian bridge and area pathways to the new site access point. The design parameters for the shared use cycleway/footway are set out in the National Cycle Manual (NCM; Section 1.5.2 Width Calculator and Section 1.9.3 Shared Facilities). The guidance specifies that a shared use cycle/pedestrian facility should have a minimum combined width of 3.0m. The design also follows NCM guidance for verge/outside edge width adjacent to a 60kph road.

The new cycle/pedestrian facility will include a 0.75m verge and a 4.0m shared use path. There is one known width constraining point where the pathway would narrow to 3.8m for a very short distance (approximately 1.0m) though still complies with the minimum shared use path standards in the NCM. The verge and shared use pathway will be grade separated from the carriageway by a kerb. Wooden bollards matching those along the shared use paths either side of the N7 near Junction 8 would be installed in the verge to discourage parking, as per the example shown in Figure 3.

Figure 3: Wooden Bollards in Verge (typical of local area)

Near its southern extent, the proposed cycle/pedestrian facility would taper to match existing shared use path widths east from the existing roundabout.

1.8.2 Additional Pathway Using Existing Carriageway

The proposed site access point will include a roundabout at the site entrance, offline from the existing Kerdiffstown Road. It is proposed that a section of the existing carriageway be retained to provide space for a shared use path south of the new site access roundabout, re-joining the existing road north-west of the site access point. The road north of the proposed site access would operate beyond this point in its present state, and pedestrians and cyclists would be required to share the space with motorised vehicles. The proposed pathway would be carried westward to a point where good visibility between non-motorised users and vehicles on the carriageway can be ensured.

This shared use pathway would be 4.0m wide, exceeding minimum NCM guidelines, and would implement bends at both ends to slow cycle traffic and square up to the carriageway before cyclists and pedestrians cross or re-join the existing carriageway. Bollards will also be included to the north-west to encourage cyclists to slow and look for traffic before proceeding from the pathway to the existing carriageway.

1.8.3 Uncontrolled Crossings

Two uncontrolled crossings are proposed – one on the eastern arm of the existing roundabout adjacent to the pedestrian bridge over the N7, and another at the southern arm of the new site access roundabout. These would be located 20 metres back from the give way line at each roundabout to ensure good visibility and stopping distance for motor vehicles. Crossings should be 4.0m wide. See Figure 4 for an example of this type of uncontrolled crossing on a 60kph road in the vicinity of the site.

Figure 4: Uncontrolled crossing (typical of local area)

These uncontrolled crossing specifications follow guidance in TII's Geometric Design of Roundabouts (DN-GEO-03033, 2009) and NRA Pedestrian Crossing Specification and Guidance (2011). Dropped kerbs, tactile paving and overall crossing layout should meet standards as described in NRA Pedestrian Crossing Specifications and Guidance (2011) and drawing numbers PCS 001 (Uncontrolled Crossing Road Markings and General Layout) and PCS 013 (Uncontrolled Crossing Tactile Paving Detail).

1.8.4 Combination Transition from Carriageway to Shared Use Pathway

Provision is made for cyclists traveling south-east from Sallins to access the main shared use pathway between the proposed site entrance and the pedestrian bridge. This will utilise a combination transition (NCM, Section 4.10.4 Combination Transitions), which consists of a horizontal leftward movement from the carriageway toward the pathway, and a vertical transition to then lift the cyclist up to the grade of the shared use path. In addition, the design provides a right angle bend, yield marker, give way lines and an area of ladder tactile paving to indicate to cyclists to slow and give way to pedestrians and cyclists on the main pathway before proceeding. This combination transition is proposed to be installed south of the uncontrolled pedestrian crossing at the proposed new site access roundabout to reduce conflict.

1.8.5 Additional Ancillary Design Features

It is proposed that the access pathway between the new uncontrolled crossing at the existing roundabout and the pedestrian bridge be widened to 2.2 metres to match the width of the pedestrian bridge.

Signage informing cyclists to dismount and walk bicycles across the existing pedestrian bridge is proposed to be included at both north and south ends of the bridge. This would be prudent as the pedestrian bridge includes parapets of insufficient height for safe cycling. Signage must follow the NRA's Traffic Signs Manual. It is recommended that this be a restrictive sign type with supplementary information regarding the walking of bicycles across the bridge. Gradients for the proposed cycle/pedestrian facility are per the National Cycle Manual as follows: 1:20 (5%) preferred; maximum gradient of 1:12.5 (8.3%) allowable for short distances only and intermediate landing mitigation may be needed. To maintain effective drainage a crossfall of 1:40 is recommended and minimum longitudinal gradient of 1:200 (0.5%). Care should be taken at curves to ensure proper drainage. This will be confirmed during a detailed design stage.

Discussion

1.9 Key Features of Roundabout

The key features of an at-grade roundabout at the site access are:

- Constructability: The majority of the construction and associated works would be at the level of the existing Johnstown Road which would have constructability benefits. Traffic management will can also be implemented easily which will help maintain the access to the site during the works.
- Noise and Vibration: Construction noise and vibration impacts associated with constructing of the new road layout; however, the at-grade roundabout does not require significant excavation or structures which will have less impact on noise and vibrations. Traffic noise is expected to be comparable to the existing condition. However, based on experience on similar projects that involve roundabouts, the acceleration and deceleration of traffic on the approaches to a roundabout can sometimes lead to a perceived, rather than actual, change in traffic noise.
- Landscape and Visual: The introduction of street lighting on the roundabout and associated approach roads in an area that is currently not lit will have localised adverse landscape and visual impacts. There is significant property conflict from the existing roundabout to the entrance of the site. However, as the works are largely on-line and at-grade, there will be limited loss of property throughout the route. Landscape and visual impacts are anticipated to be less significant than all other previous design options.
- Air Quality: Traffic acceleration and deceleration as a result of the roundabout would increase vehicle emissions, compared to free flowing traffic on Johnstown Road. This would affect local air quality in the vicinity of the roundabout. However, it is still expected that pollutant concentrations in the vicinity of the site will be below threshold levels.
- View from the Road: The roundabout is located slightly above the existing ground level. All other road alignments are predominantly on-line and at-grade so no adverse impact is anticipated.
- Relaxations and Departures from Standard: The geometric design of the roundabout incorporates a relaxation in accordance with the NRA DMRB. TD 16 states that the exit and entry radius should be between 15m and 20m, however, due to auto track analysis using 16.5m HGV vehicles, the exit radius on Johnstown west arm has been increased to 40m. All other roads are fully compliant with DMURS standards as described in section 2.2.

1.10 Key Features of Pedestrian and Cycle Access

The key features of improved pedestrian and cycleway access are:

- Constructability: The construction works are largely to be located on the current Kerdiffstown Road carriageway. However, as the footpath and cycleway are necessary to provide access to the end-use / park this can be accommodated as separate to the road construction.
- Noise and Vibration: Noise and vibration would be expected during a construction phase for a shared use pathway. During operation, noise and vibration would be minimal, aside from occasional maintenance of the facility and sounds generated by walkers and cyclists.
- Landscape and Visual: During construction, the cycle and pedestrian facility would impact on the landscape for removal of existing features impeding its path, grading, storage of construction material, paving, construction vehicles and personnel. Operationally, it would be a new paved feature on the landscape, and part of a significantly wider public accessway than currently exists at this

site. It would include a new linear grassy verge and vertical wooden bollards placed between the carriageway and pathway. It would include the presence of walkers and cyclists, presumably in greater numbers than currently use this road, as well as infrequent vehicles used for the maintenance of the pathway.

- Air Quality: Construction would include localised emissions impacting on air quality in the form of construction vehicles. It is presumed that most construction vehicles would be petrol or diesel-based. During operation, pathway users would not impact air quality. Occasional maintenance vehicles could have a localised and limited effect on air quality, depending on their type.
- View from the Road: During construction, road users would see activities including land clearance, grading, materials storage, paving and the presence of construction vehicles and personnel. Operationally, road users would see a new shared use facility adjacent to the roadway, separated by a grassy verge and wooden bollards. Receptors may also see pedestrians and cyclists using the facility, and the occasional maintenance vehicle.
- Relaxations and Departures from Standard: The shared use cycle/pedestrian path follows National Cycle Manual guidance for shared use facilities, which dictates a minimum shared width of at least 3.0m and defined widths for verge.

  No particular guidance exists for the wooden bollards specified for placement in the grassy verge between the shared use pathway and the new carriageway. These are intended to match similar features in the local landscape along other shared use pathways, particularly parallel to the N7 either side of Junction 8.
  All other features (crossings, transitions) meet current guidance.

Risk, Opportunity, Uncertainty and Inflation

It should be noted that the at grade roundabout and associated roads design is not a detailed developed design at this time (March 2017), and as such design development may pinpoint additional risks and opportunities which are yet to be identified.

Other References

Chapter 15 of the Environmental Impact Statement, prepared for the proposed Project includes further details with respect to current and projected traffic numbers.

Drainage design will be a requisite of the detailed design stage, though has been assessed at a high level to inform the outline design presented herein.

A Road Safety Audit is to be undertaken with respect to the proposed access design. The outcome of this may further inform the design.

Appendix A4.2 Assessment of Predicted Settlement

Technical Note

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Date	15 November 2016
Attention	Kildare County Council
Project	**Kerdiffstown Landfill Remediation Project**
Subject	**Waste Settlement Potential Assessment**
Doc No.	32EW5604/DOC/0035 | Rev 1 EIAR Issue

1. Introduction

1.1 Purpose of this Technical Note

This Technical Note covers the computer-based numerical assessment of the magnitude and duration of future waste settlement, due to waste degradation processes at the Kerdiffstown Landfill, together with information on calibrations of previous applications of the waste settlement model.

1.2 Restrictions

It is intended that this memo is read in conjunction with the following documents and drawings:

- Drawing Number 32EW5604-00-020 – Re-profiled Site Contours
- Drawing Number 32EW5604-00-022 – Remediation Contours
- Drawing Number 32EW5604-00-023 – Post Settlement Contours.

This work has been undertaken in advance of the additional ground investigation being undertaken for the site remediation works and thus the settlement predictions should be re-confirmed following receipt of the results of the ground investigation.

1.3 Application of the Numerical Assessment of Waste Settlement

To achieve the planned post-settlement profile for placed wastes, it is necessary to predict accurately the “percentage value” of the post-capping waste settlement which will occur following the profiling and capping of the waste which will remain in place, on completion of the remediation works for the site. The best means of determining the value which will apply to the waste in the site, is by the application of a reliable, numerical predictive waste settlement model, based on waste degradation processes. In addition, an amount of immediate elastic settlement which will occur on placement of the capping system and any other loading applied above the capping system.

With these data, the usual approach for most landfill related projects is to determine the necessary, corresponding pre-settlement profile which is required for the planned post-settlement profile to be achieved. In the case of the Kerdiffstown remediation project, an appropriate pre-settlement profile has been developed based on restoration proposals including earthworks and materials balance requirements. The post-settlement surface has been modelled from the results of the numerical study of site-specific waste settlement potential and its suitability has been examined. With local adjustments to the pre-settlement profile, a satisfactory post settlement profile has been demonstrated.

Waste settlement issues, the in-house numerical, predictive waste settlement model and the approach to confirm that the developed waste placement profile which enable a suitable post-settlement profile to be achieved, are explained below.

2. Post-capping Waste Settlement Issues

2.1 The result of underestimating the post-capping waste settlement value

Underestimation of the true magnitude of post-capping waste settlement can have serious and potentially costly environmental and engineering consequences in the medium to long term. If the post-capping waste settlement percentage is underestimated, over time the surface profile will fall to below the intended post-settlement profile for a site, as illustrated in Diagram 1.

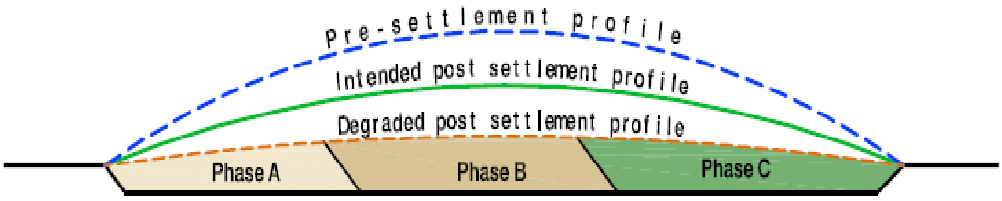

Diagram 1: Effects of underestimating post-capping waste settlement

The resultant degraded post-settlement profile will either be a dome which is too shallow, a near-flat surface or a dished surface. In all cases, there is high potential for the ponding of surface water to occur which can lead to cap degradation and breach of the capping system.

The reason why problems often arise with the actual post-settlement profile achieved after the completion of landfilling is as follows. Traditionally, for landfill site development, pre-settlement contours have been derived from assumptions made on the magnitude of post-capping settlement which will occur at a site. Percentage settlement ranges quoted in (UK) Waste Management Paper 26B (1995) are between 15% and 20% with the 15% value having been most commonly applied in the past in the design of pre-settlement profiles. The ranges quoted in Waste Management Paper 26B had been based on the range of settlement which had been observed largely only in the earlier years following the completion landfills. However, application of the numerical predictive waste settlement model has shown that the typical range of post capping waste settlement for municipal solid waste (MSW) landfills is most commonly between 25% and 35% and this range is confirmed by the calibrations of waste settlement carried out for two thirds of the modelled landfill sites.

Problems with the achieved post-settlement profile can be prevented by provision of an appropriate pre-settlement profile which takes correct account of post-capping waste settlement.

In this regard, in 2002 Enviros, a predecessor company of Jacobs, developed a reliable in-house, numerical method to accurately predict post-capping waste settlement, based on the modelling of waste degradation processes which act on the actual waste types and tonnages deposited over time at a subject landfill. This settlement prediction method utilises the mathematical representations of waste processes developed by Dr Alan Young in association with Enviros – Young (1992). The numerical, predictive waste settlement model considers waste processes and determines post-capping settlement with time, based on the mathematical prediction of mass loss due to waste degradation over time, from the commencement of the placement of waste. Post-capping waste settlement is directly related to mass loss due to waste degradation. The model is described in detail in Thomas and Cooke (2007), which includes illustrative data taken from previous practical applications of the model. Further explanation is presented in Section 3 below.

2.2 Definition of Landfill "Profiles"

Settlement issues are discussed in subsequent text with reference to the four relevant landfill restoration surface profiles shown in Diagram 2.

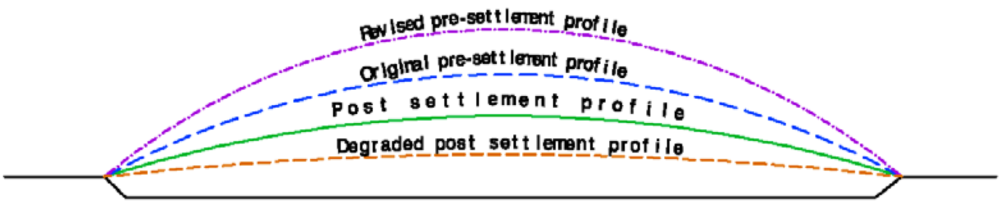

Diagram 2: Definition of four reference landfill surface profiles

The "Post-settlement profile" is the planned final profile of the landfill after all settlement has taken place. The "Original pre-settlement profile" is the level to which waste is originally placed and this profile is developed from the planned post-settlement profile based on an estimate of the likely total settlement which will eventually take place.

If the total waste settlement is underestimated at the design stage, the post-settlement profile will fall to a lower level than planned, which is shown in the diagram as the "Degraded post-settlement profile". The "Revised pre-settlement profile" shown in the diagram is the one which takes correct account of waste settlement. This will eventually settle to the planned "Post-settlement profile".

3. Numerical Predictive Waste Settlement Modelling

3.1 The In-house Numerical Predictive Waste Settlement Model

The Jacobs in house numerical, predictive waste settlement model is a proven numerical method.

When applied to remediating a completed or part-completed landfill, where it has become apparent that in the original design of the pre-settlement profile, the post-capping waste settlement percentage had been underestimated, the total waste input with time for each waste stream for a particular cell of landfilling is input to the model. The model calculates the mass loss due to the degradation of waste from the commencement of waste placement and onwards for a total of up to 200 years from the commencement of waste placement.

The waste settlement model is directly applicable to the prediction of post-capping waste settlement, since virtually all post-capping waste settlement is due to mass loss due to waste degradation. The advantage of this approach is that the model considers the site-specific nature of all of the waste landfilled, in terms of waste types, tonnages and rates of input. In addition, the model takes into account the estimated mean moisture content, temperature and pH of the waste. The model is described in the paper of Thomas and Cooke (2007).

An alternative approach is used for the determination of the appropriate input data for the model in the case of a completed landfill where comprehensive waste input records are not available. This approach assesses the nature of the landfilled waste components from boreholes drilled into the waste, which are logged specifically for this purpose. These data are processed and are directly input to the model to calculate the rate and magnitude of ongoing waste settlement from the time of the drilling of the boreholes to the time of completion of the waste settlement at the landfilled site. This is the approach which has been adopted for the Kerdiffstown Landfill. However, this approach cannot define the nature of the waste content of the landfill as accurately as the more common approach of processing continuous site records of the total waste input with time, for each waste stream for a particular cell of landfilling.

3.2 Mathematical Modelling of Waste Processes

As outlined above, predictive mathematical models of waste processes were developed as part of a research contract for the UK Department of Trade and Industry (DTI) with Enviros working in association with Dr Alan Young, then of the University of Oxford Mathematical Institute (Young 1992). The numerical, predictive waste settlement model uses these mathematical models of waste processes and their output of mass loss due to waste degradation. Prior to the development of the numerical, predictive waste settlement model, the same core mathematical models were used to develop the Enviros in-house numerical, predictive landfill gas production model. In terms validity of the approach, the first point which should be noted is that the same core mathematical models used in the development of the “GasSim” model; the model endorsed by the Environment Agency (EA), of England and Wales.

The above-mentioned in-house numerical, predictive landfill gas production model had been developed and refined over a number of years and successfully used to predict landfill gas production at a large number of sites in the UK and overseas. The model has been applied at new and existing sites and the results used for landfill gas control and gas utilisation purposes.

Examples of its use in the British Isles include Merseyside International Garden Festival Site, Liverpool; Bryn Posteg Landfill, Powys; Greenoak Hill Landfill, Glasgow and Baskets Town Landfill, County Meath, Republic of Ireland. Examples of its use overseas include Taman Beringin Landfill, Malaysia and a project comprising three landfill sites in Durban, Republic of South Africa: Bisasar Road, Mariannhill and Le Mercy. In this project, the Enviros model was used to validate carbon emission reductions for the World Bank regarding a landfill-gas-to-energy project under the Prototype Carbon Fund (PCF). This was the first PCF project of its type in Africa.

Since the in-house predictive, numerical waste settlement model uses most of the mathematical formulae used in the in-house numerical, predictive landfill gas production model, it has comparable validity. Furthermore, the numerical, predictive waste settlement model has been used to predict post-capping waste settlement in 39 phases of landfilling at 18 sites in UK, the Channel Islands, the Republic of Ireland and Finland since 2002 and to provide a sound numerical basis for determining revised restoration profiles to remediate landfill sites by remedial waste placement. It has also been examined in detail in a Public Inquiry for the Shakespeare Farm Landfill, where the model had been applied to modify pre-settlement profiles. The outcome of this Inquiry was in favour of the Biffa, Enviros’ client. Interpretation of calibrated waste settlement prediction data from previous application of the waste settlement at a number of UK landfill sites is presented in Cooke, Walker and Thomas (2007). Thomas and Cooke (2011) includes coverage of calibration and remedial works implementation.

3.3 Validity of the Waste Settlement Model

It is considered that the foregoing information demonstrates the mathematical and computational validity of the in-house numerical, predictive waste settlement model. It is added that the background to the model, the reliability and accuracy of the modelling approach and coverage of calibration and remedial works implementation have been covered in the peer-reviewed papers of Thomas and Cooke (2007), Cooke, Walker and Thomas (2007) and Thomas and Cooke (2011).

4. In-house Waste Stream Biodegradability Research from 2002 to 2007

Since the numerical, predictive, waste settlement model was developed in 2002, considerable effort has been applied to refining waste stream characterisation based on published data, detailed discussions with the operators of the various landfills on which waste settlement modelling has been undertaken and literature reviews on biodegradability of waste fractions.

As stated previously, the waste settlement model has been used to predict post-restoration waste settlement in 39 phases of landfilling at 18 sites in UK, the Channel Islands, the Republic of Ireland and Finland since 2002. Calibration of the model output by periodic, site specific waste surface survey has been undertaken at modelled phases or at completed phases adjacent to modelled phases, at approximately two thirds of the phases which have been modelled. This body of information and experience was taken further forward by additional, in-house waste stream biodegradability research undertaken between 2002 and 2007.

A literature review was conducted of source literature to clarify figures (source terms) for individual waste stream fractions in terms of their long term (150 years) biodegradability in a landfill. In addition the review was used to assess the accuracy and usefulness of GasSim assumptions when calculating biodegradability of waste (which is directly related to landfill settlement); and to formulate recommendations regarding the assumptions that should applied when GasSim data are used in the predictive modelling of landfill settlement.

Detailed explanation of the research of 2002 to 2007 is beyond the scope of this report, but the majority of the references set out in the Bibliography were part of the literature review which contributed to the research findings. (The remaining references in the Bibliography comprise a small selection of documents associated with the subject of landfill waste settlement.)

5. Modelling Settlement of the Waste Landfilled at Kerdiffstown Landfill

5.1 Method

To assess the biodegradability of the wastes within the site borehole logs from the 2012 Phase 2 Geotechnical Ground Investigation were interrogated. A representative sample of borehole logs was selected based on:-

- Spatial representation across the site;
- Quality of the recorded descriptions of the wastes and strata; and
- Boreholes which did not hit early obstructions and terminate early.

This resulted in the assessment of nine borehole logs - BH52, BH45, BH44, BH40B, BH39B, BH36B, BH34, BH26, and BH25C. The borehole logs provided relatively detailed descriptions of the waste arising from the retrieved samples including categories such as municipal waste, wood, paper, plastic, textile, cardboard, clay and gravel. Each of these descriptions had been provided with an assessment of the percentage of that material within each depth extracted from the borehole e.g. borehole depth 2 to 4m wood 20%, paper 5% etc. These descriptions and percentages were used to calculate (pro-rata) the overall composition of the full depth of the borehole based on the provided descriptions.

The following table provides a summary of the waste composition data:

	Percentage composition								
	Soils, gravels, clays etc.	Metals & wire	Wood and timber	Textile and cloth	Paper and cardboard	Plastics	Rubber	General MSW	Ash
BH52	46.1	11.3	21.1	3.9	10.5	7.2	0.0	0.0	0.0
BH45	57.2	6.7	12.6	4.9	6.2	11.1	1.3	0.0	0.0
BH44	37.4	7.9	18.4	6.3	10.2	13.4	0.0	2.6	0.0
BH40B	98.8	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
BH39B	27.3	11.5	43.0	5.6	8.9	3.6	0.0	0.0	0.0
BH36B	17.4	6.6	46.5	9.1	5.9	14.5	0.0	0.0	0.0
BH34	20.5	8.1	20.1	17.9	10.6	20.2	2.6	0.0	0.0
BH26	35.0	0.0	31.2	16.1	6.9	3.9	0.0	0.0	7.0
BH25C	13.0	0.6	23.0	13.4	21.7	30.6	0.0	0.0	0.0
Average	**39.2**	**5.9**	**24.1**	**8.6**	**9.0**	**11.6**	**0.4**	**0.3**	**0.8**

Table 1: Summary of Waste Composition

For use in the Jacobs settlement modelling it was considered that the following groups of waste should be modelled as inert waste (i.e. zero degradability) – soils, clays and gravel, metals and wire, plastics, rubber and ash. Although some of these fractions will degrade over-time, this is generally over a time period which will become irrelevant to the objectives of the settlement modelling, i.e. after 134 to 150 beyond the present and corresponding rates of settlement will be very small.

The approach provided the following summary of waste composition for input to the model.

	Percentage composition				
	Inert (Soils, plastics, metals etc.)	Wood and timber	Textile and cloth	Paper and cardboard	MSW
Average	**57.85**	**24.10**	**8.60**	**9.00**	**0.3**

Table 2: Derived Waste Composition Percentages

The above data were used as the raw input data to the Jacobs settlement model. The biodegradability of each waste fraction being based on research into the biodegradability of waste collated through the Jacobs literature review and research described above in Section 4. The values of biodegradability within the model take account of the overall biodegradability of each waste fraction (i.e. available carbon) based on cellulose, hemi-cellulose and lignin content, and also apply rates of degradation based on this. Lignin is somewhat resistant to degradation and a further assumption is made within the model that a large percentage, although not all of the lignin will degrade over the time period covered by modelled output. Using this approach the output from the model corresponds to virtual completion of waste degradation, in this case approximately 134 years beyond the present.

The focus of this study is on pre-filled waste which have been in-place for a significant time period, the models biodegradability and degradability rates were adjusted as the model has been developed predominantly for mimicking the landfilling of ‘fresh waste’. For the Kerdiffstown model it was assumed that a proportion of the rapidly degradable proportion of the waste would have already degraded, and that a large proportion of what is left will be the medium rate and slow rate biodegradable fractions.

Since at this time the landfill is “full”, a model was set up to mimic the presence of a nominal 1,000 tonnes of the waste, based on the composition discussed above. Thus, the model operates from the present time rather than from the time waste deposition had commenced. The following provides a visual summary of the model inputs:

The model inputs interpreted from the borehole logs, showing the different fractions are summarised in Figure 1.

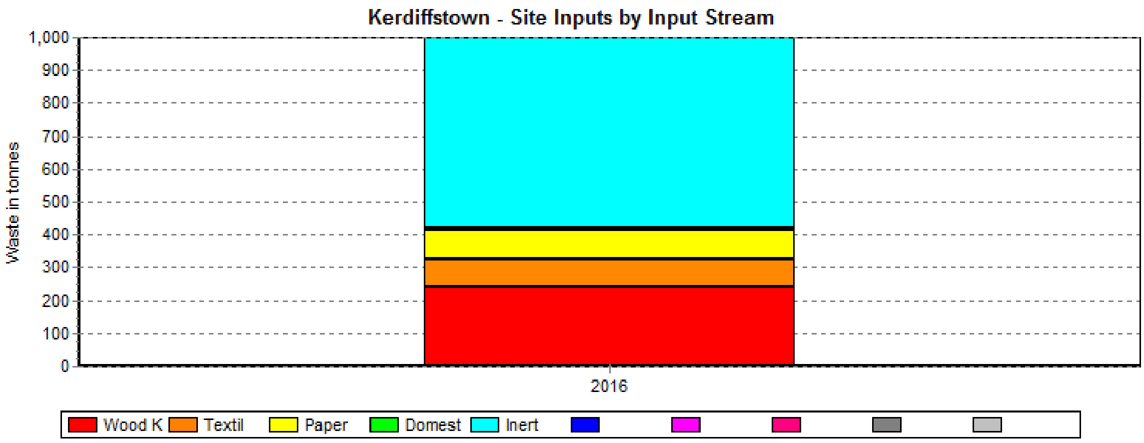

Figure 1: Site Inputs

Model inputs, showing input tonnage based on degradation rates are summarised in Figure 2.

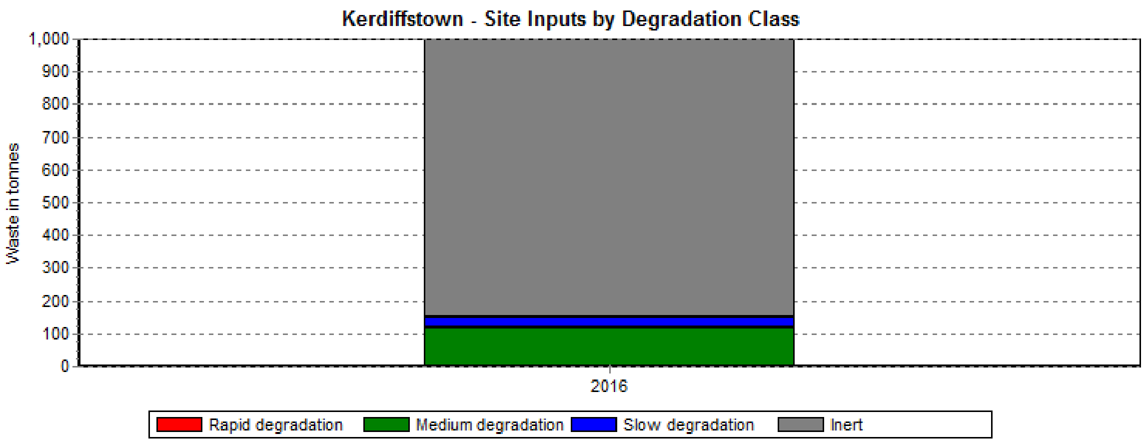

Figure 2: Site Inputs by Degradation Class

5.2 Results

The Jacobs model has user defined inputs for pH, moisture content and temperature and these factors can influence the rate of biodegradability, but not the overall biodegradability. As data to define these parameters were not available, and the focus on the study is more the overall biodegradability rather than the rate at which that will occur, model defaults were selected which mimic a ‘typical’ landfill. Thus, under these circumstances, the changing rates of settlement which will apply over the settlement period cannot be exactly estimated by the model.

The model was run using a nominal end date of 2150 and that covered a134 year period. The model outputs are presented below. These demonstrate that the waste degradation processes had, in fact essentially reached completion at this time, as discussed below.

Model output showing overall site contents, degradation rates, and the modelled settlement over time are shown in Figure 3.

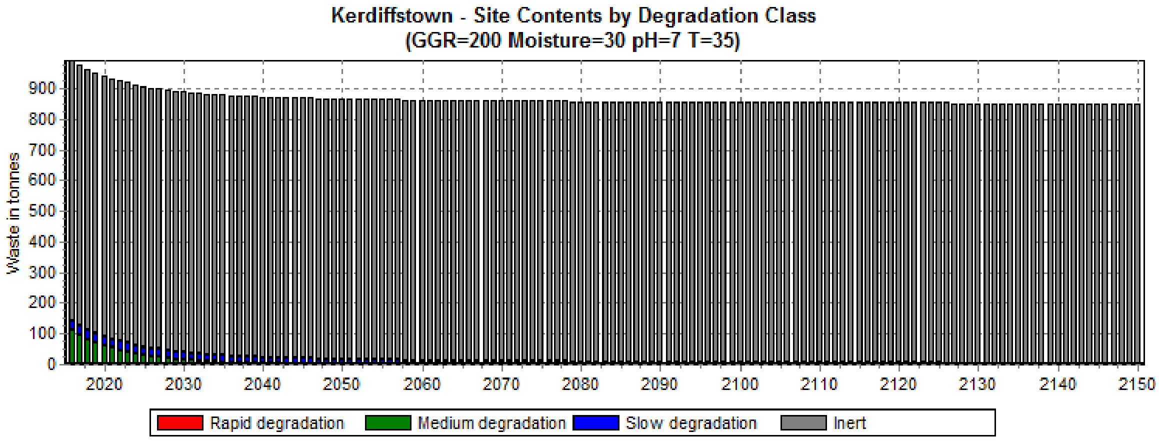

Figure 3: Site Contents Over Time, by Degradation Class

Model output showing calculated waste mass settlement percentage over time (but only representing provisional rates of settlement over the settlement period) are shown in Figure 4.

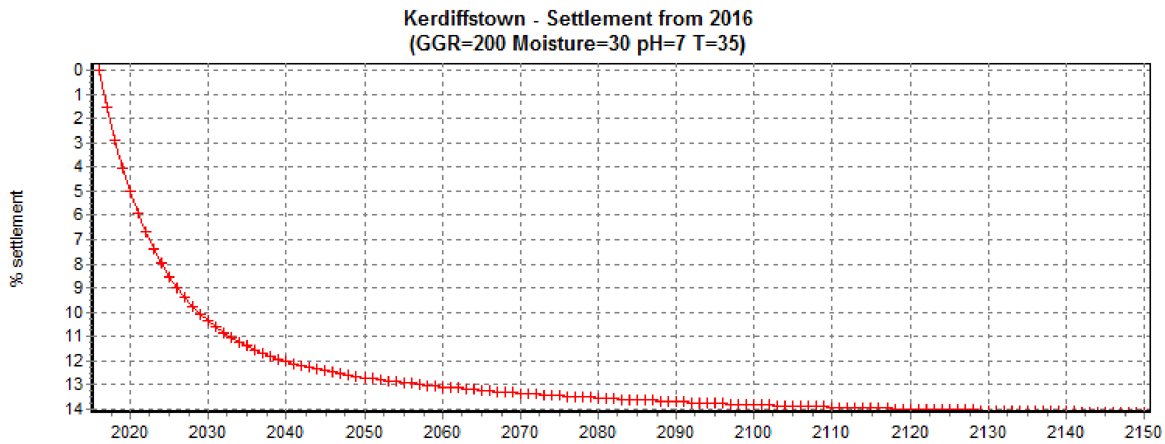

Figure 4: Total Settlement, Duration of Settlement and Provisional Representation of Rates of Settlement

The model outputs provide an estimate of approximately 14% total settlement over the modelled 134 year settlement period. Since assumed values have had to be applied for waste pH, moisture content and mean temperature in the model, the changing rates of settlement over the settlement period cannot be exactly estimated by the model. Even so, judging by the shape of the graph this appears to represent the asymptotic point for the decay curve. Although it should be noted that if longer time periods are considered i.e. beyond 134/150 years from the present, then potential further biodegradation of other waste fractions such as the plastics and rubber should be considered. However, it is likely that the corresponding ongoing settlement and additional total settlement will be comparatively small.

6. Results of the Waste Settlement Modelling

1. The model output predicts that the remaining waste settlement potential for the wastes landfilled at the Kerdiffstown Landfill is approximately 14% of the waste thickness at any given point on the surface.

2. Effectively, the ongoing waste settlement will have ceased by approximately 2150.

7. Confidence in the Waste Settlement Prediction for Kerdiffstown Landfill

The development, calibration and extensive commercial application of the numerical, predictive waste settlement model (see Section 3), together with the extensive research which has been carried out on waste stream biodegradability (refer Section 4), demonstrate the overall validity of the model.

The likely accuracy of the predicted settlement from the modelling of the landfilled waste at Kerdiffstown is supported by consideration of two previous applications of the waste settlement modelling at two other landfills where the overall waste biodegradability was comparatively low. The following results should also be considered in the context of the typical range of post-capping waste settlement for municipal waste landfills is most commonly between 25% and 35% and this range is confirmed by the calibrations of waste settlement carried out for two thirds of the sites which have been assessed by the in-house waste settlement model.

A previously modelled cell of landfilling which contained a high proportion of contaminated soils yielded a total waste settlement percentage of 16% which would be achieved at approximately 150 years post capping. Another previously modelled cell of landfilling which contained a high proportion of inert materials and wood, yielded a total waste settlement percentage of 21% which would be achieved at approximately 150 years post capping. Both cases were subjects of settlement calibration based on periodic site surface survey.

The wastes at Kerdiffstown Landfill are likely to have been in place for a period in the order of two decades, thus the present overall degradability would be comparatively low and would be somewhat similar in that regard to the overall biodegradability of the two other cases described above. The predicted total waste settlement percentage for the Kerdiffstown landfill is 14%, with waste settlement continuing for approximately 134 years. Thus, the general similarity of the predicted total waste settlement for Kerdiffstown landfill and the other two sites, provides confidence in the waste settlement prediction for Kerdiffstown Landfill.

In this regard it should be noted that calibration carried out on landfills where waste settlement modelling has been carried out has shown that the accuracy of the initial output of the model has steadily increased since its development in 2002. This is a result of extensive research which has been carried out on waste stream biodegradability from 2002 to 2007 as outlined in Section 4. However, in each of these cases, continuous site records of the total waste input with time for each waste stream, for a particular cell of landfilling, had been available for processing, to obtain the input for each model. Figure 5 illustrates one of several cases since 2005 where calibration has demonstrated that no adjustment is required to output from the predictive modelling of post-capping waste settlement. This case is also presented in Thomas and Cooke (2011).

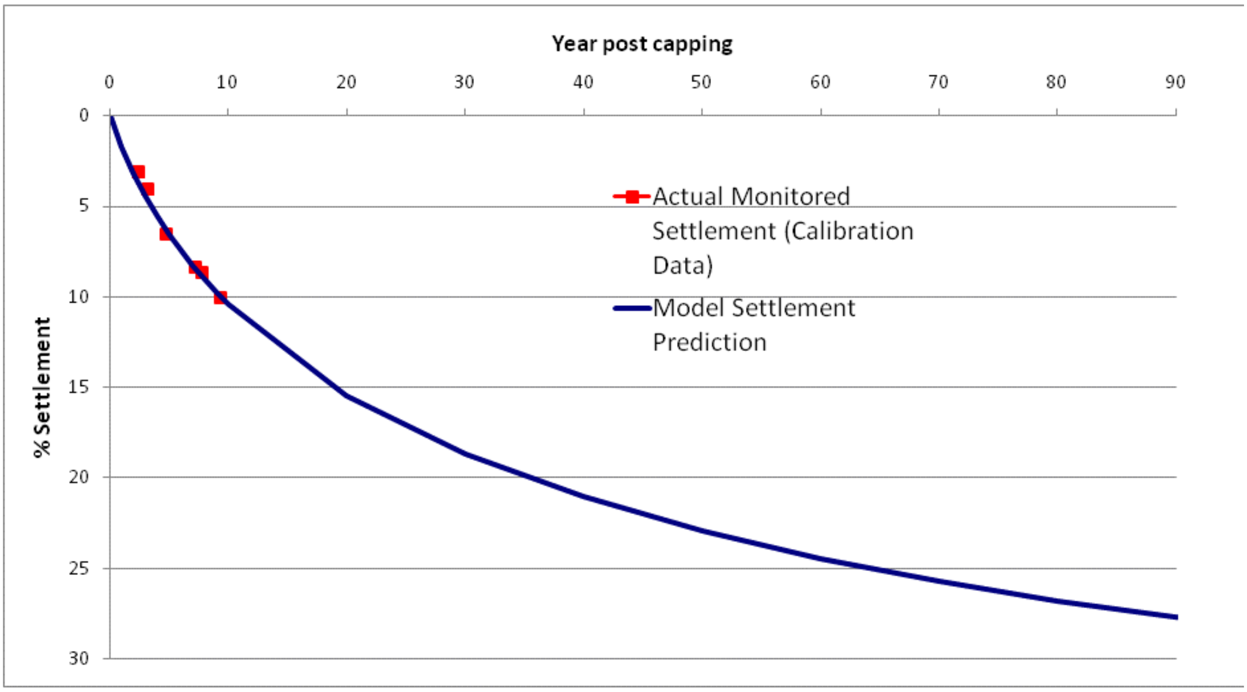

Figure 5: Post-capping settlement calibration data points for a 9 year 4 month period shown on part of an unadjusted predictive model of settlement for a single phase of landfilling.

8. Waste Settlement Modelling

8.1 Immediate Settlement Due to Re-profiling Works

Substantial waste re-profiling works are proposed as part of the restoration proposals. Where waste placement occurs settlement will be induced in any underlying waste materials and / or natural materials.

Settlement induced in the waste materials is expected to occur immediately during construction, reflecting anticipated generally free draining characteristics of the bulk waste materials present at the site.

The natural material underlying the site are indicated by available ground investigation information to be predominantly granular in nature (sands and gravels) hence, settlement induced by waste re-profiling works in the natural deposits underlying the site is also expected to occur relatively instantaneously during construction.

On the above basis it can be assumed that the waste re-profiling works will not directly affect post restoration settlement profiles.

8.2 Settlement Due to Waste Degradation

The majority of post restoration settlement will occur as a result of waste degradation.

To determine the magnitude of total waste settlement (in metres) which will apply at any point on the surface profile, the underlying thickness of the waste (in metres) is multiplied by the predicted total waste settlement percentage, as a “decimal” value. The total predicted percentage waste settlement is 14%, thus, as a decimal value, this is 0.14.

The calculated 14% total settlement value has been applied to the waste placement profile which will apply following the remodelling of the site as part of the remediation works. The waste profile has been iteratively modified over comparatively small areas to provide a suitable post-settlement profile for the site.

Where modifications were required to accommodate changes to the cut and fill proposals and materials balance, the suitability of the waste placement profile was re-checked and confirmed to remain suitable.

The final proposed waste profile is illustrated in drawing 32EW5604/044 - Re-profiled Top of Waste Contours and the end of remediation capping profile in drawing 32EW5604/046 - Remediation Contours. Post settlement contours are illustrated in drawing 32EW5604-047 - Post Settlement Contours.

8.3 Zone 3 Sensitivity Check

Ground investigation records are not available to characterise the waste materials currently placed within the Zone 3 area. Furthermore, the placement of unprocessed surface wastes from Zones 2 and 4 into the Zone 3 area is proposed. Consequently, there is a possibility that the waste materials within the Zone 3 area will contain a higher degradable content than other wastes at the site.

To account for the possibility of waste materials within Zone 3 area with an increased degradable content, sensitivity analysis was undertaken considering an increased waste settlement percentage of 20%. This demonstrated that the post-settlement profile remained acceptable.

8.4 Capping System Induced Settlement

Immediate elastic settlement will also result from the placement of the capping and restoration system, together with any other regulating or profiling inert materials should be determined. Since the present proposal for the majority of the capping system is for a comparatively thin, 650mm system, immediate elastic settlement following its placement will be comparatively small.

At all locations, almost certainly it will be no greater than the thickness of the capping system itself. However, it is recommended that when the additional GI has been completed, immediate elastic settlement is calculated for the placement of the capping system. This will refine the definition of the post-settlement profile which will be achieved across the site.

8.5 Loading Above Capping System

The current settlement assessment has not considered additional settlement that may be induced by loading above for the capping system (e.g. by the placement of landscape fill). Depending on the extent of loading applied this may result in substantial additional settlement and resulting deformation of the capping system which would require separate assessment.

9. Conclusions and Recommendations

From this study it is concluded that:-

1. Settlement induced by waste re-profiling works will predominantly occur during construction, with post restoration settlement occurring as a result of waste degradation and to a minor extent settlement associated with the placement of the capping system.

2. Post restoration settlement potential for the wastes landfilled at the Kerdiffstown Landfill is estimated be approximately 14% of the waste thickness at any given point on the surface.

3. Effectively, the ongoing waste settlement will have ceased by approximately 2150.

4. There is potential for very slow degradation of waste fractions such as plastics and rubber to continue beyond 134/150 years from the present, but corresponding ongoing settlement and additional total settlement will be comparatively small.

5. Since assumed values have had to be applied for waste pH, moisture content and mean temperature in the model, the changing rates of settlement over the settlement period cannot be exactly estimated by the model.

6. Application of the 14% total settlement value to the intended final capping profile (see Drawing 32EW56-046 'Remediation Contours') to demonstrates that a suitable post-settlement profile will result (see Drawing 32EW5604-047 'Post Settlement Contours').

7. Additional application of an extreme, nominal post-capping waste settlement percentage of 20% to the waste placement profile for Zone 3 demonstrated that the post-settlement profile would remain satisfactory under such extreme conditions.

8. Since the present proposal for the majority of the capping system is for a comparatively thin, 650mm system, immediate elastic settlement following its placement will be comparatively small. At all locations, almost certainly it will be no greater than the thickness of the capping system itself therefore numerical calculation of capping induced settlement is not considered necessary.

9. It is recommended that when the additional GI has been completed, settlement predictions are reviewed to account for any changes in inferred waste thicknesses and / or waste composition.

10. Should substantial loading above the capping system be required, supplementary settlement calculations should be undertaken to confirm deformation of the capping system remains within acceptable tolerances.

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Appendix A4.3 Capping and Waste Slope Stability Assessment

Technical Note

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Date	16 November 2016
Attention	Kildare County Council
Project	**Kerdiffstown Landfill Remediation Project**
Subject	**Preliminary Capping and Waste Slope Stability Assessment**
Doc No.	32EW5604/DOC/0036 | Rev 1 EIAR Issue

1. Introduction

1.1 Purpose of this Technical Note

This Technical Note covers the initial, generic design analyses to support planning and waste licence applications, completed for optional configurations of multilayer capping systems for the steep perimeter slopes of the Kerdiffstown Landfill. This initial work provides factor of safety output for various optional design configurations and material combinations. In addition, initial slope stability assessments have been completed for the steep waste slopes on the northern perimeter of the site, following proposed trimming, for waste placement in lined Zone 3 and for temporary waste slopes which may be formed during the earthworks phase of the proposed remediation works. The results have informed the development of the pre-settlement surface profile of the site and have informed the subsequent selection of the preferred option for the multilayer capping system, which is further discussed separately in this report.

Overall waste mass stability is rarely an issue in waste slopes of modest gradient in a correctly designed and permitted landfill. However, for steep, high perimeter slopes of a land-raise landfill that are expected to have been placed in an uncontrolled manner, overall waste mass stability should be analysed, as it is likely that the slopes were never the subject of analytical design. Therefore, in anticipation of remedial construction works, overall waste mass stability analyses for the proposed, trimmed steep perimeter slopes has been undertaken. In addition, as indicated above, waste slope stability analyses have been completed for waste placement in lined Zone 3 and for temporary waste slopes which may be formed during the earthworks phase of the proposed remediation works.

1.2 The Potential Need for Capping the Surfaces of the Landfilled Waste

The Kerdiffstown Landfill site is the subject of a numerical, probabilistic hydrogeological risk assessment which has investigated the degree of risk of groundwater receptors to groundwater contamination resulting from infiltrating rainwater and surface water percolating through the placed waste and creating leachate in this largely unlined landfill site. This assessment has examined the present state of the landfill and has been run to assess the effects of proposed mitigation and capping measures. The provision of an efficient, robust capping system always has a beneficial impact on the mitigation of potential groundwater contamination in cases such as this.

1.3 The Presently Preferred Option for the Multilayer Capping System

A range of configurations and materials were considered at the commencement of this stage of multilayer capping system design analysis. Subsequently, the requirements for restoration soils were refined and a double textured, high density polyethylene (HDPE) flexible membrane “liner” (FML) has been selected as the preferred option for the low permeability element of the capping system. This option is one of those analysed in the initial stages of the development of capping system.

1.4 The Need for a Multilayer Capping System for the Steep Perimeter Slopes

Significant lengths of perimeter slopes of the Kerdiffstown Landfill are steep and high. Although some re-grading to achieve a reduction in slope gradient is proposed, gradients will be comparatively steep in the context of multilayer capping systems.

Conventional low permeability mineral capping systems are potentially the least stable and most difficult to construct on steep perimeter waste slopes. Furthermore, suitable low permeability material may not be readily available for the capping works. Multilayer capping systems which use geosynthetic clay lining elements (GCL) or linear low density polyethylene (LLDPE), medium density polyethylene (MDPE) or high density polyethylene (HDPE) flexible membrane “liners” (FMLs) as the low permeability capping element, are more practical than a mineral element in terms of ease of placement and construction and level of performance for a steep slope. Nevertheless, informed, careful numerical design analysis and a high standard of construction by experienced operatives are essential for successful completion of a suitable, effective and durable multilayer capping system.

1.5 Restrictions

This work has been undertaken in advance of completion of the additional ground investigation (GI) being undertaken for the site remediation works, thus review and checking of the analyses will be necessary following receipt and interpretation of the final GI data.

Following confirmation of the proposed capping material sources it will be necessary to undertake laboratory testing to determine the material properties of the mineral regulating layer and proposed restoration soils, together with large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen components of the multilayer capping system. At this detail design stage, capping stability checks will require re-running to demonstrate acceptability.

2. Multilayer Capping System Design and Construction Issues

2.1 Design Issues

In very general terms, for waste slopes with a gradient of 1 in 3 or shallower, multilayer capping stability problems are unlikely in a correctly designed capping system. For gradients steeper than 1 in 3, multilayer capping instability is more likely to be an issue. Therefore, for all sloping capping systems it is advisable to carry out multilayer lining stability analyses.

Multilayer capping system stability analyses must determine the factor of safety applying for each component at each stage of construction. For any design case where adequate factors of safety cannot be achieved for all capping system components, at all stages of construction, the addition of uniaxial geogrid reinforcement may be the means of achieving a satisfactory design. Although lower strength uniaxial geogrid reinforcement can raise the factor of safety when the shortfall is small, the required tensile capacity rapidly increases, as the initially analysed shortfall in factor of safety increases with increasing slope gradient and / or slope height.

The rated ultimate tensile strength of any given uniaxial geogrid is not that which can be taken for use in multilayer lining systems. The appropriate strain limited value should be taken. In most if not all cases, this will have to be the value applying at 2% strain to limit the movement which could be transmitted to, for instance, an HDPE FML and induce adverse tensile forces. The 2% strain value may be as little as 22% of the ultimate tensile value of a geogrid. These issues have cost implications for the provision of geogrid reinforcement.

For slopes of the order of 1 in 3 gradient, often a single-textured HDPE FML is used, which is placed with the textured side downwards on a suitable protective sub-grade, such as fine to medium sand. The textured surface helps to keep the HDPE FML in place during construction and the future operation of the capping system. The subsequent placement of sub-soil and topsoil (over, for instance, a geotextile protection layer) is likely to be stable in this case on 1 in 3 slopes. However, the smooth upper surface of the mono-textured HDPE FML allows small initial movements in the overlying layers to take place without inducing tension in the HDPE FML. This is because the textured underside restrains the HDPE FML and the small transmitted forces from above are taken in shear by the HDPE FML, rather than in tension. HDPE FML is very strong in shear, but not in tension. This is because "environmental stress cracking" arising from surface abrasion and scratches caused during construction activities, can result in tensile failure at loads far below those applied in factory conformance testing of the virgin HDPE FML. The foregoing matters are carefully considered at the analytical design stage.

If steeper gradient slopes require capping, double-textured FML may be required to allow stable deployment at the construction stage of the overlying geotextile protection layer and the overlying soils. For such steeper slopes, it is likely that geogrid reinforcement will be required in the restoration soils, to minimise the tensile forces in the geosynthetic components and to keep shear loads applied to the double-textured HDPE FML within reasonable bounds. Although HDPE has high strength in shear and double-textured HDPE FML in this configuration still acts in shear rather than in tension, any form of textured HDPE FML has lower tensile strength than smooth HDPE FML with the same sheet thickness. For this reason, textured HDPE FML is slightly more susceptible to environmental stress cracking than smooth sheet. Thus, the geogrid reinforcement must be designed to prevent tensile forces developing in the HDPE FML during construction and during its ongoing operation. Again, the foregoing matters are carefully considered at the analytical design stage.

Single-textured GCL is available and would normally be used in a sloping multilayer capping system with the textured side downwards on a suitable protective sub-grade, such as fine to medium sand. If single-textured GCL is used as the low permeability capping element, depending on its proprietary design there may be potential for hydrated bentonite to pass out of the surface of the host material during the ongoing operation of the lining system. This could have a considerable effect on the original interface friction and adhesion properties. For these preliminary, generic analyses, what are intended to be conservative parameters have been assumed. However, later, laboratory testing of the specific, preferred proprietary single-textured GCL in conjunction with those elements with which it will be in contact, must be carried out to determine material-specific interface friction and adhesion properties for final design purposes.

2.2 Construction Issues

The steeper and higher the waste slope; the greater are the multilayer capping system construction difficulties and construction safety issues.

For landfill capping slopes of 1 in 3 gradient or shallower, benches can often be omitted from the slope design, especially since ongoing waste settlement due to waste degradation processes reduces further the gradient over time. However, if capping slopes have to be steeper, benches become increasingly likely to be needed to achieve multilayer lining stability. This is due to slopes of lesser height benefitting more in terms of stability from the "toe support" achieved in the thicker capping system layers such as the restoration soils. Also, a benched slope of moderate inter-bench height makes it easier to achieve successful deployment and placement of the capping system components.

Very high capacity uniaxial geogrids may be unsuitable for deployment in a sloping multilayer capping system due to their potential to have difficulty in conforming to the change of gradient between the waste slope and intermediate benches. This may be an even greater problem in the case of geogrid deployment into "anchor" trenches; however, currently it is proposed that the geogrid in the 1 in 2.5 gradient capping system will be anchored by continuing back through the capping system of the shallower slopes for a few metres behind the crest of the steep slopes. This will be the subject of design analyses at the detail design stage.

One potential option to accommodate the need for high capacity geogrid would be to provide two layers of geogrid to achieve the same tensile resistance. However, with proposed subsoil thickness being only 350mm, this may make successful placement of the subsoils and geogrid a complex process on 1 in 2.5 gradient slopes.

3. Multilayer Capping System Design Method

The method of analysis employed for analysing multilayer lining stability is that of Giroud, J.P., Williams, N.D., Pelte, T., Beech, J.F. (1995) "Stability of geosynthetic-soil layered systems on slopes", *Geosynthetics International*, Vol 2, No 6, pp1115-1148. This is a recognised method which is comprehensive in terms of the cases which can be analysed and which is rigorous in its approach. It has been one of the preferred multilayer capping system analytical methods of the past two decades.

At this preliminary stage, the approach adopted has been to examine the global factor of safety achieved for each element of the multilayer lining system, at each stage of construction. This is an appropriate, robust, rapid means by which a large number of analyses can be completed in a reasonable time. As these capping systems are to form a part of permanent perimeter slopes, a global factor of safety of 1.3 has been considered appropriate.

At the detail design stage, analyses compliant with Eurocode 7 can be undertaken.

4. Configurations of the Multilayer Capping System for Assessment and Analytical Approach

4.1 Defined Slope Geometry

Presently proposed remediation contours and slope gradients (pre-settlement) are shown in the following drawings:

- Drawing 32EW5604-00-022 – Remediation Contours
- Drawing 32EW5604/051 – Remediation Slope Gradients

The critical slope to be capped occurs along the north-eastern boundary of Zone 1 with the following characteristics:

- Toe of slope ~ 85mAOD
- Break in slope (lower steep to upper shallow) ~ 105mAOD
- Maximum height of landfill ~ 115mAOD

The resulting approximate maximum waste slope heights are as follows:

- Lower steeper slope: ~20m
- Upper shallow slope: ~10m
- Overall height: ~30m

The following slope gradients have been examined for the capping of the perimeter waste slopes:

- 1 vertical : 3 horizontal
- 1 vertical : 2.5 horizontal
- 1 vertical : 2 horizontal

The upper, shallow gradient, nominal 10 m high waste slopes require no separate multilayer capping system stability analysis at this stage, since the 1 in 3 slope analyses for the perimeter slopes can be considered indicative of the design case for the shallower 10m high slopes.

4.2 Capping System Configurations Examined Initially

In summary, the capping system configuration and components considered for each of the slope gradients are as follows:

<u>HDPE Options</u>

- Top soil 0.15m / Subsoil 0.35m / Geotextile Protection / HDPE / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.85m / Geotextile Protection / HDPE / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.35m / Geodrain / HDPE / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.85m / Geodrain / HDPE / Regulating Layer / Waste

GCL Options

- Top soil 0.15m / Subsoil 0.35m / Geotextile Protection / GCL / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.85m / Geotextile Protection / GCL / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.35m / Geodrain / GCL / Regulating Layer / Waste
- Top soil 0.15m / Subsoil 0.85m / Geodrain / GCL / Regulating Layer / Waste

The above definitions of system configuration cover total restoration soil thicknesses of 0.5m and 1.0m. For the restoration soil parameters, typical mean values have been applied for the topsoil and subsoil together, but for restoration soil interface friction and adhesion, values appropriate for angular, gravelly subsoil have been applied.

4.3 Inclusion of Benches

As is demonstrated later by the results of the multilayer capping system stability analyses for a number of cases, for 1m restoration soils and 1v in 2h gradient slopes, continuous 20m high slopes are generally inappropriate, as excessive and impractical geogrid reinforcement would be required to render the multilayer capping system stable. Therefore, additional cases have been examined with intermediate benches forming one third height slopes of 6.7m. Other options can be considered at any later stage, if necessary.

4.4 Additional Description of Components Considered for the Multilayer Capping System

For all cases, as part of the multilayer lining system construction, an angular fine to medium sand regulating layer is placed above the landfilled waste of the perimeter slopes. Potentially, this form of regulating layer achieves the best interface parameter values and provides the overlying low permeability element adequate protection from the underlying waste.

For the basic double-textured HDPE and single-textured GCL cases, a protective non-woven geotextile layer has been included above each. These cases also cover the situations where a geosynthetic drainage layer is provided beneath the restoration subsoil, where the drainage layer design has outer layers of non-woven geotextile over a space-making geosynthetic component to carry the majority of the drainage flow.

The alternative cases for inclusion of a geosynthetic drainage layer beneath the restoration soils has been examined for a design which has outer layers of woven geotextile over a space-making geosynthetic component to carry the majority of drainage flow.

Where appropriate, the need for and capacity of geogrid reinforcement has been examined for the cases defined above.

4.5 The Range of Analyses

To examine sensitivity to variations in material parameters, two sets of parameters have been applied in the analyses. These are termed “best case parameter values” and “typical parameter values”. In the case of interface friction and adhesion properties, the best case parameters are based on the mean results obtained by laboratory testing for typical materials, reported in:

- UK Environment Agency R&D Technical Report P1-385/TR2, January 2003; and
- Lopes *et al.* (2001).

The corresponding “typical parameters” are a slightly more conservative set to include, at this stage, a nominal degree of conservatism. It should be noted that the analytical design method considers the theoretical toe buttressing effect in all components, but this is only truly significant in the thicker components such as the restoration soils. Other than unit weight, and other than in the case of toe buttressing in the regulating layer and in the restoration soils, the remaining material properties of each component have little bearing on the calculations of multi-layer lining stability, but they help inform the selection of interface friction and adhesion values.

Therefore, to cover the combination of cases described above in Sections 4.1 to 4.3, approximately 130 generic, multilayer capping design analyses have been completed. The results informed the development of the pre-settlement surface profile of the site and the later selection of the “preferred” form of the multilayer capping system. The presently “preferred” configuration for the multilayer capping system is covered in Section 7.

5. Material Parameters

The approach to the selection of material parameters has been described above in Section 4.5.

Although it is intended that representative values for the design parameter values have been selected from published data, the material parameters and interface parameters are very dependent on the specific mineral materials and proprietary geosynthetic materials which will be finally chosen. Therefore, for completion of the final detail design, it will be necessary to undertake laboratory testing to determine the material properties of the mineral regulating layer and proposed restoration soils, together with large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen components of the multilayer lining system.

In Tables 1 to 8, the first item shown is the first component placed in construction and so on down the first part of the table to the last item placed. In the second part of each table, Interface 1 is that between the subgrade and the first component placed, Interface 2 is between the first and second components placed, Interface 3 is between the second and third components placed and Interface 4 is between the third and fourth components placed.

For the restoration soil parameters, mean values have been applied for the topsoil and sub soil together, but for restoration soil interface friction and adhesion, values appropriate for an angular, gravelly subsoil have been applied. The parameters for the principal cases examined are tabulated below.

	Unit Weight kN/m²	Internal Friction degrees	Cohesion, c' kN/m²	Thickness m
Angular sand regulating layer	19	26	0	0.3
Double-textured HDPE	9.22	30	5	0.008
Prot. non-woven geotextile/drain	1.22	24	0	0.01
Topsoil and subsoil (mean values)	17.5	23	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	24	0
Interface 2	24	3
Interface 3	24	3
Interface 4	24	0

Table 1: "Typical Parameters" for HDPE Case with Protective Geotextile and for HDPE Case with Non-woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m²	Internal Friction degrees	Cohesion, c' kN/m²	Thickness m
Angular sand regulating layer	19	28	0	0.3
Double-textured HDPE	9.22	30	5	0.008
Prot. non-woven geotextile/drain	1.22	26	0	0.01
Topsoil and subsoil (mean values)	17.5	25	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	26	0
Interface 2	25	4
Interface 3	25	4
Interface 4	26	0

Table 2: "Best Case Parameters" for HDPE Case with Protective Geotextile and for HDPE Case with Non-woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m^2	Internal Friction degrees	Cohesion, c' kN/m^2	Thickness m
Angular sand regulating layer	19	26	0	0.3
Single-textured GCL	9.22	26	2	0.01
Prot. non-woven geotextile/drain	1.22	24	0	0.01
Topsoil and subsoil (mean values)	17.5	23	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	24	0
Interface 2	23	0
Interface 3	13	1
Interface 4	24	0

Table 3: “Typical Parameters” for Single-textured GCL Case with Protective Geotextile and for Single-textured GCL Case with Non-woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m^2	Internal Friction degrees	Cohesion, c' kN/m^2	Thickness m
Angular sand regulating layer	19	28	0	0.3
Single-textured GCL	9.22	26	2	0.01
Prot. non-woven geotextile/drain	1.22	26	0	0.01
Topsoil and subsoil (mean values)	17.5	25	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	26	0
Interface 2	25	0
Interface 3	13	2
Interface 4	26	0

Table 4: “Best Case Parameters” for Single-textured GCL Case with Protective Geotextile and for Single-textured GCL Case with Non-woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m^2	Internal Friction degrees	Cohesion, c' kN/m^2	Thickness m
Angular sand regulating layer	19	26	0	0.3
Double-textured HDPE	9.22	30	5	0.008
Protective woven geotextile drain	1.22	24	0	0.01
Topsoil and subsoil (mean values)	17.5	23	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	24	0
Interface 2	24	3
Interface 3	10	2
Interface 4	26	0

Table 5: "Typical Parameters" for HDPE Case with Woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m^2	Internal Friction degrees	Cohesion, c' kN/m^2	Thickness m
Angular sand regulating layer	19	28	0	0.3
Double-textured HDPE	9.22	30	10	0.008
Protective woven geotextile drain	1.22	26	0	0.01
Topsoil and subsoil (mean values)	17.5	25	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	26	0
Interface 2	25	4
Interface 3	11	3
Interface 4	28	0

Table 6: "Best Case Parameters" for HDPE Case with Woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m²	Internal Friction degrees	Cohesion, c' kN/m²	Thickness m
Angular sand regulating layer	19	26	0	0.3
Single-textured GCL	9.22	26	2	0.01
Protective woven geotextile drain	1.22	24	0	0.01
Topsoil and subsoil (mean values)	17.5	23	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	24	0
Interface 2	23	0
Interface 3	13	1
Interface 4	26	0

Table 7: "Typical Parameters" for Single-textured GCL Case with Woven Outer Geotextile Components for the Geosynthetic Drainage Layer

	Unit Weight kN/m²	Internal Friction degrees	Cohesion, c' kN/m²	Thickness m
Angular sand regulating layer	19	28	0	0.3
Single-textured GCL	9.22	26	2	0.01
Protective woven geotextile drain	1.22	26	0	0.01
Topsoil and subsoil (mean values)	17.5	25	0	Either 0.5 or 1.0 as applicable to case analysed

	Interface Friction	Interface Adhesion
Interface 1	26	0
Interface 2	25	0
Interface 3	13	2
Interface 4	28	0

Table 8: "Best Case Parameters" for Single-textured GCL Case with Woven Outer Geotextile Components for the Geosynthetic Drainage Layer

6. Factor of Safety Considerations and Summary of Results of the Initial, Generic Multilayer Capping System Design Analyses

6.1 Reporting of Results

6.1.1 Presentation of results

The detailed model output for each separate analysis comprises the factors of safety for each capping system component at each stage of construction. Since 155 generic analyses have been completed to cover the alternative configurations and components of the cases defined above in Sections 4.1 to 4.4, the results obtained are summarised below in a simplified form in Tables 9, 10, 11 and 12, rather than 155 separate comprehensive result tables being presented for each case analysed.

6.1.2 Factors of safety for construction stage and permanent works

For any configuration to be considered a stable design, a factor of safety of 1.3 must apply for each component at the end of construction. At intermediate stages of construction a minimum factor of safety of 1.2 can apply, provided that the inclusion of geogrid in the restoration soil layer will be sufficient to bring all components in the capping system to a factor of safety of 1.3. The abovementioned factor of safety of 1.2 is normally the minimum which can apply for temporary slopes. In some specific cases, a factor of safety of a little below 1 in 2 may be acceptable, depending on the analysed effect of the placement of the overlying component or components on the factors of safety of the previously placed component or components. At the detail design stage, analyses of downslope braking forces and upslope acceleration forces also must be carried out if mechanical plant will be used at any stage of sloping multilayer capping system construction.

6.1.3 Construction stage factors of safety for GCL interfaces

In many of the initial, generic multilayer capping system analyses presented in this report where GCL is used in the capping system, the consideration of factors of safety in the construction stage is a “special case”. This is because, as explained in Section 2.1, depending on the proprietary GCL component design, there may be potential for hydrated bentonite to pass out of the surface of the host material during the ongoing operation of the capping system. This could have a considerable effect on the original interface friction and adhesion properties. For these preliminary, generic analyses, what are intended to be conservative parameters have been assumed. However, in an un-hydrated state in the construction stage, GCL will be stable in many of the analysed cases, but geogrid reinforcement will be needed to achieve the factor of safety for the ongoing operation of the capping system should the GCL have the potential to pass out of the host material following hydration.

Thus, later, laboratory testing of the specific, preferred GCL proprietary item, in conjunction with those elements with which it will be in contact, must be carried out to determine whether or not following hydration, bentonite may pass out of the host material and to determine the material-specific interface friction and adhesion properties for final design purposes. Under the best circumstances, it is possible that in a number of GCL cases, the magnitude of the tensile strength of necessary geogrid reinforcement could be reduced from the values obtained in the preliminary analyses presented in this report.

6.2 HDPE Low Permeability Component Cases without a Geodrain below the Subsoil and HDPE Cases with a Geodrain with Non-woven Outer Components below the Subsoil

The overall results for HDPE low permeability component cases without a geodrain below the subsoil and for HDPE Cases with a geodrain with non-woven outer components below the subsoil are the same. This is because in the first category, the protection layer above the HDPE is a non-woven geotextile which has the same interface properties as those of a geodrain with non-woven outer components.

The overall results of the analyses for the suitability of each option covered in this section are shown below in Table 9. However, firstly some general comments are made.

1 in 3 slopes

For all 1 in 3 waste slope capping system cases, with or without the provision of geodrain with non-woven geotextile face elements below the subsoil layer, a stable design can be achieved without the provision of geogrid reinforcement.

1 in 2.5 slopes

In all cases for the results reported in this section for the 1 in 2.5 slopes of 6.7m inter-bench height, the case with 1.0m restoration soil cover is more stable than the case with 0.5m restoration soil cover. This is because in these particular cases the increased mass of the restoration soils has a beneficial effect in the mobilisation of interface friction for the sand regulating layer and waste and for the restoration soils and the non-woven geotextile. A similar situation applies for the 1 in 2.5 slopes of 20m height, with the “best parameters” applying.

1 in 2 slopes

No practical, conventional solution can be developed for 1 in 2 multilayer capping system slopes based on the presently examined cases and presently applied soil material parameters, interface friction and adhesion parameters, together with the provision of geogrid reinforcement. If 1 in 2 slopes prove necessary for the perimeter waste slopes, special, non-standard multilayer capping approaches (which would not be acceptable for the design of a new landfill) may be capable of achieving a configuration which would be stable, but that is beyond the scope of this present study.

Material Parameters	Total restoration soil thickness m	Inter bench Slope Height m	Gradient	Without Geogrid	Geogrid Capacity if required and feasible kN/m (ultimate)
"Best"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	✓	—
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	105
			1 in 2	x	x
	1.0	6.7	1 in 3	✓	—
			1 in 2.5	✓	—
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	x
			1 in 2	x	x
"Typical"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	x	65
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	x
			1 in 2	x	x
	1.0	6.7	1 in 3	✓	—
			1 in 2.5	x	25
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	x
			1 in 2	x	x

Symbols:- ✓ case feasible without geogrid. — geogrid not required. x no practical, conventional solution can be developed

Table 9: Results of Analyses for HDPE Cases without a Geodrain and for HDPE Cases with a Geodrain with Non-Woven Outer Components

6.3 HDPE Low Permeability Component Cases with a Geodrain with Woven Outer Components below the Subsoil

The overall results of the analyses for the suitability of each option in the classes covered in this section are shown below in Table 10. However, firstly some general comments are made regarding 1 in 2 slopes.

1 in 2 slopes

No practical, conventional solution can be developed for 1 in 2 multilayer capping system slopes based on the presently examined cases and presently applied soil material parameters and interface friction and adhesion parameters together with the provision of geogrid reinforcement. If 1 in 2 slopes prove necessary for the perimeter waste slopes, special, non-standard multilayer capping approaches (which would not be acceptable for the design of a new landfill) may be capable of achieving a configuration which would be stable, but that is beyond the scope of this present study.

Material Parameters	Total restoration soil thickness m	Inter bench Slope Height m	Gradient	Without Geogrid	Geogrid Capacity if required and feasible kN/m (ultimate)
"Best"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	✓	—
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	44
			1 in 2	x	x
	1.0	6.7	1 in 3	x	5
			1 in 2.5	x	100
			1 in 2	x	x
		20	1 in 3	x	205
			1 in 2.5	x	x
			1 in 2	x	x
"Typical"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	x	85
			1 in 2	x	x
		20	1 in 3	x	60
			1 in 2.5	x	460
			1 in 2	x	x
	1.0	6.7	1 in 3	✓	—
			1 in 2.5	x	205
			1 in 2	x	x
		20	1 in 3	x	605
			1 in 2.5	x	x
			1 in 2	x	x

Symbols:- ✓ case feasible without geogrid. — geogrid not required. x no practical, conventional solution can be developed

Table 10: Results of Analyses for HDPE Cases with a Geodrain with Woven Outer Components

6.4 Single-textured GCL Low Permeability Component Cases without a Geodrain below the Subsoil and Single-textured GCL Cases with a Geodrain with Non-woven Outer Components below the Subsoil

The overall results are the same for single-textured GCL low permeability component cases without a geodrain below the subsoil and for single-textured GCL Cases with a geodrain with non-woven outer components below the subsoil. This is because in the first category, the protection layer above the GCL is a non-woven geotextile which has the same interface properties as those of a geodrain with non-woven outer components.

For all single-textured GCL capping system cases which require geogrid reinforcement, the “special case” which applies to the construction stage 1.2 factors of safety and to the potential for hydrated bentonite to pass out of the host material, as described above in Section 6.1, is relevant.

The overall results of the analyses for the suitability of each option in the classes covered in this section are shown below in Table 11. However, firstly some general comments are made regarding 1 in 2 slopes.

1 in 2 slopes

No practical, conventional solution can be developed for 1 in 2 multilayer capping system slopes based on the presently examined cases and presently applied soil material parameters and interface friction and adhesion parameters together with the provision of geogrid reinforcement. If 1 in 2 slopes prove necessary for the perimeter waste slopes, special, non-standard multilayer capping approaches (which would not be acceptable for the design of a new landfill) may be capable of achieving a configuration which would be stable, but that is beyond the scope of this present study.

Material Parameters	Total restoration soil thickness m	Inter bench Slope Height m	Gradient	Without Geogrid	Geogrid Capacity if required and feasible kN/m (ultimate)
"Best"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	x	35
			1 in 2	x	x
		20	1 in 3	✓	—
			1 in 2.5	x	275
			1 in 2	x	x
	1.0	6.7	1 in 3	x	40
			1 in 2.5	x	130
			1 in 2	x	x
		20	1 in 3	x	325
			1 in 2.5	x	x
			1 in 2	x	x
"Typical"	0.5	6.7	1 in 3	x	50
			1 in 2.5	x	180
			1 in 2	x	x
		20	1 in 3	x	200
			1 in 2.5	x	x
			1 in 2	x	x
	1.0	6.7	1 in 3	x	140
			1 in 2.5	x	290
			1 in 2	x	x
		20	1 in 3	x	635
			1 in 2.5	x	x
			1 in 2	x	x

Symbols:- ✓ case feasible without geogrid. — geogrid not required. x no practical, conventional solution can be developed

Table 11: Results of Analyses for Single-Textured GCL Cases without a Geodrain and for Single-Textured GCL cases with a Geodrain with Non-Woven Outer Components

6.5 Single-textured GCL Low Permeability Component Cases with a Geodrain with Woven Outer Components below the Subsoil

For all single-textured GCL capping system cases which require geogrid reinforcement, the "special case" which applies to the construction stage 1.2 factors of safety and to the potential for hydrated bentonite to pass out of the host material, as described above in Section 6.1, is relevant.

The overall results of the analyses for the suitability of each option in the classes covered in this section are shown below in Table 12. However, firstly some general comments are made regarding 1 in 2 slopes.

1 in 2 slopes

No practical, conventional solution can be developed for 1 in 2 multilayer capping system slopes based on the presently examined cases and presently applied soil material parameters and interface friction and adhesion parameters together with the provision of geogrid reinforcement. If 1 in 2 slopes prove necessary for the perimeter waste slopes, special, non-standard multilayer capping approaches (which would not be acceptable for the design of a new landfill) may be capable of achieving a configuration which would be stable, but that is beyond the scope of this present study.

Material Parameters	Total restoration soil thickness m	Inter bench Slope Height m	Gradient	Without Geogrid	Geogrid Capacity if required and feasible kN/m (ultimate)
"Best"	0.5	6.7	1 in 3	✓	—
			1 in 2.5	X	35
			1 in 2	X	x
		20	1 in 3	✓	—
			1 in 2.5	X	225
			1 in 2	X	x
	1.0	6.7	1 in 3	X	40
			1 in 2.5	X	130
			1 in 2	X	x
		20	1 in 3	X	325
			1 in 2.5	X	x
			1 in 2	X	x
"Typical"	0.5	6.7	1 in 3	X	50
			1 in 2.5	X	150
			1 in 2	X	x
		20	1 in 3	X	200
			1 in 2.5	X	x
			1 in 2	X	x
	1.0	6.7	1 in 3	X	140
			1 in 2.5	X	265
			1 in 2	X	x
		20	1 in 3	X	635
			1 in 2.5	X	x
			1 in 2	X	x

Symbols:- ✓ case feasible without geogrid. — geogrid not required. x no practical, conventional solution can be developed

Table 12: Results of Analyses for Single-Textured GCL Cases with Geodrain with Woven Outer Components

7. Presently Selected Preferred Design for the Multilayer Capping System

7.1 Background

It should be noted that the "presently selected preferred design for the multilayer capping system" is that for the capping system on the 1 in 2.5 gradient Zone 1 northern perimeter waste slopes. A modified design in terms of some of the capping system elements can be applied to sloping capping systems of 1 in 3 gradient or shallower, subject to final detail design following the receipt and interpretation of the additional GI data. This matter is addressed briefly at the end of Section 7.2.

A range of configurations and materials were considered for the initial generic analytical design of the multilayer capping system for the northern perimeter waste slopes. These covered the alternative use of GCL and HDPE for the low permeability element in the capping system. Total restoration soil thicknesses of 0.5m and 1.0m were analysed for all cases. Cases analysed included 1 in 2.5 gradient slopes of 20m height without any intermediate benches.

7.2 The Preferred Configuration

Subsequent to the generic analytical design process covering the numerous, potentially viable multilayer lining system generic configurations and based on subsequent technical discussions, a "preferred" configuration for the multilayer capping system was confirmed. This comprised 1 in 2.5 gradient slopes of 20m height without any intermediate benches, with a double textured, HDPE FML as the low permeability element of the capping system. A geo-composite drainage layer be provided and will also act as the HDPE FML protection layer. The total restoration soil thickness was the 0.5mm. This is made up of 350mm of subsoil and 150mm of topsoil. This is one of the generic designs examined in the earlier part of this study.

To achieve an adequate factor of safety four requirements must be addressed:-

1. Careful selection must be carried out of the materials for use in the multilayer capping system to obtain materials with better than average internal friction, interface adhesion and interface friction values. It is possible that materials and interfaces with "average" values could be used but the heavy geogrid reinforcement would be needed, which may be impractical to install on the 1 in 2.5 slopes. One potential option to accommodate the need for high capacity geogrid would be to provide two layers of geogrid to achieve the same tensile resistance. However, with subsoil thickness being only 350mm, this may make successful placement of the subsoils and geogrid a complex process on 1 in 2.5 gradient slopes.

2. To achieve an adequate factor of safety of 1.3 for this multilayer lining system design, it would be necessary to incorporate geogrid reinforcement within the subsoil layer. This would need to have an ultimate tensile capacity of 105kN/m to ensure the 2% strain limited value would be sufficient.

3. As normal good practice and to ensure that item1 above is correctly addressed, later it will be necessary to undertake laboratory testing to determine:

    a. the material properties of the mineral regulating layer and proposed restoration soils, together with; and

    b. large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen components of the multilayer capping system.

4. Following completion of the testing described above in item 3, the detail analytical design will require re-running to demonstrate acceptability.

As mentioned previously, for geogrid anchorage, it is proposed that the geogrid in the 1 in 2.5 gradient capping system will be anchored by continuing back through the capping system of the shallower slopes for a few metres behind the crest of the steep slopes. This will be one of the subjects of design analyses at the detail design stage.

Based on the results of present design analyses, for all 1 in 3 gradient waste slope capping system cases, with or without the provision of geodrain with non-woven geotextile face elements below the subsoil layer, a stable design can be achieved without the provision of geogrid reinforcement. However, this will be a subject of further design analyses at the detail design stage.

For the multilayer capping systems provided for slopes of less than 1 in 3 gradient, it is likely that the specification of the sand regulating layer and of the subsoil layer can be reduced in terms of the angle of internal friction required. Similarly some relaxation in the specified values for the interface adhesion and friction values for some interfaces could be accommodated. That would enable the use of lapped, linear low density polyethylene (LLDPE) FML in place of HDPE FML at some gradients shallower than 1 in 3. This could bring cost and construction time savings to the project. These matters will be the subject of further design analyses at the detail design stage.

8. Waste Slope Stability

8.1 Introduction to assessment of waste slope stability

Overall waste mass stability is rarely an issue in waste slopes of modest gradient in a correctly designed and permitted landfill. However, for steep, high perimeter slopes of a land-raise landfill that are expected to have been placed in an uncontrolled manner, overall waste mass stability should be analysed, as it is likely that the slopes were never the subject of analytical design. Therefore, in anticipation of construction works, overall waste mass stability analyses for the proposed, trimmed steep perimeter slopes has been undertaken. In addition, as indicated above, waste slope stability analyses have been completed for waste placement in lined Zone 3 and for temporary waste slopes which may be formed during the earthworks phase of the proposed remediation works.

This waste slope stability work has been undertaken in advance of completion of the additional GI for the site, thus review and checking of the analyses will be necessary following receipt and interpretation of the GI data. In this regard it should be noted that all evidence presently points to there being no greater than very shallow leachate levels in the waste and no obvious perched leachate levels. Typically, the toes of the relevant waste slopes are a few metres above the base of the waste, at the floor level of previous mineral extraction operations. Due to this, the present studies have not considered the presence of leachate but this situation will be revisited following receipt and interpretation of the GI data.

8.2 Northern Perimeter Waste Slope Stability

It should be noted that the present steep waste slopes on the northern boundary approach a gradient of 1 in 2 and have remained generally stable to date. In the remediation works these will be trimmed to a shallower gradient of 1 in 2.5. These slopes will be capped with a multilayer capping system, presently anticipated to be in the form of the presently preferred design described in Section 7.

Slope stability analyses compliant with Eurocode 7, Design Approach 1 and Combination 2 for the application of partial factors of safety, have been completed for the wastes slopes in their 1 in 2.5 face slope configuration. For all analyses, the bulk unit weight assumed at this stage for the landfilled waste, which has a high inert content, was 18kN/m^3. The shear strength parameters applied in the analyses were based on the recommended design value from UK Environment Agency R&D Technical Report P1-385/TR2 "Stability of Landfill Lining Systems: Report No 2 Guidance", ISBN 1 85705 945, January 2003, but included a number of sensitivity analyses to model suitably, the nature of the waste landfilled at Kerdiffstown, based on currently available borehole logs.

The range shear strength parameters applied in the sensitivity analyses were in steps from effective cohesion c' = 5kPa and effective friction = 25° to effective cohesion c' = 0kPa and effective friction = 32°. The results demonstrated that stability was in compliance with the requirements of Eurocode 7. However, following receipt and interpretation of the additional GI data for the site, these analyses will be re-run.

8.3 Stability of Waste Placement in Lined Zone 3

If waste is placed adjacent to a sloping multilayer lining system in a landfill cell on a strip parallel to the lined face and to full face height there is considerable potential for instability to be caused in the lining system if the strip along which waste is placed is comparatively narrow.

Planar failure surfaces within the multilayer lining system have been examined for waste placed in a strip to the sloping lining system, in widths of 4m, 6m and 8m. For all analyses, the bulk unit weight assumed at this stage for the landfilled waste, which has a high inert content, was $18kN/m^3$.

The interface friction and adhesion values applied to the multilayer lining system interfaces for these analyses were as shown in Table 13.

Interface	Interface Friction Phi' degrees	Interface Adhesion kPa
Subgrade to geosynthetic clay lining (GCL)	26	0
GCL to smooth HDPE	18	0
GCL to textured surface of mono-textured HDPE	30	10
Smooth HDPE to geosynthetic drainage layer	19	0
Geosynthetic drainage layer to landfilled waste	24	0.5

Table 13:- Zone 3 Sloping Multilayer Lining System Interface Friction and Adhesion Values

From the analyses, it was found that failure of the sloping multilayer capping system could occur if waste were placed adjacent to the sloping lining system to full height, on a strip 4m wide. If waste were placed adjacent to the sloping lining system to full height, on a strip 6m wide marginal stability would be achieved. If waste were placed adjacent to the sloping lining system to full height, on a strip 8m wide adequate factors of safety would apply if the waste were left in this configuration in the long term.

However, for waste placement in a single cell of limited area as applies in Zone 3, the most reliable approach in terms of waste slope stability would be to place waste in turn in compacted layers of 1m thickness across the complete, available base of Zone 3.

8.4 Preliminary, Indicative Stability of Temporary, Cut Waste Slopes

As a preliminary indication of the stability of temporary slopes cut in waste as part of the earthworks stage of the reprofiling of the site, a selection of slope stability analyses were undertaken for a range of temporary wastes slope heights and gradients. These comprised 5m, 10m, 15m and 20m slope heights and cut slope gradients of 1 in 2 and 1 in 2.5.

For all analyses, the bulk unit weight assumed at this stage for the landfilled waste, which has a high inert content, was $18kN/m^3$. The shear strength parameters applied in the analyses were based on the recommended design value from Environment Agency R&D Technical Report P1-385/TR2 “Stability of Landfill Lining Systems: Report No 2 Guidance”, ISBN 1 85705 945 X, January 2003, but considerably adjusted in light of the nature of the waste landfilled at Kerdiffstown, based on currently available borehole logs. A conservative set of shear strength parameters were applied, namely effective cohesion, c' = 0.5kPa and effective friction = 25°.

On the basis that due to unforeseen circumstances, at any stage temporary cut slopes may be left in place for a number of weeks or months, a selection of slope stability analyses were undertaken compliant with Eurocode 7, Design Approach 1 and Combination 2 for the application of partial factors of safety, have been completed for the temporary wastes slopes. Hence, in these analyses, the temporary slopes were examined against factors of safety which should apply to permanent slopes.

The results demonstrated that for any slope height up to 20m for 1 in 2.5 gradient slopes, the temporary slopes would achieve an acceptable factor of safety to accommodate being left in place and unchanged in the longer term. Conversely, for any slope height for 1 in 2 gradient slopes, the temporary slopes would not achieve an acceptable factor of safety to accommodate being left in place and unchanged in the longer term.

For the set of shear strength parameters considered, 1 in 2 gradient slopes would be unsatisfactory as temporary slopes. At this stage, it has not been considered appropriate to consider further analyses in the form of sensitivity analyses, due to the number which would be require to give indicative results for various slope heights and gradients which could be considered for temporary slopes. However, if necessary, following the receipt and interpretation of the additional GI data for the site, these analyses can be re-run for a range of sets of shear strength parameters, slope heights and slope gradients.

9. Discussion

9.1 Approach to the Discussion of the Results

Although a presently preferred design option has been selected for the multilayer lining system, full discussion is presented first for the numerous potentially viable multilayer lining system configurations examined in the first stage of this study. This is because full understanding of the capping options is useful in case the results of the additional GI or the later testing to determine material specific for the components of the multilayer capping system or any other factors require the selection of a different design option. Discussion related to the presently preferred capping system is presented in subsequent text.

Discussion of waste slope stability follows that of the multilayer lining system options.

9.2 Multilayer Capping System Generic Design Option Study

Although it is intended that representative values for the design parameter values have been selected from published data, the material parameters and interface parameters are very dependent on the specific mineral materials and proprietary geosynthetic materials which will be finally chosen. Therefore, for completion of the final detail design, it will be necessary to undertake laboratory testing to determine the material properties of the mineral regulating layer and proposed restoration soils, together with large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen components of the multilayer lining system. This is likely to be most critical for cases which include a single-textured GCL and components with woven geotextile surfaces.

Based on the presently applied values for the design parameters, the generic analyses generally define what configurations of slope and capping system can be achieved for different soil materials, geosynthetic components, restoration soil thicknesses, slope angles and slope heights.

Safe design for the satisfactory performance of the multi-layer lining system must be based on the assumption that no geosynthetic component other than geogrid can accommodate tensile forces. Thus, where needed, geogrid reinforcement must be sized to take all the tensile forces identified in each multi-layer capping system design calculations. To ensure that any induced tensile forces are kept to an absolutely minimum, the geogrid reinforcement must limit strain movements induced in the capping system during construction activities and over the design life of the multi-layer capping system. This normally requires that the tensile strength of the necessary geogrid reinforcement is that of the 2% strain case. The tensile strength of geogrid reinforcement at 2% strain is approximately one fifth of the ultimate strength; the value of which usually forms part of the name of a particular geogrid.

No practical, conventional solution can be developed for 1 in 2 multilayer capping system slopes based on the presently examined cases and applied soil material parameters and interface friction and adhesion parameters together with the provision of geogrid reinforcement. If 1 in 2 slopes prove necessary for the perimeter waste slopes, special, non-standard multilayer capping approaches (which would not be acceptable for the design of a new landfill) may be capable of achieving a configuration which would be stable, but that is beyond the scope of this present study.

An alternative, should 1 in 2 perimeter slopes be required, would be to reduce inter-bench slope height by adding one or more benches, but this has the disadvantage of requiring greater volumes of excavation of the waste materials from the existing steep perimeter slopes. Thus, on this basis, adopting a lower slope gradient in the design is considered a more practical option.

If it were acceptable to restrict total restoration soil thicknesses to 0.5m and sloping cap construction materials and components could be selected and demonstrated by laboratory testing to achieve the "best parameters", a 1 in 2.5 slope without benches could be capped if the low permeability element were textured HDPE, appropriate geogrid reinforcement were provided and any geodrain installed beneath the restoration soils were of the type faced with non-woven geotextile. The same would be the case if a geodrain were not installed but the HDPE protection layer were non-woven geotextile.

The same situation applies for a case where double-textured HDPE is replaced with single-textured GCL, but geogrid with more than twice the tensile capacity of that needed for the double-textured HDPE case would be required.

For the case of a single-textured GCL combined with a geodrain faced with woven geotextile, with total restoration soil thickness of 0.5m and sloping cap construction materials and components achieving the "best parameters" values, a 1 in 2.5 slope without benches would be feasible with the provision of appropriate geogrid reinforcement which would not have to be very high tensile capacity. For this particular combination of materials and geosynthetic components, the necessary geogrid tensile strength is slightly less than the single-textured GCL case combined with a non-woven protection layer or a geodrain of the type faced with non-woven geotextile.

For the flatter waste slopes present above the steep perimeter slopes, any of the multi-layer capping systems examined in this study could be used. This is demonstrated by the results obtained from the analyses of 1 in 3 waste slopes.

With the provision of benches, a wider range of options are feasible for 1 in 3 and 1 in 2.5 slopes, however, the provision of benches compared with using planar slopes requires greater volumes of excavation of the waste materials from the existing steep perimeter slopes.

9.3 Discussion of the Preferred Multilayer Capping System Option

The presently "preferred" configuration for the multilayer capping system comprised 1 in 2.5 gradient slopes of 20m height without any intermediate benches, with a double textured, HDPE FML as the low permeability element of the capping system. A geo-composite drainage layer be provided and will also act as the HDPE FML protection layer. The total restoration soil thickness was the 0.5m. This is made up of 350mm of subsoil and 150mm of topsoil. This is one of the generic designs examined in the earlier part of this study.

In section 7.2, four issues have been identified which must be addressed at the final detail design stage to ensure an adequate factor of safety will be achieved. One important issue is the execution of material specific laboratory testing and another is the provision of geogrid reinforcement in the subsoil layer. A further important issue is careful selection the materials for use in the multilayer capping system to obtain materials with better than average internal friction, interface adhesion and interface friction values. However, it is possible that materials and interfaces with "average" values could be used but the heavy geogrid reinforcement would be needed, which may be impractical to install on the 1 in 2.5 slopes, nevertheless there is potential to increase geogrid reinforcement so some practical degree to overcome one or two material suitability problems, should they arise.

One potential option to accommodate the need for high capacity geogrid would be to provide two layers of geogrid to achieve the same tensile resistance as for a single layer. However, with subsoil thickness being only 350mm, this may make successful placement of the subsoils and geogrid a complex process on 1 in 2.5 gradient slopes.

9.4 Multilayer Capping Systems for Slope Gradients Shallower than 1 in 3

It should be noted that the "presently selected preferred design for the multilayer capping system" is that for the capping system on the 1 in 2.5 gradient northern perimeter waste slopes. A modified design in terms of some of the capping system elements can be applied to sloping capping systems of 1 in 3 gradient or shallower, subject to final detail design following the receipt and interpretation of the additional GI data.

For the multilayer capping systems provided for slope of less than 1 in 3 gradient, it is likely that the specification of the sand regulating layer and of the subsoil layer can be reduced in terms of the angle of internal friction required. Similarly some relaxation in the specified values for the interface adhesion and friction values for some interfaces could be accommodated. That would enable the use of lapped, linear low density polyethylene (LLDPE) FML in place of HDPE FML at some gradients shallower than 1 in 3. This could bring cost and construction time savings to the project. This will be one of the subjects of design analyses at the detail design stage.

9.5 Northern Perimeter Slopes Waste Stability

Slope stability analyses compliant with Eurocode 7, Design Approach 1 and Combination 2 for the application of partial factors of safety, have been completed for the wastes slopes in their 1 in 2.5 face slope configuration. A range shear strength parameters applied in the sensitivity analyses in steps from effective cohesion c' = 5kPa and effective friction = 25° to effective cohesion c' = 0kPa and effective friction = 32°. The results demonstrated that stability was in compliance with the requirements of Eurocode 7. However, following receipt and interpretation of the additional GI data for the site, these analyses will be re-run.

9.6 Stability of Waste Placement in Lined Zone 3

If waste is place adjacent to a sloping multilayer lining system in a landfill cell on strip parallel to the lined face and to full face height there is considerable potential for instability to be caused in the lining system if the strip along which waste is placed is comparatively narrow. Therefore, planar failure surfaces within the multilayer lining system have been examined for waste placed in a strip to the sloping lining system, in widths of 4m, 6m and 8m.

From the analyses, it was found that failure of the sloping multilayer lining system could occur if waste were placed adjacent to the sloping lining system to full height, on a strip 6m wide or less. However, for waste placement in a single cell of limited area as applies in Zone 3, the most reliable approach in terms of waste slope stability would be to place waste in turn in compacted layers of 1m thickness across the complete, available base of Zone 3.

9.7 Indicative Stability of Temporary, Cut Waste Slopes

On the basis that due to unforeseen circumstances, at any stage temporary cut slopes may be left in place for a number of weeks or months, a selection of slope stability analyses were undertaken compliant with Eurocode 7, Design Approach 1 and Combination 2 for the application of partial factors of safety, have been completed for the temporary wastes slopes. Hence, in these analyses, the temporary slopes were examined against factors of safety which should apply to permanent slopes.

The results demonstrated that for any slope height up to 20m for 1 in 2.5 gradient slopes, the temporary slopes would achieve an acceptable factor of safety to accommodate being left in place and unchanged in the longer term. Conversely, for any slope height for 1 in 2 gradient slopes, the temporary slopes would not achieve an acceptable factor of safety to accommodate being left in place and unchanged in the longer term.

For the set of shear strength parameters considered, 1 in 2 slopes would be unsatisfactory as temporary slopes. At this stage, it has not been considered appropriate to consider further analyses in the form of sensitivity analyses, due to the number which would be require to give indicative results for various slope heights and gradients which could be considered for temporary slopes. However, if necessary, following the receipt and interpretation of the additional GI data for the site, these analyses can be re-run for a range of sets of shear strength parameters, slope heights and slope gradients.

10. Conclusions

10.1 Multi-layer Capping System

1. The conclusions regarding sloping multi-layer capping design are based on the presently applied values for the design parameter, which are considered representative in advance the receipt and interpretation

of additional GI data and in advance of the laboratory testing which should be undertaken at the detail design stage. The present analyses should be re-run following receipt and interpretation of the additional GI data and on receipt of the laboratory testing which should be undertaken at the detail design stage.

2. Based on the generic analytical design process covering the numerous, potentially viable multilayer lining system generic configurations, and based on subsequent technical discussions, a "preferred" configuration for the multilayer capping system was confirmed. This comprised 1 in 2.5 gradient slopes of 20m height without any intermediate benches, with a double textured, HDPE FML as the low permeability element of the capping system. A geo-composite drainage layer be provided and will also act as the HDPE FML protection layer. The total restoration soil thickness was the 0.5mm. This is made up of 350mm of subsoil and 150mm of topsoil. This is one of the generic designs examined in the earlier part of this study.

3. To achieve an adequate factor of safety four requirements must be addressed:

   a. Careful selection must be carried out of the materials for use in the multilayer capping system to obtain materials with better than average internal friction, interface adhesion and interface friction values. It is possible that materials and interfaces with "average" values could be used but the heavy geogrid reinforcement would be needed, which may be impractical to install on the 1 in 2.5 slopes. One potential option to accommodate the need for high capacity geogrid would be to provide two layers of geogrid to achieve the same tensile resistance. However, with subsoil thickness being only 350mm, this may make successful placement of the subsoils and geogrid a complex process on 1 in 2.5 gradient slopes.

   b. To achieve an adequate factor of safety of 1.3 for this multilayer lining system design, it would be necessary to incorporate geogrid reinforcement within the subsoil layer. This would need to have an ultimate tensile capacity of 105kN/m to ensure the 2% strain limited value would be sufficient.

   c. As normal good practice and to ensure that item1 above is correctly addressed, later it will be necessary to undertake laboratory testing to determine:

      i. the material properties of the mineral regulating layer and proposed restoration soils, together with

      ii. large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen components of the multilayer capping system.

4. The geogrid in the 1 in 2.5 gradient capping system should be anchored by continuing back through the capping system of the shallower slopes for a few metres behind the crest of the steep slopes. This should be a subject of design analyses at the detail design stage.

5. For all 1 in 3 gradient waste slope capping system cases, with or without the provision of geodrain with non-woven geotextile face elements below the subsoil layer, a stable design can be achieved without the provision of geogrid reinforcement. However, this should be a subject of further design analyses at the detail design stage.

6. For the multilayer capping systems provided for slope of less than 1 in 3 gradient, it is likely that the specification of the sand regulating layer and of the subsoil layer can be reduced in terms of the angle of internal friction required. Similarly some relaxation in the specified values for the interface adhesion and friction values for some interfaces could be accommodated. That would enable the use of lapped, linear low density polyethylene (LLDPE) FML in place of HDPE FML at some gradients shallower than 1 in 3. This could bring cost and construction time savings to the project. This should be one of the subjects of design analyses at the detail design stage.

10.2 Waste Slope Stability

1. Present analyses of the stability of the northern perimeter waste slopes demonstrate that stability was in compliance with the requirements of Eurocode 7. However, following receipt and interpretation of the additional GI data for the site, these analyses should be re-run.

2. From the stability, it is found that failure of the sloping multilayer lining system of Zone 3 could occur if waste were placed adjacent to the sloping lining system to full height, on a strip 6m wide or less. However, for waste placement in a single cell of limited area as applies in Zone 3, the most reliable approach in terms of waste slope stability would be to place waste in turn in compacted layers of 1m thickness across the complete, available base of Zone 3. This approach should be adopted

11. Recommendations

1. The present analyses for multilayer capping system design and waste slope stability analysis should be re-run following receipt and interpretation of the additional GI data and on receipt of the laboratory testing which should be undertaken at the detail design stage.

2. For final, detail design of the sloping multilayer capping system, laboratory testing should be undertaken to determine the material properties of the mineral regulating layer and proposed restoration soils, together with large shear box testing to confirm the interface friction and adhesion properties for each interface between the chosen, proprietary components of the multilayer lining system.

3. A preliminary, indicative study of the stability of temporary, cut waste slopes has been undertaken in this stage of work and the results discussed. However, if necessary, following the receipt and interpretation of the additional GI data for the site, consideration should be given to rerunning these analyses for an appropriately extended range of sets of shear strength parameters, slope heights and slope gradients.

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Appendix A4.4 Leachate Management Plan

Kerdiffstown Landfill Remediation Project (KLRP)

Kildare County Council (KCC)

Leachate Management Plan

32EW5604/DOC/0041 | 2

30 June 2017

Kerdiffstown Landfill Remediation Project (KLRP)

Project No:	32EW5604
Document Title:	Leachate Management Plan
Document No.:	32EW5604/DOC/0041
Revision:	2
Date:	30 June 2017
Client Name:	Kildare County Council (KCC)
Client No:	
Project Manager:	Rhianna Rose
Author:	Nataliya Dimova
File Name:	\\Iedub1-fil001\ji\Sustainable Solutions\Kerdiffstown Landfill\4 - Documents\4.3 - Draft Documents\32EW5604 L Additional Design Work\3 Leachate\KLRP_LMP Rev 2.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
0	13/12/16	Preliminary	HS	CD	RR
1	09/03/17	Minor Amendments	ND	CD	RR
2	30/06/2017	Final EIAR Issue	UD	SS	RR

Contents

1. Introduction

1.1 Background

The site of the proposed Project, is located in County Kildare, approximately 3km north-east of central Naas, approximately 400m north-west of Johnstown village and in close proximity to the strategically important M7/N7 corridor. The site is located in close proximity to a number of residential and commercial receptors as well as being a short distance away from the larger settlements of Johnstown and Naas. In addition to the above, the site neighbours a number of recreational land uses, specifically Palmerstown House Estate and Naas Golf Course to the north-east and north-west respectively.

Kerdiffstown Landfill occupies approximately 30 hectares near Johnstown Village and is a former sand and gravel quarry which was progressively backfilled by a number of operators from the 1950s onwards. In January 2011 a major fire developed in a mound of waste material in the northern part of the site. This required intervention of a number of state agencies including Kildare County Council and the Environmental Protection Agency (EPA). The site was under the control of Kildare Fire Service until late February 2011, when it was handed over to the care of the EPA. Since 2011, measures have been taken to secure the site and limit environmental impact.

In April 2015 the Minister for the Environment, Community and Local Government, Alan Kelly TD, announced that funding would be made available for the remediation of the landfill site, and that Kildare County Council would take control of the site and commence remediation.

The objective in remediating the site in terms of leachate management is to:

- Take all necessary and reasonable measures to prevent and limit future leachate impact upon groundwater and surface water receptors and reduce/control the future production of leachate from the site; and
- Reduce contaminant loads discharging to groundwater.

Linked to the overarching objectives of the project is the aim to provide a future landform and end use appropriate for the site and of potential benefit to the local community. To that end, the intended end-use for the site is public access parkland and recreational use.

1.2 Aims and Objectives

This Leachate Management Plan has been prepared in support of a planning application and industrial emissions licence for the remediation and operational (end-use) phases, outlined as follows:

- *Development / Remediation* – The works required to re-profile the site including excavation of waste and other materials for deposition on site to achieve the proposed final landform. The works will also include the installation of landfill infrastructure such as capping, landfill gas, leachate and surface water management. A second stage of remediation will comprise the works required to restore the site to the proposed park end use, including planting and landscaping, installation of sports pitches, changing rooms, car parks and associated services.
- *Operational / Aftercare* – The life cycle stage of the site following the remediation works when the site will be used for public access parkland and recreation. The responsibility for the management of the site and the landfill infrastructure systems as well as park operation and maintenance will be retained by Kildare County Council (KCC).

At all stages the aim of the management plan is to:

- Ensure the site is compliant with relevant regulations and best practice at all stages (during development / remediation and operation / aftercare);
- Ensure that the management plan is based on the current site operations and development, data arising from the site and foreseen future proposals for changes to the site;

- Ensure safety of site operatives and contractors working on site;
- Limit future leachate impact on groundwater and surface water receptors;
- Be sufficiently flexible to control leachate throughout different phases of the remediation works;
- Integrate with landfill gas management and other environmental control systems;
- Be compatible with final restoration and after-use of the site; and
- Reduce potential environmental impact of the site throughout its whole life.

Section 2 of Annex 1 of the 1999 EU Landfill Directive outlines leachate control requirements which are applicable for all classes of landfill sites. The specific requirements with regards to leachate management are:

- Control water from precipitations entering into the landfill body;
- Collect contaminated water and leachate; and
- Treat contaminated water and leachate collected from the landfill to the appropriate standard required for discharge.

This Directive was transposed into Irish law by the Waste Management Licensing Regulations 2004 (S.I. 395 of 2004) and the Waste Management Act 1996 (as amended). The development of the site, comprising remediation works, takes cognisance of the Directive as far as reasonably practicable, whilst applying Best Available Techniques (BAT) where appropriate.

Relevant guidance and best practice documents referred to in the development of this management plan are provided in Appendix A.

1.3 Roles and Responsibilities

This management plan is a live document where site use and operations, monitoring and performance data informs regular updates to the proposals and procedures within the document in order to mitigate the risks posed by leachate. The following provides definition of some of the terms used within the management plan:

- *Operator* – Kildare County Council, who hold responsibility and liability for the operation and maintenance of the leachate management system;
- *Site Manager* – the individual representing the Operator on site during the remediation works and operation of the park/ aftercare of the site; and
- *Designated Representative* – the entity or individual appointed by the Operator to undertake management of the leachate system for a defined phase of its lifecycle.

The Operator will have full responsibility to ensure that leachate is properly managed on site in accordance with relevant regulations, guidance and best practice at all times and that all activities are fully documented in the Site File.

2. Leachate Properties

2.1 General

Landfill leachate is a liquid which forms when water passes through degrading waste dissolving environmentally harmful substances which may then enter the environment, migrating away from the waste mass into groundwater or surface water courses, in doing so causing pollution to water resources.

The main components of concern with respect to water contamination are ammonia (directly toxic to fish and other aquatic life), dissolved organic material (mainly organic acids) which give rise to high demands for oxygen (chemical oxygen demand (COD) and biological oxygen demand (BOD)) which can deoxygenate waters (leading to fish kills) and chloride (which increases salinity of water and changes ecological make-up). Leachate also contains other components such as dissolved metals including iron, which causes the characteristic brown colour associated with leachate seepages.

Given these potential impacts on water quality and ecology leachate must be managed. Preferably, it should be prevented from entering water. Where prevention of leachate ingress is not possible, pollution impacts must be reduced to an acceptable level; this level of acceptance being determined through risk assessment and modelling of the site for agreement with the environmental regulator.

2.2 Leachate Parameters

2.2.1 Leachate Volumes

It is difficult to conduct an accurate estimation of future leachate generation from the site since many of the waste deposits have been placed, excavated, processed and the non-recyclable fraction replaced within the landfill, and there were few records of what wastes were placed during operation and how they were placed. In some areas non-processed aged wastes are present.

Ground investigation data shows localised pockets of free leachate are present but much of the waste is not yet saturated. Without any remedial intervention, rainfall will continue to infiltrate wastes. Wastes will absorb rainfall and free leachate will be produced more extensively once the absorptive capacity of the waste mass has been reached.

The bulk of the wastes in uncapped and unlined areas of the site are present in Zone 1 in the north western corner of the site and it is likely that absorptive capacity will be reached across much of this area of the site in a similar time frame, giving rise to a sudden increase in leachate production and migration from the site if no control measures are put in place.

Further assessment of water balance calculations is discussed in Section 3.

2.2.2 Leachate Quality

The leachate from Zone 3 (lined cell) has been subject to weekly monitoring since 2012 as a quality control measure in connection with permit conditions at Ringsend WwTW. These data give a very good representation of the component concentrations, although the cell was open to rainwater infiltration hence the leachate is dilute.

Leachate generated following capping of the lined cell is expected to be typical of municipal waste landfill leachate. Monitoring of leachate will continue during the remediation works and aftercare phase as outlined in Section 4.

3. Risk Assessment

The effect of leachate generation on groundwater has been assessed as part of Detailed Quantitative Risk Assessments (DQRAs) undertaken for each zone at the site.

Model input data used in the development of the DQRA is outlined in Table 3.1 below for the unlined and uncapped zones (1, 2A, 2B and 4). Modelled areas take account of remediated waste extents and allowance for hardstanding areas, though being retained in the remediation works.

Zone	Modelled area (m^2)	Estimated recharge rate (mm/a)		Estimated leachate generation (m^3/year)	
		Uncapped	**Capped**	**Uncapped**	**Capped**
1	90,000	350	41	31,500	3,690
2A	36,000	350	59	6,300	1,062
2B	30,000	350	59	10,500	1,770
4	60,000	350	59	21,000	3,540

Table 3.1 : Estimate of Leachate Generation Rates

Zone 3 has a temporary cap installed presently, thus rainfall is already separated from the waste mass. Only temporary ‘opening’ of the waste mass will be undertaken to permit emplacement of materials from other zones. A fully engineered capping system will be installed following completion of waste infilling. Presently Zone 3 (lined cell) has a leachate drainage, collection and management system installed as outlined in Section 4.1. The DQRA and estimated leachate generation rates indicate that continuation and expansion of the leachate management system is required in order to control leachate generated within the site.

4. Leachate Generation

4.1 Current Control and Management Measures

4.1.1 Zone Characteristics

Leachate will be generated at Kerdiffstown Landfill, although various characteristics allow some distinctions to be drawn between zones of the site, as outlined in Table 4.1 below.

Zone	Estimated (plan) Area	Estimated Waste Volume		Basal & Side Lining	Cap Status	Other
1	100,000m^2	2,023,000m^3	(66%)	Unlined	None	-
2A & 2B	83,000m^2	660,000m^3	(21%	Unlined	25,000m^2 uncapped	58,000m^2 concrete hardstanding
3	24,000m^2	179,000m^3	(6%)	Lined	Temporary cap	-
4	45,000m^2	227,000m^3	(7%)	Unlined	33,000m^2 uncapped	12,000m^2 concrete hardstanding

Table 4.1 : Zone Characteristics

There is no formal capping of waste in Zones 1, 2 and 4 at present although much of the waste is partially covered by a dressing of daily cover, used by the former operator to suppress odours, which largely comprises woodchips that have composted to a rudimentary soil which has formed a thin crust and which supports self-sown vegetation. This vegetative cover currently provides some interception and evapo-transpiration of rainfall.

Zone 3 comprises a lined cell constructed with a composite lining system designed in accordance with the EPA Landfill Site Design Manual. The lining system is an effective low permeability barrier to prevent the downward migration of leachate into groundwater. The cell also has a temporary, geomembrane cap applied over the waste mass to reduce leachate generation.

4.1.2 Infrastructure

Leachate is collected in Zone 3 via a granular drainage layer overlying the basal liner. Leachate is directed through the granular drainage layer to two inclined risers in the cell; one in the north-west corner and one in the south-west corner. These risers are used to monitor leachate levels and extract leachate to two tanks located adjacent to the lined cell, for collection by road tanker. Leachate is currently removed from the site for disposal to Ringsend WWTP. A target pad has also been constructed within the lined cell to assist retro-drilling in the future should this be required due to failure of an inclined riser.

A leachate monitoring well (BH39B) was installed in Zone 1 during August 2012. This well extends to around 15m depth within the existing waste mass. Leachate was detected during installation, however, monitoring data recorded since has shown this well to be dry.

As can be seen in Table 4.1 the majority of wastes are located in the north-western area of the site (Zone 1), which has generally remained open to rainwater infiltration. As the site was developed for waste processing and related activities other areas of the site (Zones 2 and 4) were progressively surfaced by concrete hardstandings. The hardstandings divert rainwater from the underlying wastes thus reducing the potential for leachate generation.

4.1.3 Risk to Groundwater

Leachate from all areas of the site, other than the lined cell in Zone 3, currently continues to infiltrate into the ground and groundwater, hence current and long term groundwater quality is considered to be at risk from wastes at the site due to the following factors:

- The majority of the landfill is unlined and therefore there is no engineered barrier across much of the site to prevent discharge of leachate to groundwater;
- The unsaturated zone (where it exists) between the base of the wastes and the local water table is relatively thin and there is therefore little attenuation capacity; and
- The landfill is currently not capped, which will mean that in its current state leachate will continue to be generated, especially after the main waste mass reaches full saturation (referred to as field capacity).

As identified in Section 1 the current leachate management measures do not meet the current project objectives. Remediation works will be undertaken to prevent and limit future leachate impact upon groundwater and surface water receptors and reduce/control the future production of leachate from the site.

4.2 Future Control and Management Measures

4.2.1 Remediation Works

Remediation works are to be undertaken at the site in phases, over a period likely to be in the order of four years duration. During this period, there will be excavation and movement of some wastes to achieve the agreed planning landform. At this stage high level construction phasing plans have been developed for achieving the remediation of the site and as such only outline leachate management proposals have been developed for this, as the scope and the phasing may change.

To instigate capping works site clearance would be required involving the removal of existing vegetation. Earthmoving will remove the crust of cover material that promotes some degree of surface run-off and will disturb the underlying waste. Rainfall during the construction period may infiltrate and be absorbed by the waste unless the waste has already reached saturation, in which case seepages of leachate would be expected and would require on site management. The responsibility for remediating leachate outbreaks, via stone collection trenches, would be assigned to the contractor undertaking the remediation works.

Depending on the sequence of earthmoving, the geometry of cut faces and the methods used by the contractor there could potentially be a stream of relatively high volume, slightly contaminated, surface water and leachate break-outs to be impounded and treated. The volumes and quality of this source cannot be determined at this stage. As is normal practice for construction works the contract for the remediation works will include on-site management pollution control measures to be implemented by the contractor, for agreement by the Operator as key stakeholder in determining the options for site management and disposal routes. Discharge of run-off will not be permitted from the site during construction works, with ponds lined with geomembrane liner to offer additional protection to groundwater during this period.

Each phase and stage of remedial works will require the contractor appointed to undertake the remediation works to produce a detailed method statement of working which will include assessment of potential environmental, health and safety risks and details of measures to mitigate risks from leachate. Mitigation measures will need to fulfil the following interconnected objectives:

- Reduce likelihood of increased lateral off-site migration of landfill gas;
- Control gas emissions to air (and hence odours);
- Minimise dust emissions from the site;
- Reduce potential to contaminate surface water run-off with leachate and suspended solids; and
- Minimise attraction of insects such as flies and scavenging birds to the site.

The generation of leachate will be managed during the remediation stage through a number of on-site management operations, including:

- Operation in discrete areas to minimise the area of exposed waste;
- Interception of leachate outbreaks, identified during waste excavation and reprofiling activities;
- Provide daily cover to exposed wastes, occurring as part of the remediation works; and
- Progressively restore the site with a landfill cap.

In broad terms the remediation works sequence and associated outline leachate management approach will be:

Phase of Works	Leachate Management Proposals
Prior to remediation works.	• Target pad constructed within Zone 3 to allow future retro-drilling should inclined riser fail. • On-going leachate monitoring of Zone 3 and Zone 1. Perimeter groundwater monitoring data to be collated and used as baseline for detection of migration and increased risk e.g. determination of trends. • Continued extraction of leachate from Zone 3.
Works to site entrance and access area, including construction of new landfill infrastructure compound.	• On-going leachate monitoring of Zone 3 and Zone 1. • Continue perimeter monitoring of groundwater boreholes at agreed frequency to identify any changes in groundwater quality. • Inclined risers within Zone 3 to be maintained in operation during filling of Zone 3, and leachate discharged through existing process. • Building to house new leachate pumps, treatment system and control panels, storage tank and containment system constructed within new landfill infrastructure compound. • Leachate rising main and connection to public sewer network, via Johnstown Pumping Station, constructed.
Remediation of slopes in Zone 4, including the removal of wastes. Clean materials to be stockpiled on Zones 2A and 2B for re-use within Zone 4 or elsewhere on site. Waste materials to be disposed of within Zone 3 or Zone 1.	• Reprofiling of slopes to safe profile, including removal of identified wastes as far as reasonably practicable. • Regrading of existing wastes in Zones 1 and 3 to achieve a domed restoration profile. • Inspection of reprofiling works to identify any indications of leachate presence. • Placement of low permeability soils to Zone 4. • Remedial works to inclined riser pump chambers. • Inclined risers within Zone 3 to be maintained in operation during filling of Zone 3, and leachate discharged through new system to Johnstown Wastewater Pumping Station (WwPS).
Capping of Zone 3.	• Inclined risers within Zone 3 to be maintained in operation during filling of Zone 3, and leachate discharged through new system to Johnstown Pumping Station. • Construct leachate recirculation system in lined cell. • Install permanent capping system (geosynthetic) in Zone 3. • Place cover soils and vegetation over capping system.

Phase of Works	Leachate Management Proposals
Progressive capping of Zones 2A and 2B beyond extents of concrete slabs.	• Retention of the concrete yard slabs. • Inspection of reprofiling works to identify any indications of leachate presence. • Placement of low permeability capping layer (soils) on areas outwith concrete slabs. • Place cover soils and vegetation over capping system. • Locate drainage systems from concrete slabs and direct to surface water system (with intermediate controls, e.g. silt trap).
Re-grading wastes in Zone 1 to achieve proposed landform.	• Inspection of reprofiling works to identify any indications of leachate presence. • Increased monitoring frequency for all boreholes along western perimeter, increase monitoring of boreholes to the northern border in the direction of Kerdiffstown House. • Capping system (geosynthetic) to be installed in phases, requiring the corresponding phased decommissioning of currently installed leachate well to permit cap system installation. • Place cover soils and vegetation over capping system. • Adoption of leachate monitoring wells to follow as soon as practicable in phases. • Leachate level monitoring to be commenced in new wells. • Install leachate extraction pumps and pipework to connect to landfill infrastructure compound. • Where leachate presence is confirmed, removal to leachate management system to be enacted.
Final site works – installation of park infrastructure and planting.	• Site enters Aftercare Phase for leachate management and monitoring.

Table 4.2 : Leachate Management Proposals

4.2.2 Post Completion

The proposed strategy for leachate management at Kerdiffstown is a combination of leachate containment in Zone 3, accompanied by removal for above-ground treatment and disposal, and controlled extraction from the base of Zone 1 when confirmed / required.

The main change in leachate composition is likely to be realised from Zone 3. Raw leachate following capping of the lined cell will be generated, with leachate continuing to percolate and collect in the base of the cell, from where it will be pumped out. This leachate stream will potentially have higher concentrations of substances to be treated. The flow rate would initially reduce from that of the current scenario because of the elimination of rainfall; however, it is anticipated that the volume may then steadily increase as the newly placed waste further decomposes. It is considered that the flow rate would decline and the leachate stream be exhausted in about 20 years.

Leachate monitoring wells are to be provided in Zone 1 with three points installed per five hectares, as shown on Drawing Number 32EW5604/031. However a detailed check of monitoring data will be required to confirm that the levels detected are reflective of leachate and not groundwater, given the unlined nature of that zone.

Leachate monitoring wells are not proposed for Zones 2A and 2B. The waste types are low risk and shallower in depth and do not pose a significant risk to groundwater. This is further detailed in the DQRA.

Throughout the period of remediation works monitoring of all off-site boreholes should be conducted at least monthly. During active remedial works, or where materials are moved on to uncapped areas of wastes for temporary storage, more frequent monitoring of off-site boreholes adjacent to affected areas is likely to be required. Frequency will be determined by the risk assessment for each phase of works and incorporated within the method statement for working.

Whilst there are measures detailed in Table 4.2 above which will help to reduce leachate generation, appropriate methods to control the leachate that is generated are also proposed, including:

- Monitoring of leachate via wells;
- Collection of leachate via extraction wells and pipework;
- Storage of leachate (untreated) within on-site balancing tank;
- Treatment of leachate within a methane stripping plant;
- Leachate discharge to sewer as a trade effluent;
- Leachate recirculation within the lined landfill cell;
- Storage of leachate (treated) within on-site tank; and
- Tankering leachate to a suitably licensed treatment facility (only at times when there are any abnormal occurrences with the treatment process or restrictions on discharge to sewer).

Details of the proposed leachate management and control systems are shown on Drawing Numbers 32EW5604-00-035, 32EW5604-00-036 and 32EW5604-00-037. Details of the proposed leachate extraction infrastructure are outlined further in Section 5. Work instructions detailing duties of staff carrying out leachate management are detailed in Section 8.

5. Leachate Management System

5.1 Normal Operating Conditions

The following section sets out the proposed leachate extraction and treatment infrastructure that will be in place following the completion of the remediation works. The layout of the proposed leachate management system is outlined on Drawing Number 32EW5604-00-031. The normal operation of the system is outlined in Figure 5.1.

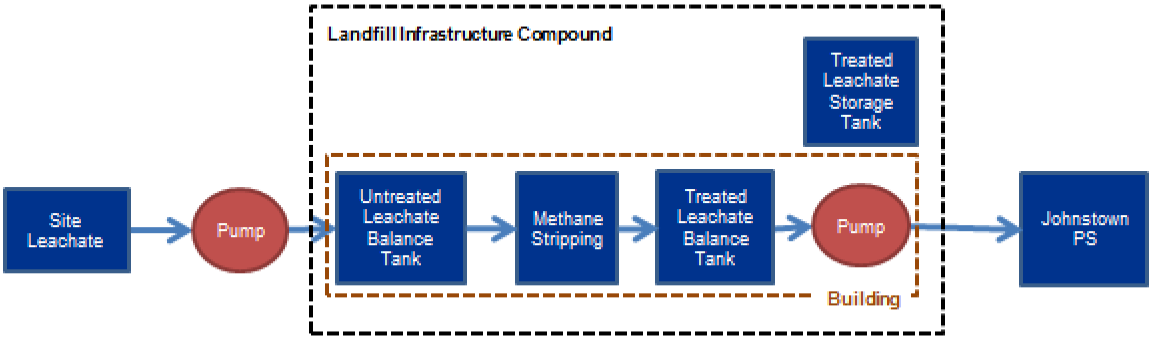


Figure 5.1 : Normal Operating Conditions Flow Diagram

A piping and instrumentation drawing (P&ID) of the leachate management system is shown on Drawing Number 32EW5604-00-035.

Leachate extracted from the waste mass will be pumped along a pipeline to the Landfill Infrastructure Compound. A building will be constructed housing the leachate infrastructure. Leachate will be discharged into a balancing tank (for untreated leachate). The tank is designed to hold 10m^3 of leachate.

Flows from the balancing tank will gravitate into the methane stripping plant/tank (also located within the leachate management building) where the leachate is retained in the tank for a minimum of 2 hours while dissolved methane is removed by aeration. The dissolved methane concentration in the leachate is designed to reduce to at least the upper consented limit of 0.14 mg/l with the excess methane drawn off in the process air stream to be burnt in the gas flare located immediately adjacent to the building within the landfill infrastructure compound. The treated leachate will overflow from the methane stripping tank into the treated leachate balance tank. The proposed layout of the leachate management building is shown on Drawing Number 32EW5604-00-034.

From the treated leachate balance tank leachate will be pumped through a 150mm (ID) MDPE pipeline (rising main / gravity main) to the public sewer network via Johnstown Wastewater Pumping Station (WwPS), located approximately 450m to the east of the site. The pipe will be installed within the bounds of the landfill up to the east boundary, where it will be buried in a field at a minimum depth of 0.9m below ground level and with a minimum 5m wayleave proposed (subject to landowner agreement). There will be a requirement to directional drill beneath the N7 road and Morell River, immediately west of the pumping station. Leachate will discharge into a chamber located within the pumping station grounds, to flow into Johnstown WwPS collection tank via buried pipework. The proposed route of the rising main and associated pipework are shown on Drawing Numbers 32EW5604-00-031 and 32EW5604-00-032.

Agreement with Irish Water for this connection has been agreed in principle. A copy of the connection agreement will be appended to the management plan for record purposes.

The leachate will be transferred through the public sewer network by Irish Water for treatment at Osberstown WWTP, with final effluent quality monitored to meet agreed standards.

5.2 Abnormal Operating Conditions

5.2.1 Process Diagram

There will be occasions when effluent levels are high within the public sewer network and specifically within the WwPS where Irish Water (IW) will request leachate discharges to the WwPS to cease. A telemetry system will be utilised to stop pumps operation. The hierarchy of leachate management shown in Figure 5.2 will then be initiated, specific to the source of leachate. As outlined in Section 4 there is a requirement to validate that levels observed in Zone 1 are representative of leachate for normal operation to apply to this source.

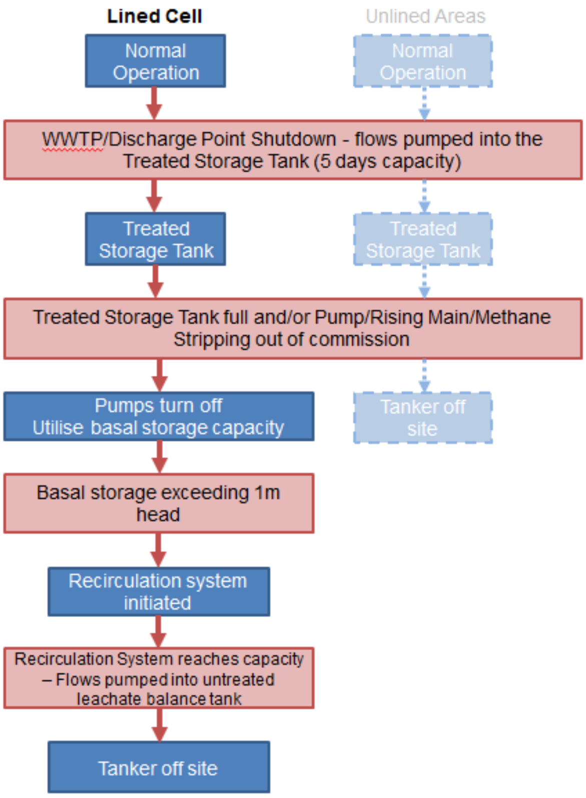


Figure 5.2 : Abnormal Operating Conditions Process Diagram

5.2.2 Storage

The treated leachate storage tank is designed to provide three days storage at maximum flow ($150m^3$). This tank will located in the landfill infrastructure compound and will be constructed of glass reinforced steel. After each use the tank will be drained and washed down to prevent any remaining leachate becoming stagnant. The treated leachate storage tank will be constructed within a similar tank that will act as the 110% bund to account for a catastrophic failure. The proposed location of the treated leachate storage tank is detailed on Drawing Number 32EW5604-00-033. Should the leachate storage tank reach capacity and sewer network still not be available for recommencement of discharge, level monitoring of the lined cell will determine whether storage capacity is available, up to a maximum 1m head above the liner. To utilise this storage the extraction pumps located within the inclined risers will be turned off, with monitoring of head continuing. This stage is interchangeable with leachate recirculation, described below.

5.2.3 Leachate Recirculation

Recirculation of leachate will be used to employ absorptive capacity within the landfill cell. When the leachate is recirculated, the constituents are attenuated by biological activity and by other physical and chemical reactions within the landfill, which can lead to accelerated stabilisation of the landfill mass.

Recirculation of the untreated leachate in the lined cell will be achieved via the operation of a recirculation unit and various actuated valves, which will as far as possible, evenly distributed the recycled leachate throughout the body of the lined cell. Any leachate recirculation works will be undertaken and managed in such a way as to avoid the spraying of leachate into the atmosphere, and will not impact upon air quality around the installation boundary, or cause odours.

As identified in EPA guidance (Landfill Operational Practices), recirculation of leachate within cells designed without basal lining and leachate drainage is not recommended. As such recirculation will not take place within Zones 1, 2A, 2B or 4.

5.2.4 Tanker Arrangements

The utilisation of various storage capacities within the site allow for a period for tankers to be mobilised to site to remove leachate directly from the leachate system. This use of capacities is necessary as a fail-safe as the prevention of discharge to sewer network via sewer may also apply for direct disposal to a treatment plant, which requires the assignation and agreement of Irish Water.

The treated leachate storage draw-off point will be located externally on the plant building in order to contain any potential spillages within the tanker draw-off area. The transfer of leachate to the draw-off point will be done via a pipe of fully welded construction. The pipe will be located below ground to offer enhanced hydraulics control, enabling full leachate transfer from the tank.

An underground tank will be constructed adjacent to the plant building. The tank will have a reinforced concrete surround for structural support. This has an added benefit of reduce risk of leaks escaping to the ground. The tank will have sufficient volume to collect all potential spillage from the building, delivery area and tanker draw-off area. This volume will be assessed on the basis of detailed design, risk assessment including probability of incident and supported by an appropriate Hazard And Operability Study (HAZOP) stage. For the purposes of outline design, a worst case scenario of 30m^3 capacity (largest permissible road tanker) is assumed, recognising that such plant may be sectional with compartment tanks reducing this storage requirement.

It is anticipated that a call-off agreement with a licensed contractor would be in place such that when tankers are required these can be mobilised within the period prior to full utilisation of storage capacity on site.

5.3 Leachate Management Review

5.3.1 Leachate Management

Management of leachate will be maintained under review by site management to ensure that as far as is reasonably practicable the leachate collection, treatment and disposal system will have sufficient capacity to handle the maximum predicted rate of leachate generation for the installation and maintain leachate levels in the lined cell and to monitor levels within the unlined areas.

If the review process identifies potential shortfalls in the provision of leachate management facilities at the installation, action will be taken to upgrade the system capability. Proposed changes are to be discussed with the EPA prior to implementation.

5.3.2 Detailed Design

Detailed design will be undertaken to confirm arrangements for leachate management at the site. This design process will also include a HAZOP assessment to determine required security controls for each key part of the system.

5.3.3 Incident Control Measures

The following table provides the outline for the incident control measures put in place in order to minimize the risk of any leachate pollution / release into the environment.

Incident	Probability	Impact	Control Measures
Spillage of leachate within the plant building	1	1	• Any leachate spillage in the plant building will be contained within the building. • The plant building floor will be impermeable and drainage channels will collect any spillage. • Spillages will be transferred to an underground tank, located adjacent to the plant building. • Sensors will be installed in the underground tank to inform the site personnel of the current level and provide an alarm when the tank requires emptying. • Testing of water required to confirm presence of contamination. Where clean, this can be discharged to site surface water drainage system. Where deemed unsuitable, tank contents to be pumped out from the underground tank via road tanker.
Failure of treated leachate storage tank	1	5	• The treated leachate storage tank will be provided with minimum 110% bunding capacity provided by an external tank of similar construction, to account for a catastrophic failure of the treated leachate storage tank. • The external tank will have a conical roof and therefore no rainwater will be collected to ensure that the bunded capacity is maintained at min. 110%. • Sensors will be installed to inform the site personnel of the current level of the internal tank and provide an alarm when the tank requires emptying. • Secondary sensor will be provided to indicate reduction in level in the internal tank where extraction is not being initiated. • Further sensor installed to indicate presence and level of effluent in outer tank, setting off alarm to inform the site personnel of potential internal tank failure.
Failure of pipework from leachate storage tank	1	3	• The pipe transferring the leachate from the treated leachate storage tank to the leachate draw-off point (located adjacent to the plant building) will be of fully welded construction to remove the risk of leaks.
Spillage within tanker draw-off area	2	3	• The tanker draw-off area will be impermeable and drainage channels in the centre of the area will collect any spillages. • Spillages will be transferred to an underground tank. • A manual valving arrangement will be used to divert rainwater to the site drainage during normal operations to ensure that the tank remains empty of rainwater. During tanker operations the valves will be set to divert all flows to the underground tank. The area must be washed down fully prior to the flow being diverted back to the site drainage, with sampling to confirm quality as suitable for discharge to the site surface water management system. • Sensors will be installed in the underground tank to inform the site personnel of the current level and provide an alarm when the tank requires emptying. • The leachate will be pumped out from the underground tank as required via road tanker.

Incident	Probability	Impact	Control Measures
Spillage within delivery area	1	2	• The delivery area will be impermeable and drainage channels in the centre of the area will collect any spillages. • Spillages will be transferred to an underground tank. • A manual valving arrangement will be used to divert rainwater to the site drainage during normal operations to ensure that the tank remains empty of rainwater. During tanker operations the valves will be set to divert all flows to the underground tank. The area must be washed down fully prior to the flow being diverted back to the site surface water drainage system. • Sensors will be installed in the underground tank to inform the site personnel of the current level and provide an alarm when the tank requires emptying. • Spillages will be pumped out from the underground tank as required via road tanker.
Valve, coupling and hose failure (tank to tanker draw-off area)	1	4	• Pressure sensors will constantly monitor the pressure during tanker operations and will be able to identify any increased flow resulting from the failure of the valve, coupling and/or hose. This will result in the automatic closure of the actuated emergency shut off valves and prevent large volume of leachate escape. • Should leachate escape from valves, coupling or hoses it will be minimal in quantity and will be contained within the underground tank. • Sensors will be installed in the underground tank to inform the site personnel of the current level and provide an alarm when the tank requires emptying. • Spillages will be pumped out from the underground tank as required via road tanker.

Probability / Incident rating is on the 1 to 5 scale where 1 is the lowest and 5 the highest.

Below is non-exhaustive list of guidance that should be followed when designing the incident control measures.

Guidance	
EPA Final Draft BAT Guidance Note on Best Available Techniques for the Waste Sector: Landfill Activities	2011
EPA Landfill Manual - Guidance note of Landfill Monitoring	2003

Review of these and prevailing best practice should be made when all of the control measures are designed.

6. Installation, Monitoring and Maintenance

6.1 Installation Plan

The leachate rising/gravity main shall undergo a water pressure test in accordance with BS EN 805:2000 to ensure the integrity of pipes, joints, fittings and other components such as anchor blocks.

During the operation of the leachate rising/gravity main, routine volume checks will be carried out to ensure that the integrity leachate transfer system is operating as designed. The volume of leachate received at Johnstown WwPS will be monitored to determine any change in volume. Where there is no reduction, within a specified allowance, the integrity of the rising/gravity main will be considered to be assured.

After installation, the treated leachate storage tank and the external bunding tank will be tested as per the Civil Engineering Specification for the Water Industry to ensure the integrity of the tank. This testing typically comprises filling the tank with water and measuring levels for three days to determine level change, as a possible indicator of leakage.

6.2 Construction Quality Assurance

The outline design principles for the leachate management system are provided herein. Detailed design of future leachate management facilities will be undertaken following agreement with Irish Water regarding the connection agreement to Johnstown WwPS, to include a Hazard And Operability Study (HAZOP) to assist in determining the level and detail of security controls required on the infrastructure and management system.

The installation of the requisite infrastructure and management measures will be subject to Construction Quality Assurance and Control. This will provide assurance that the leachate management system was constructed as specified in the design and will include inspections, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility.

To enable overall quality management works to the leachate management system will be governed by a comprehensive Construction Quality Assurance (CQA) Plan, prepared for submission to and review by the EPA. CQA is defined as a planned system of activities that provide assurance that the materials used meet design specifications and infrastructure is constructed in accordance with the contract and technical specifications. The CQA Plan will set out:

- Construction quality control (CQC) procedures;
- Technical specification and the conditions of contract drawn up by the designer; and
- Roles and responsibilities for the works. The Construction Environmental Management Plan (CEMP) may also inform and be informed by the CQA Plan.

On completion of the infrastructure works a CQA Report will be prepared, to demonstrate that the system(s) and associated components comply with the specification as set out in the CQA Plan.

6.3 Monitoring Plan

Routine monitoring of the site to assess the performance of the leachate management systems will be undertaken. Details of the monitoring programme/plan for the site are set out in the Monitoring and Control Management Plan and will cover (as a minimum):

- Leachate monitoring (on-site; levels, quality and quantities);
- Leachate monitoring (off-site; flows to network; quality; capacity);
- Leachate infrastructure inspections;
- Leachate infrastructure maintenance programmes; and
- Leachate recirculation procedures (where required).

6.4 Maintenance and Reporting Procedures

The leachate management system will be subject to an operational, preventative maintenance and servicing programme. Procedures detailing all the operational and maintenance requirements for the leachate management plant will be contained within the operational and maintenance manual, which will be retained in the Site Office. The operational and maintenance manual will include the following:

- System description (construction, process and operational parameters) including full as built drawings, together with a record of all subsequent changes;
- Operating instructions;
- Commissioning into service and out of service procedures;
- Specification for routine operational monitoring;
- Register of all routine adjustments;
- Record of all non-routine incidents;
- Health and safety instructions for routine operation and further guidance on procedures to adopt in the event of an accident or emergency;
- Detailed inspection programme with inventories and frequencies (including responsibilities for monitoring, inspection and maintenance, daily, weekly and monthly requirements, documentation and recording procedures, procedures for implementing corrective actions);
- Register of fault conditions and corrective actions taken to overcome faults;
- Details of routine repairs and replacements;
- Review requirements for fault conditions and repairs; and
- Inventory of replacement parts and contact details for relevant suppliers and manufacturers.

Personnel responsible for the operation and maintenance of the leachate management system require to be fully conversant with the operational procedures and safety and maintenance programmes. See Section 8 for Work Instructions for responsible personnel.

7. Leachate Action Plan

7.1 Overview

As identified in Section 4 reductions in infiltration will be achieved by progressive phases of capping works, across areas of the landfill. The surface water management scheme is also important in providing a collection system for surface water runoff that will reduce the loading on the leachate collection and disposal system (see also Surface Water Management Plan (Document reference 32EW5604/DOC/0042)).

It is proposed that the Leachate Management Plan and Leachate Action Plan would be regularly reviewed, and updated where necessary, to ensure that sufficient leachate management options are available to adequately control leachate generation at the site, and to prevent any uncontrolled escape of leachate into the surrounding environment.

7.2 Action Plan

The following Action Plan provides the outline for processes to be followed during abnormal operating occurrences/ incidents associated with the leachate management system.

Incident	Actions
Current, Pre-Remediation Phase	
Road accident causing environmental pollution caused by tankering of leachate from site	• Contractor to report to emergency services. • Contingency plan to be arranged with contractor.
Leachate level exceeds 1m head in lined cell	• Arrange for additional tankers to site to remove excess leachate.
Leachate outbreak observed	• Report to Site Manager. • Immediately instigate installation of drain back into waste mass to prevent run-off. • Inspect off-waste area for pollution and remediate. • Report to EPA, if environmental risk identified. • Arrange repairs to cap or determine whether leachate extraction is necessary as soon as possible.
Development / Remediation Phase	
Construction run-off found to be contaminated	• Procedures to be detailed in construction contract, to include reiteration of no discharge from site being permitted. • Ensure Contractor assesses level of contamination and agrees disposal route with Operator.
Spillage of leachate on tankering location(s)	• Report to Site Manager. • Arrange for spilled leachate to be collected and either recirculated to lined cell or returned to storage tank. • Check storage tanks and pipework - arrange repairs, as necessary.
Spillage of leachate outwith tankering locations	• Report to Site Manager. • Immediately contain with spill kit or other equivalent as necessary. • Arrange for spilled leachate to be collected and either recirculated to lined

Incident	Actions
	cell or returned to storage tank. • Report to EPA, if environmental risk identified. • Check storage tanks and pipework - arrange repairs, as necessary.
Leachate outbreak observed	• Report to Site Manager. • Report to EPA, if environmental risk identified. • Arrange repairs to cap or determine whether leachate extraction is necessary as soon as possible.
Inclined riser blocked (Zone 3)	• Report to Site Manager. • Ensure pump in other riser is operational. • Determine extent of blockage and instigate remedial works. • If remedial works are unsuccessful instigate retro-drilling to target pad.
Blocked leachate abstraction pipework	• Report to Site Manager. • Turn off pumps. • Maintain monitoring of leachate level in lined cell. • Initiate repair of pipework with appropriate quality checks and commissioning.
Failure of leachate extraction pumps	• Report to Site Manager. • Check levels of • Retain boxed spare pump on site for use in emergency. • Rectify pump fault with supplies and tools on site if possible, if not order relevant parts or specialist contractor assistance to fix.
Leachate level monitoring equipment fails	• Utilise dip meter (check inclined riser calculation to compensate for slope gradient adjustment). • Replace inducer as soon as possible.
Leachate level exceeds 1m head in lined cell	• Turn on pumps; pump to Leachate storage tank. • Pump to recirculation facility in lined cell. • Arrange for additional tankers to site to remove excess leachate.
Operational / Aftercare Phase	
High level within IW pumping station reached	• Report to Site Manager. • Divert treated leachate to the treated leachate storage tank. Tank provides 5 days of storage at $50m^3$ per day. • Following confirmation from IW that the high level within the pumping station has receded the treated leachate pumps will pass treated leachate to the IW pumping station taking the flow from the methane stripping plant in precedence over the treated leachate storage tank.
High levels within IW pumping station and treated leachate storage tank	• Report to Site Manager. • Methane stripping plant will be taken off line. • Use lined cell pumps to recirculate untreated leachate within the lined cell via the operation of various actuated valves.

Incident	Actions
	• Following confirmation from IW that the high level within the pumping station has receded revert to normal treatment and operating procedures.
High levels within IW pumping station, treated leachate storage tank and lined cell	• Report to Site Manager. • Use lined cell pumps to manually transfer leachate to the untreated leachate balancing tank. • Arrange for tankers to remove leachate off-site from the untreated leachate balancing tank. • Following confirmation from IW that the high level within the pumping station has receded revert to normal treatment and operating procedures.
Failure of methane stripping plant	• Report to Site Manager. • Take methane stripping plant offline. • Recirculate untreated leachate in lined cell. • Where high levels are recorded in the lined cell, use lined cell pumps to manually transfer leachate to the untreated leachate balancing tank and arrange to remove from site via tanker. • Arrange repairs to methane stripping plant.
High level within untreated leachate balance tank	• Report to Site Manager. • Use lined cell pumps to recirculate untreated leachate within the lined cell via the operation of various actuated valves. • Or arrange to remove untreated leachate from balancing tank via tanker.

Following incidents occurring at the site the Action Plan should be updated to ensure that the document is kept relevant.

8. Work Instructions

8.1 Maintaining Leachate Infrastructure

Work instructions for the Site Manager, Designated Representative and Site Operatives are as follows:

8.1.1 Duty of Site Manager

- Ensure that all constructed engineering works prevent the uncontrolled escape of leachate into the surrounding environment or into the surface water collection system;
- Undertake daily inspections of leachate storage tanks, pumps and methane stripping plant for signs of leaks;
- Regularly inspect bunded areas for ponding liquids and remove as necessary;
- Undertake regular inspection and maintenance of the underground tank;
- Check alarms system(s) are maintained and regularly tested;
- Ensure building in Landfill Infrastructure Compound is securely locked each night;
- Ensure that routine monitoring of leachate is undertaken in accordance with the guidelines detailed within this management plan;
- Ensure that weekly checks upon the operation of the installed leachate extraction system are undertaken;
- Ensure that any notifications required by this management plan are submitted to the EPA or IW as appropriate; and
- Ensure that the Action Plan detailed within this management plan is implemented.

8.1.2 Duty of the Designated Representative

- Ensure that the pumps, pipework, treatment plant and other ancillary equipment required as part of the extraction system are regularly serviced / maintained as per the manufacturer's instructions; and
- Where faults/errors are noted within the leachate extraction system, the Designated Representative will notify the Site Manager as soon as reasonable practicable and will arrange repairs, as required.

8.1.3 Duty of the Site Operative

- Take all reasonable precautions when deposition and compaction of waste takes place adjacent to the leachate collection sumps and chambers to mitigate the likelihood of damage occurring;
- Where damage does occur to either the surrounding stone structure or the inclined riser pipework notify the Site Manager as soon as reasonable practicable;
- Ensure that no debris or waste enters the leachate collection sumps / wells, and if this does occur contact the Site Manager immediately; and
- Maintain personnel access to the leachate extraction chambers at all times for the purpose of inspection and monitoring.

Appendix A. Relevant Guidance Documents

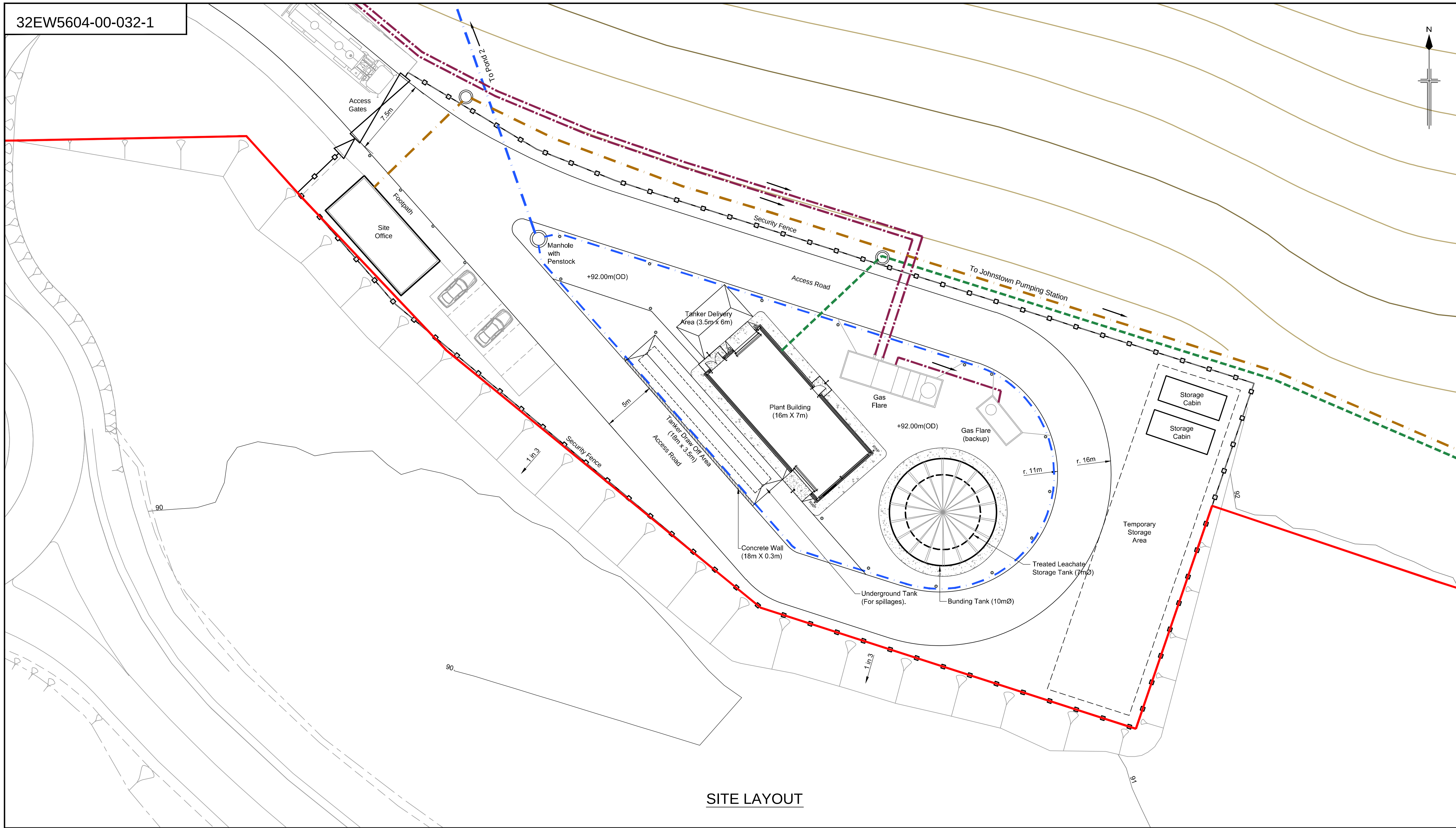
Below is a non-exhaustive list of guidance. Review of this and prevailing best practice should be made on future updates to this Management Plan:

Guidance	Year
Sewers for Adoption (7th Edition)	2013
Civil Engineering Specification for the Water Industry (7th Edition)	2011
Sewers for Scotland(3rd Edition)	2015
Scottish Water Standard and Specifications for Waste Water Pump Stations	2015
EPA Final Draft BAT Guidance Note on Best Available Techniques for the Waste Sector: Landfill Activities	2011
EPA Landfill Manual - Guidance note of Landfill Monitoring	2003
EPA Landfill Site Design	2000
EPA Landfill Manuals Investigations for Landfills	1995
EPA Landfill Manuals Landfill Operational Practices	1997
EPA Landfill Manuals Landfill Restoration and Aftercare	1999
EPA Landfill Manuals Landfill Monitoring	2003
EA Guidance for the Treatment of Landfill Leachate	2007
The Safety, Health and Welfare at Work Act	2005
The Safety, Health and Welfare at Work (Construction) Regulations 2013 SI 291	2013
ATEX 94/9/EC Directive, the ATEX 'Product' Directive, concerned with the manufacture of equipment and protective systems designed for use in potentially explosive atmospheres	1994
ATEX 1999/92/EC Directive, the Worker Protection Directive (also known as the 'ATEX 137' Directive), concerned with the "minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres"	1999

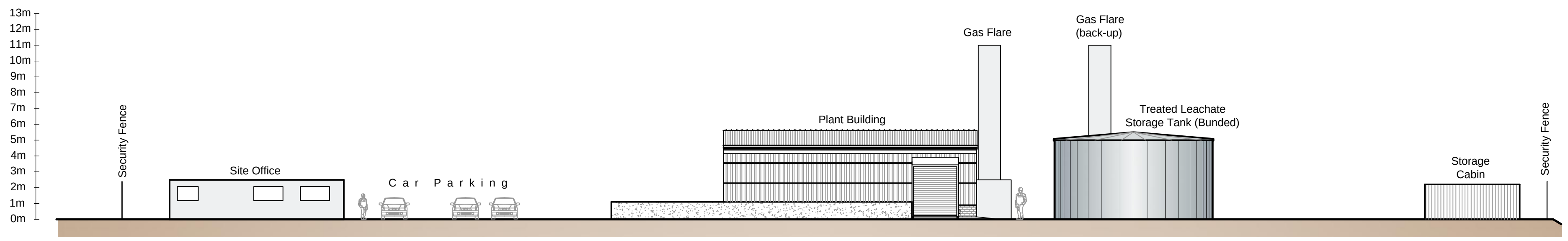
The UK landfill industry has also developed a series of Industry Codes of Practice (ICoPs), comprising guidelines on compliance with ATEX regulations with respect to landfill gas, leachate, drilling and general landfill operations, including the undertaking of area classifications / zoning around landfill infrastructure.

Available [Online] from www.esauk.org/reports_press_releases/esa_reports/dsear_guidance.html [accessed 9 December 2016].

32EW5604-00-032-1



SITE LAYOUT



INDICATIVE ELEVATION

KEY:

- Licence Boundary
- Surface Water Drainage
- Treated Leachate Transfer Pipe
- Foul Water Pipeline
- Landfill Gas Carrier Main

NOTES:

1. All levels to metres OD (Malin Head).
2. All dimensions to millimetres unless otherwise stated.
3. For details of plant building and leachate storage tank refer to Drawing 32EW5604-00-033, for details of site office refer to Drawing 32EW5604-00-034.
4. For details of Leachate Management Infrastructure refer to Leachate Management Plan.
5. For details of Landfill Gas Flares refer to Landfill Gas Management Plan.

0 5 10 15 20 m

SCALE 1 : 200

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
1	30/06/2017	EIAR SUBMISSION	KMA	CD	CD	RR
0	26/09/2016	DRAFT EIAR SUBMISSION	AR	ND	CD	RR

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Kildare County Council

Comhairle Contae Chill Dara

Project

KERDIFFSTOWN LANDFILL REMEDIATION PROJECT

Drawing title

LEACHATE MANAGEMENT PLAN

LANDFILL INFRASTRUCTURE COMPOUND

LAYOUT AND INDICATIVE ELEVATION

Drawing status

EIAR SUBMISSION

	1:200 @ A1	DO NOT SCALE
Jacobs No.	32EW5604	
Client no.	6286	

Drawing number: 32EW5604-00-032 Rev: 1

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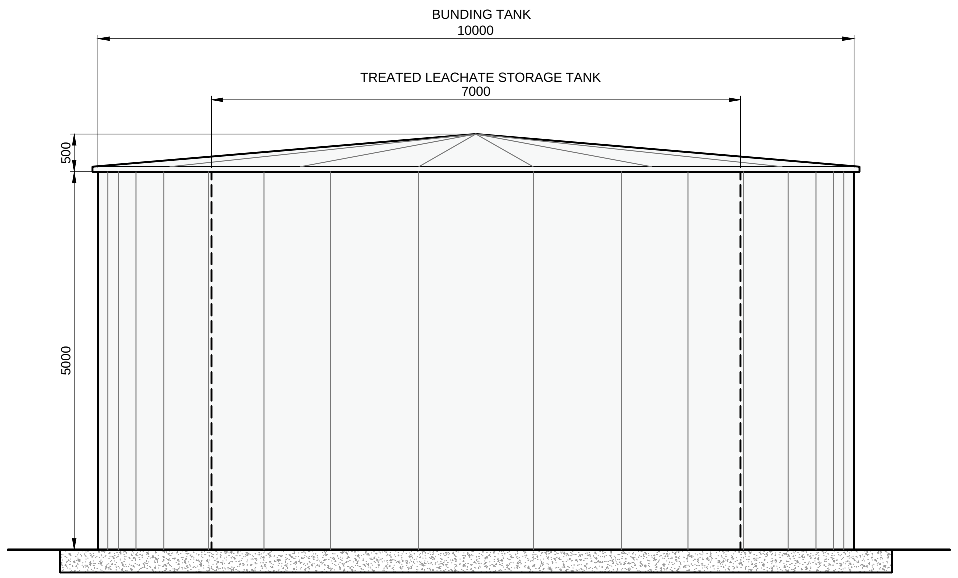
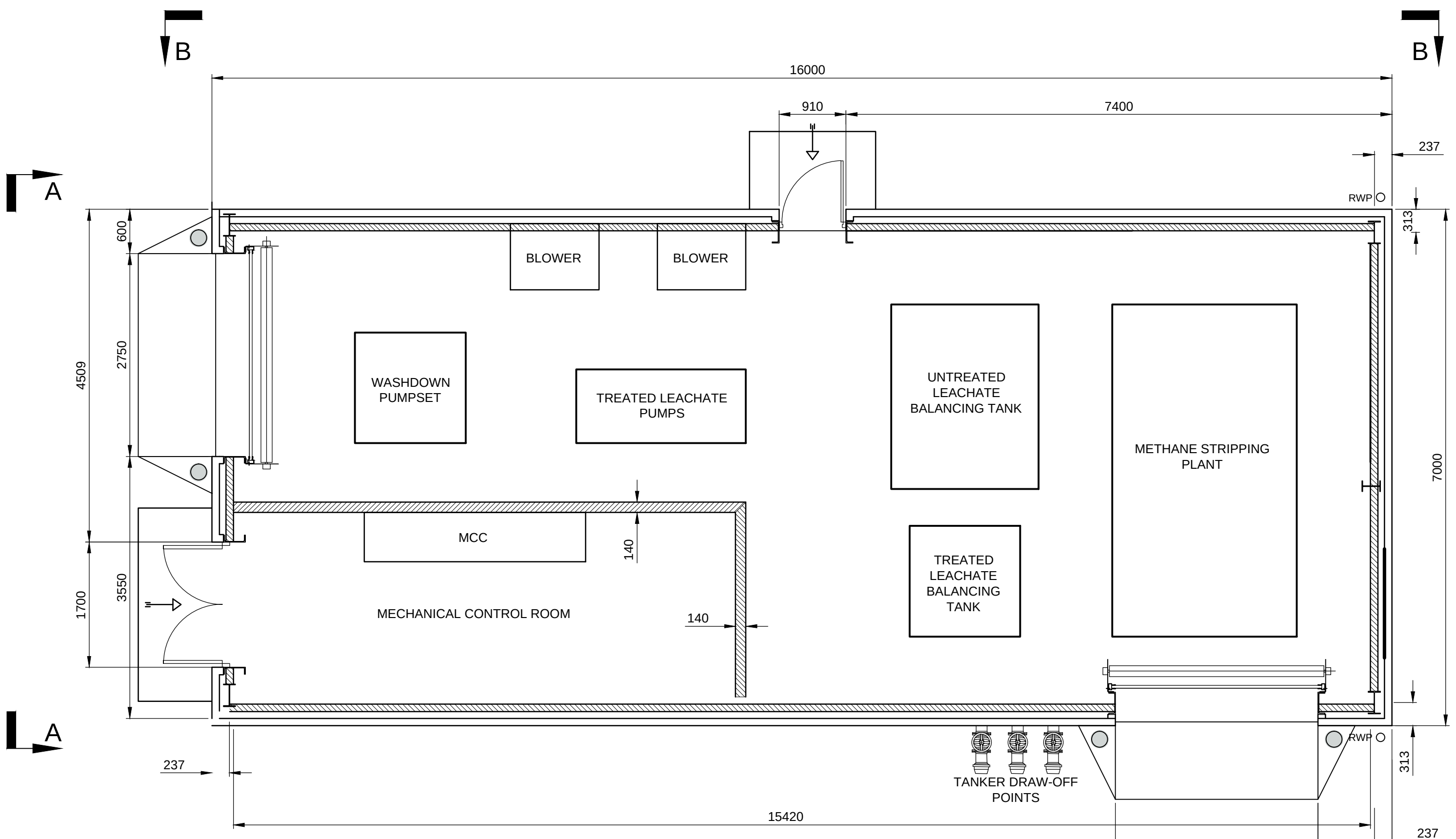
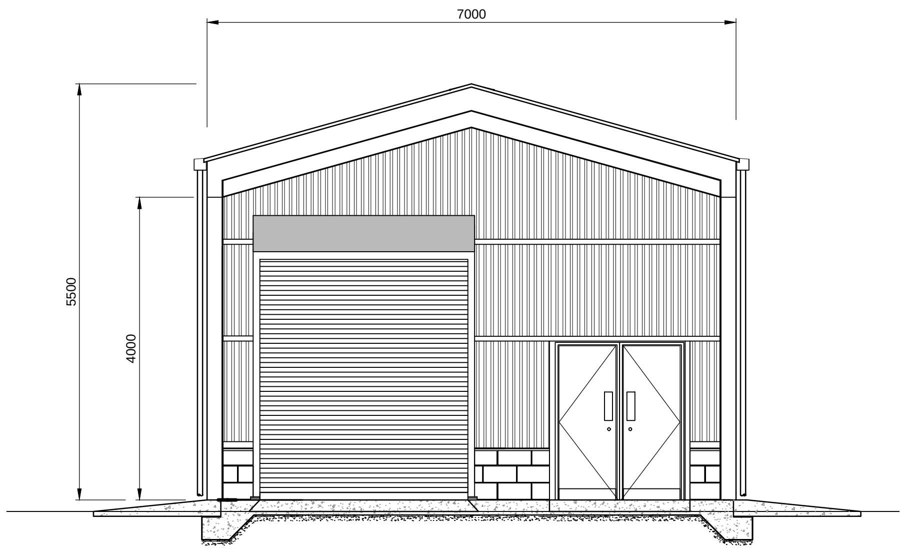
32EW5604-00-033-1



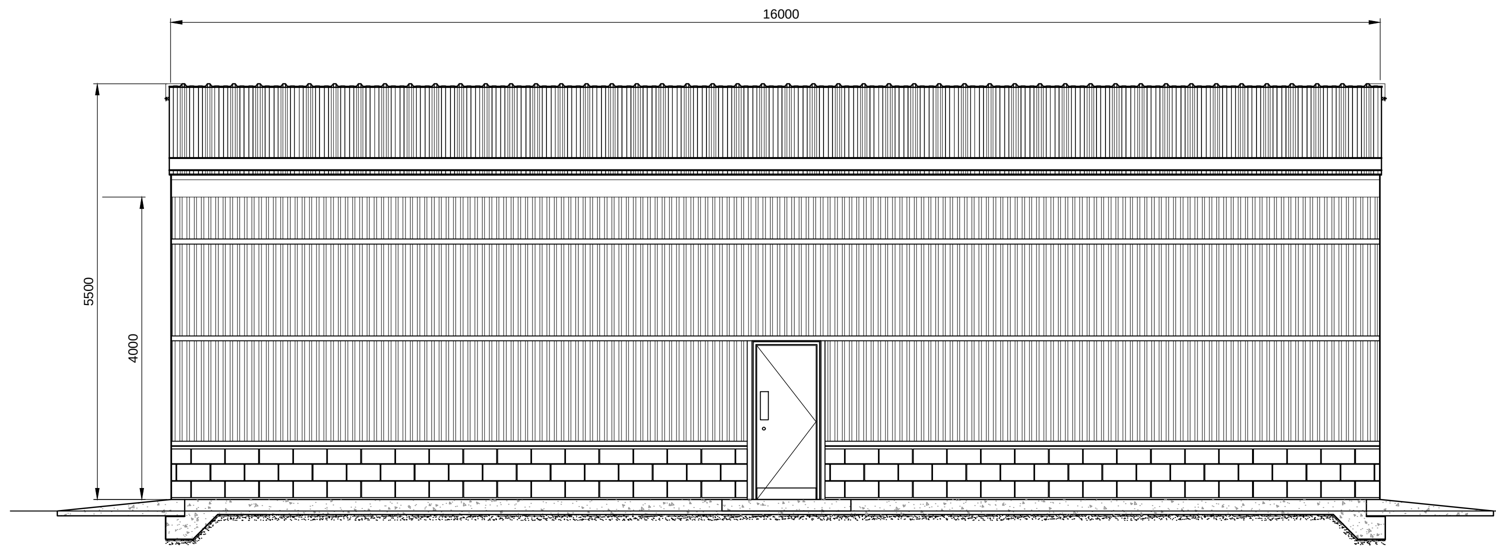
INDICATIVE ELEVATION
TREATED LEACHATE STORAGE TANK



FLOOR PLAN



ELEVATION A-A



ELEVATION B-B

NOTES:

1. All dimensions in millimetres unless otherwise stated.
2. Layout of internal infrastructure is indicative only.

0 1000 2000 3000 4000 5000 mm

SCALE 1 : 50

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
1	30/06/2017	EIAR SUBMISSION	KMA	CD	CD	RR
0	26/09/2016	DRAFT EIS SUBMISSION	AR	ND	CD	RR

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Project

KERDIFFSTOWN LANDFILL
REMEDIATION PROJECT

Drawing title

LEACHATE MANAGEMENT PLAN

LEACHATE MANAGEMENT BUILDING AND LEACHATE STORAGE TANK

LAYOUT AND INDICATIVE ELEVATIONS

Drawing status

EIAR SUBMISSION

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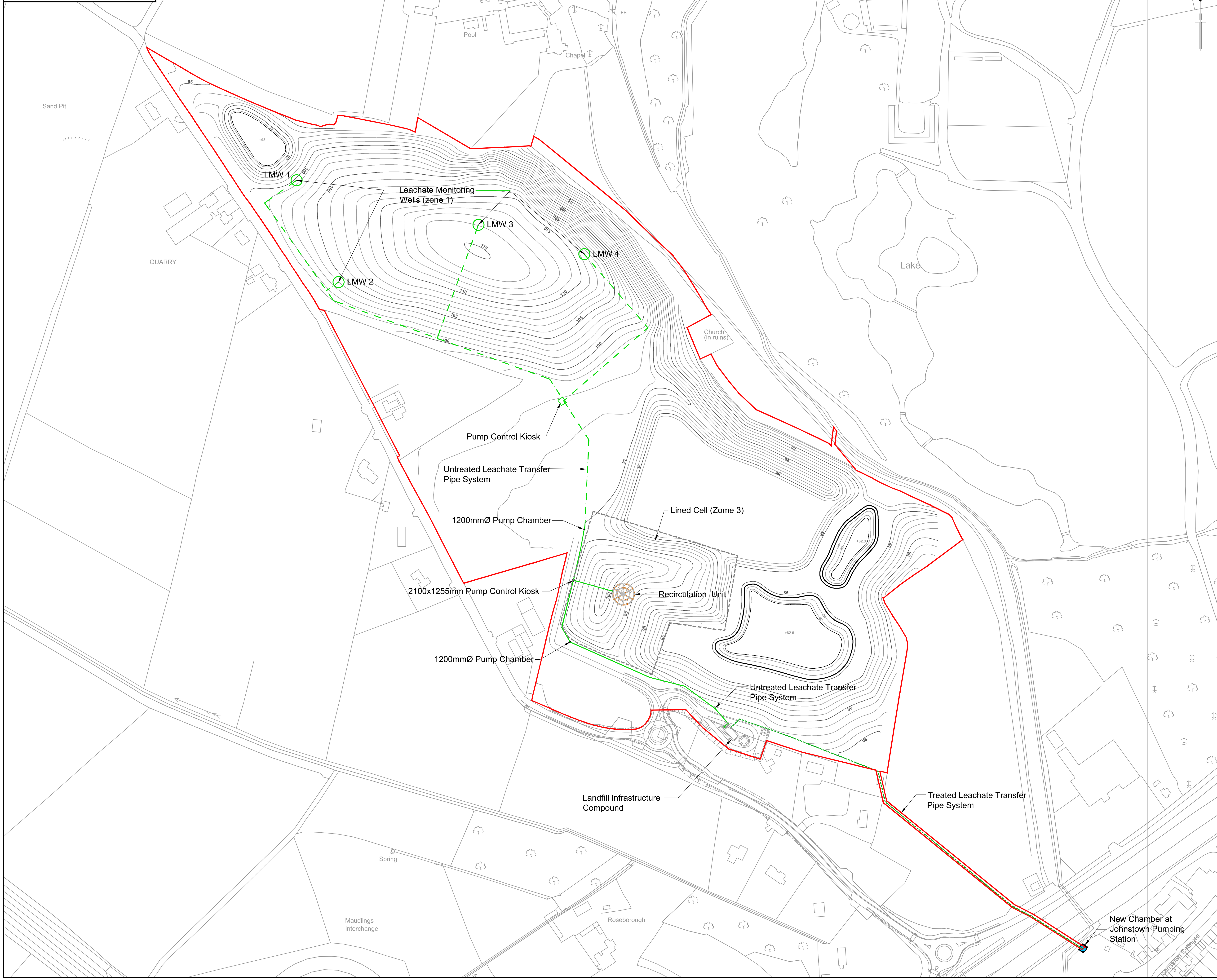
Client no.	6286	

Drawing number: 32EW5604-00-033

Rev: 1

32EW5604-00-035-1



KEY;

- Licence Boundary
- Untreated Leachate Transfer Pipe System
- Treated Leachate Transfer Pipe System
- Untreated Leachate Transfer Pipe System (Zone 1)
- Emission to Sewer
- LMW Leachate Monitoring Well.

NOTES:

1. For details of The Leachate Management System refer to Drawing No.32EW5604-00-037. (In Leachate Management Plan).
2. Pumping from Zone 1 initiated when monitoring confirms presence of leachate.
3. Leachate Monitoring Wells to be adapted from existing boreholes: BH61, BH63, BH64 and BH38.

0 50 100 150 200 m
SCALE 1 : 2000

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
1	30/06/2017	EIAR SUBMISSION	KMA	CD	CD	RR
0	26/09/2016	DRAFT EIAR SUBMISSION	KA	JB	CD	RR

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Comhairle Contae Chill Dara

Project
KERDIFFSTOWN LANDFILL REMEDIATION PROJECT

Drawing title
OUTLINE LEACHATE MANAGEMENT PLAN

Drawing status
EIAR SUBMISSION

1:2000 @ A1	DO NOT SCALE
Jacobs No.	32EW5604
Client no.	6286

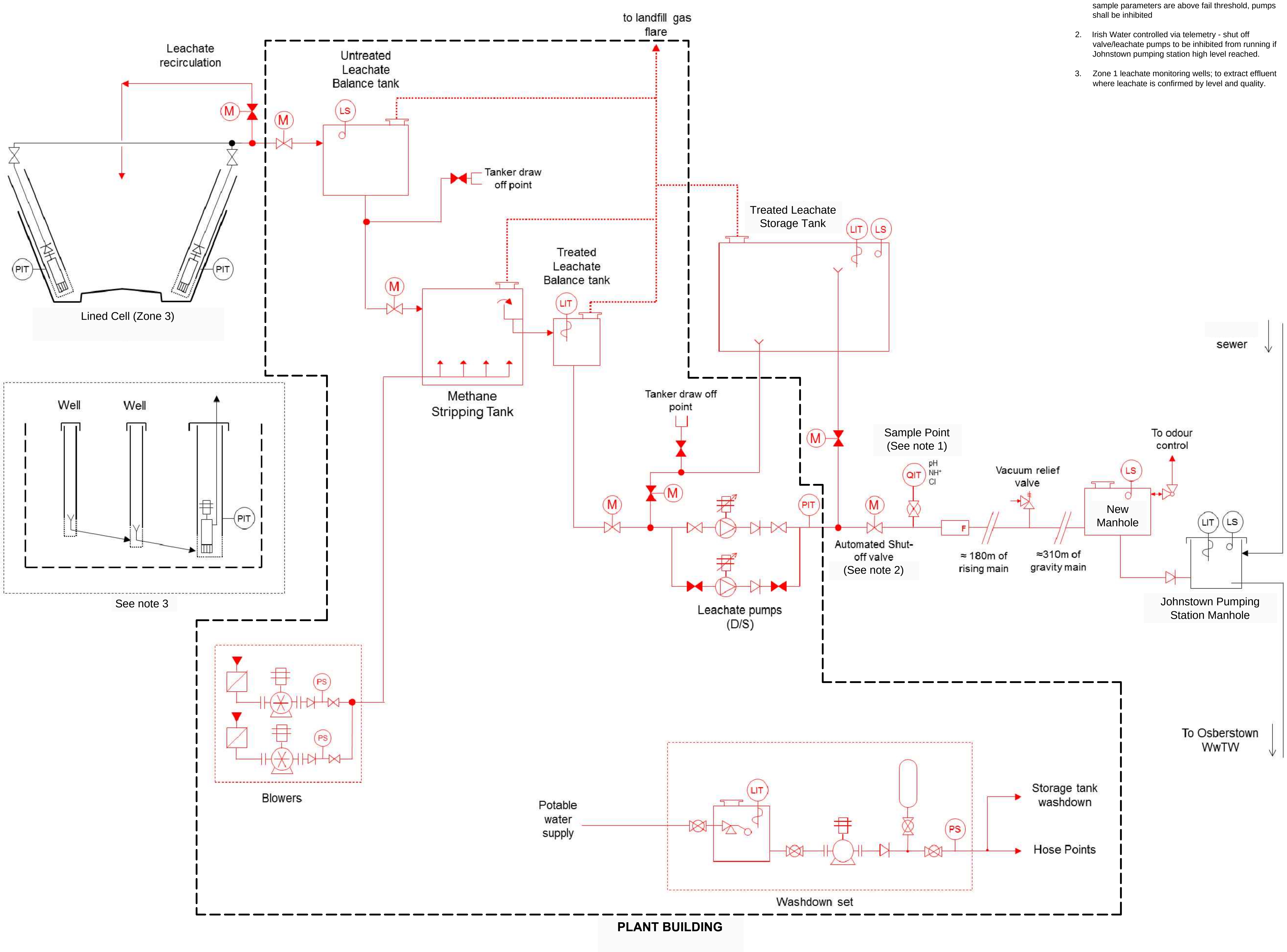
Drawing number: 32EW5604-00-035
Rev: 1

This drawing is not to be used in whole or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Drawing number / Rev
32EW5604-00-037-1

NOTES :

1. Sample points to draw off flows for monitoring ph, ammonia and chlorine. Lab sample available for metals concentration, BOD load etc. If continuous sample parameters are above fail threshold, pumps shall be inhibited
2. Irish Water controlled via telemetry - shut off valve/leachate pumps to be inhibited from running if Johnstown pumping station high level reached.
3. Zone 1 leachate monitoring wells; to extract effluent where leachate is confirmed by level and quality.



KEY:

- Existing/Outside Scope
- New
- Gas Pipework
- Valve (normally open)
- Valve (normally closed)
- Ball Valve
- Actuated Valve
- Sealed Tank
- Level Sensor
- Ultrasonic Level Indicator
- Pressure Indicator
- Pressure Sensor
- Quality Instrument
- Flowmeter
- Angle Float Valve
- Variable Speed Motor and Pump
- Pump
- Air Blower
- Non Return Valve
- Pressure Relief Valve
- Vacuum Relief Valve
- Borehole Pump
- Submersible Pump
- Pressure Vessel
- Air Intake and Filter

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
1	30/06/2017	EIAR SUBMISSION	KMA	CD	CD	RR
0	26/09/2016	DRAFT EIAR SUBMISSION	AR	ND	CD	RR

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Project
KERDIFFSTOWN LANDFILL
REMEDIATION PROJECT

Drawing title
LEACHATE MANAGEMENT
HIGH LEVEL P&ID

Drawing status
EIAR SUBMISSION

Scale	NTS	DO NOT SCALE
Jacobs No.	32EW5604	
Client No.	6286	

Drawing number: 32EW5604-00-037 | Rev: 1

Appendix A4.5 Landfill Gas Management Plan

Kerdiffstown Landfill Remediation Project (KLRP)

Kildare County Council (KCC)

Landfill Gas Management Plan

32EW5604/DOC/0040 | 2

30 June 2017

Kerdiffstown Landfill Remediation Project (KLRP)

Project No:	32EW5604
Document Title:	Landfill Gas Management Plan
Document No.:	32EW5604/DOC/0040
Revision:	2
Date:	30 June 2017
Client Name:	Kildare County Council (KCC)
Client No:	
Project Manager:	Rhianna Rose
Author:	Steven Cooke
File Name:	\\Iedub1-fil001\ji\Sustainable Solutions\Kerdiffstown Landfill\4 - Documents\4.3 - Draft Documents\32EW5604 L Additional Design Work\1 Gas Risk\KLRP_LFG-MP - Rev 2 final.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
0	09/12/2016	Preliminary	SC	CD	RR
1	07/03/2017	Final for Client Review in EIS	SC	CD	RR
2	30/06/2017	Final EIAR issue	UD	SS	RR

Contents

1. Introduction

1.1 Background

The site of the proposed Project, is located in County Kildare, approximately 3km north-east of central Naas, approximately 400m north-west of Johnstown village and in close proximity to the strategically important M7/N7 corridor. The site is located in close proximity to a number of residential and commercial receptors as well as being a short distance away from the larger settlements of Johnstown and Naas. In addition to the above, the site neighbours a number of recreational land uses, specifically Palmerstown House Estate and Naas Golf Course to the north-east and north-west respectively.

Kerdiffstown Landfill occupies approximately 30 hectares near Johnstown and is a former sand and gravel quarry which was progressively backfilled by a number of operators from the 1950s onwards. In January 2011 a major fire developed in a mound of waste material in the northern part of the site. This required intervention of a number of state agencies including Kildare County Council and the Environmental Protection Agency (EPA). The site was under the control of Kildare Fire Service until late February 2011, when it was handed over to the care of the EPA. Since 2011, measures have been taken to secure the site and limit environmental impact.

In April 2015 the Minister for the Environment, Community and Local Government, Alan Kelly TD, announced that funding would be made available for the remediation of the landfill site, and that Kildare County Council would take control of the site and commence remediation.

The objective in remediating the site in terms of landfill gas management is to:

- Manage and control landfill gases and odours in such a way that they do not constitute a future risk to nearby properties and residents and other identified receptors.

Linked to the overarching objectives of the project is the aim to provide a future landform and end use appropriate for the site and of potential benefit to the local community. To that end, the intended end-use for the site is public access parkland and recreational use.

1.2 Aims and Objectives

This Landfill Gas Management Plan has been prepared in support of a planning application and industrial emissions licence for the remediation and operational (end-use) phases, outlined as follows:

- *Development / Remediation* – The works required to re-profile the site including excavation of waste and other materials for deposition on site to achieve the proposed final landform. The works will also include the installation of landfill infrastructure such as capping, landfill gas, leachate and surface water management. A second stage of remediation will comprise the works required to restore the site to the proposed park end use, including planting and landscaping, installation of sports pitches, changing rooms, car parks and associated services.
- *Operational / Aftercare* – The life cycle stage of the site following the remediation works when the site will be used for public access parkland and recreation. The responsibility for the management of the site and the landfill infrastructure systems as well as park operation and maintenance will be retained by Kildare County Council (KCC).

Due to the significance of risks posed by landfill gas, location of sensitive receptors on and around the site and the proposed end-use, a detailed assessment has been undertaken to determine the risks associated with the site and put in place a framework to ensure that the landfill gas is appropriately controlled and managed throughout the gassing life of the site. These risks will need to be re-assessed and appraised during the stages of site development and operation. This framework is to be referred to and adapted as required by the person or entity responsible for the site during the various stages of development (see Section 1.3 Roles and Responsibilities).

At all stages the aim of the management plan is to:

- Ensure the site is compliant with regulation and best practice at all stages (during development/ remediation and operation/ aftercare);
- Ensure that the management plan is based on the current site operations and development, data arising from the site and foreseen future proposals for changes to the site;
- Prevent lateral gas migration from the site boundary;
- Control emissions of gas to atmosphere to acceptable levels to reduce odour impact;
- Minimise global warming potential from gas emissions;
- Ensure safety of site operatives and contractors working on site;
- Be sufficiently flexible to control gas occurrence throughout different phases of the remediation works;
- Integrate with leachate management and other environmental control systems;
- Be compatible with final restoration and after-use of the site; and
- Reduce potential environmental impact of the site throughout its whole life.

Section 4 of Annex 1 of the 1999 EU Landfill Directive outlines the gas control requirements for all classes of landfills. The specific requirements with regards to treatment and use of landfill gas are:

> *4.2 Landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared.*
>
> *4.3 The collection, treatment and use of landfill gas under paragraph 4.2 shall be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health.*

This Directive was transposed into Irish law by the Waste Management Licensing Regulations 2004 (SI 395 of 2004) and the Waste Management Act 1996 (as amended). Relevant guidance and best practice documents referred to in the development of this management plan are provided in Appendix A.

1.3 Roles and Responsibilities

This management plan is a live document where site use and operations, monitoring and performance data informs regular updates to the proposals and procedures within the document in order to mitigate the risks posed by landfill gas. These requirements will vary during the lifecycle stages of the site and according the specific works and operations being undertaken on the site.

The following provides definition of some of the terms used within the management plan:

- *Operator* – Kildare County Council, who hold responsibility and liability for the operation and maintenance of the gas management system;
- *Site Manager* – the individual representing the Operator on site during the remediation works and operation of the park/ aftercare of the site; and
- *Designated Representative* – The entity or individual appointed by the Operator to undertake management of the landfill gas system for a defined phase of its lifecycle.

The Operator, Site Manager or Designated Representative will have full responsibility to ensure that landfill gas is properly managed on site in accordance with relevant regulations, guidance and best practice at all times and that all activities are fully documented in the Site File.

2. Landfill Gas Properties

Landfill gas is generated from the breakdown of degradable fractions of wastes. Under typical landfill conditions wastes degrade anaerobically, producing a mixture of methane, carbon dioxide and trace components (which can number two to three hundred different compounds). In some situations, wastes may degrade in the presence of oxygen. Aerobic degradation produces carbon dioxide and trace components. Aerobic break-down usually occurs for a short period immediately following waste emplacement and for a longer period when the wastes are near the end of their degradation potential, and air is able to diffuse into wastes. Aerobic degradation may also occur at sites with active gas extraction, where over-extraction results in significant air ingress to the waste body.

Landfill gas constitutes a hazard as follows:

- Methane is flammable within the range of concentrations 5% to 15% in air. Ignition of a gas mixture within the flammable range in a confined space can result in an explosion. Methane concentrations in air greater than 15% still represent a hazard, since the gas mixture will at some point become diluted within the flammable range. Mixtures of methane in air below 5% by volume cannot ignite.
- Methane has a Global Warming Potential (GWP) estimated to be approximately 21 to 26 times higher than carbon dioxide. Therefore combustion or oxidation of landfill gas will significantly reduce GWP of emitted gas.
- Carbon Dioxide is an odourless, asphyxiant gas. Industrial occupational health levels for carbon dioxide are set at 0.5% for 8 hour exposure and 1.5% for 10 minute exposure for workers.
- Trace Components are variable across landfills, depending on the nature of waste materials deposited and the age of waste degradation. Trace components give rise to odours, some are asphyxiates or poisonous, and some have carcinogenic properties. The landfill gas at Kerdiffstown is odorous. Trace gas analysis has identified a range of odorous constituents, including sulphides and mercaptans, which are typical constituents of trace gases in landfill gas. Gaseous releases such as Hydrogen Sulphide and Carbon Monoxide can pose significant risk at relatively low concentrations.
- Odour thresholds for many trace components, including those above, are low and a large dilution with air (for some compounds of the order of a million times) is required to render the gases odourless (although odour detection is subject to the sensitivity of individuals).
- Some trace components have GWPs orders of magnitudes higher than methane and carbon dioxide, hence require to be oxidised prior to emission to atmosphere.

3. Risk Assessment

3.1 Principles of Risk Assessment

The management plan is based on Source-Pathway-Receptor risk assessment. This risk assessment uses the current understanding of the site for development of a Conceptual Site Model (CSM) based on the available information and data from the site, and proximity of receptors. Identified receptors to the site with respect to landfill gas migration are shown on Drawing Number 32EW5604-00-38. A CSM has been developed for the four key zones on the site, as presented on Drawing Numbers 32EW5604-00-039 to 042 inclusive.

It is recognised that this management plan and risk assessment will evolve in response to on-going investigations and monitoring, and observations on the phasing of the remediation works, for example:

- Data collected from the perimeter monitoring wells, which may provide evidence of migration or preferential pathways;
- Ongoing ground investigation works, including gathering data on wastes and gas production, and installation and monitoring of in-waste and perimeter boreholes;
- The findings of FID survey or other investigations undertaken as remediation works progress;
- General observations from the remediation works, e.g. areas of relatively high biodegradable wastes, areas that are observed to be gassing or odorous, location and extent of wastes;
- Any changes or additions to receptors around the site;
- Gas flows and concentrations from the existing landfill gas wells;
- The as-built details including final remediation landform as, for example, slopes may not be suitable for drilling vertical wells.

As a result review of this gas management plan should be undertaken at regular intervals, and revised on significant change at the site and / or following key stages of delivery of the remediation works. This will be managed on an on-going basis by the Operator.

3.2 Source

3.2.1 Gas Production

The future volume of landfill gas to be generated depends on the composition of materials that have been deposited at the site. The time for which gas will be produced depends on the rate of gas generation. Generation rate is influenced by a number of factors, key of which are the nature of the waste, the physical size of waste components, temperature within the waste body and moisture content of the waste.

Factors influencing landfill gas production:

Nature of wastes	Degradable materials can be categorised by their relative contents of cellulose, hemicellulose and lignin (woody component). Materials with relatively high proportions of cellulose to lignin (such as food) degrade more rapidly than materials with a higher proportion of lignin (such as cloth). It is likely that a large proportion of the highly degradable wastes landfilled will have undergone significant decomposition by this stage. Likely to be left are the more slowly degradable fractions of the waste. Loss on Ignition (LoI) tests for the borehole waste arisings at Kerdiffstown (2011 site investigations on Zone 1) indicated an average value of approximately 13% w/w (dry matter) and a maximum of approximately 35% w/w (dry matter).

Physical Form of Wastes	Notwithstanding the above, small particles of material will generally degrade faster than larger particles of the same material, since smaller particles have a much higher surface area to volume ratio, allowing microbes to be more effective in the degradation process. Therefore shredded paper will degrade faster than whole newspaper, and finely chipped wood will degrade faster than large chunks of wood (which may take thousands of years to achieve complete degradation). A large proportion of the wastes at the site have been through a waste treatment process, where the previous site operator attempted to extract marketable materials from the deposited wastes. These processed wastes are likely to have been reduced physically in size, which may increase the degradation rate, but the waste processing may also have removed some of the biodegradable fraction of the wastes. Review of borehole data in areas where processed wastes are said to be located (e.g. Zone 2B) appear to indicate less biodegradable wastes being present that zones where wastes had not been processed (e.g. Zone 1).
Temperature	The effectiveness of the micro-organisms facilitating breakdown of waste increases with temperature, with maximum effectiveness occurring at approximately 65^{o}C. Above this temperature, the rate of breakdown falls rapidly. If the temperature is too high (approaching 75^{o}C) microbes will die.
Moisture content	Increasing moisture content increases the rate of degradation, with maximum rate achieved when wastes are approaching 100% moisture content provided the wastes remain free draining. Moisture content of waste samples was measured by the UK Water Research Centre (WRC) during waste categorisation investigations when the site was operational. Results ranged from 3.8% to 20% w/w dry residue. Laboratory analyses for moisture content in wastes taken during the 2012 site investigation indicated that the wastes arising had an average of approximately 28% moisture content.

3.2.2 Current Active Gas Extraction

Currently (March 2017) active gas extraction occurs in two areas of the site; the lined cell (Zone 3) where the majority of the currently in place waste has gas extraction well coverage, and the north-western section (Zone 1) where only approximately a quarter of the currently in place waste has gas well coverage.

The aims of the existing landfill gas management measures are to control off-site migration along the north-western boundary of the site (where wastes are deep and close to the edge of the original sand quarry wall, and houses and outbuildings are present within 10m of the site boundary) and reduce emissions to atmosphere to control odours (these two areas of the site were identified in previous studies as being significant for gas emissions to atmosphere and hence odour).

Within the Zone 3 lined cell wastes have been covered with a temporary heavy duty membrane to assist with odour management and to reduce air from being drawn in during gas extraction operations. No formal capping system presently exists on Zone 1.

Gas is removed and burnt in specially manufactured stainless steel high temperature gas flares. There are two flares on site; one with 250 m^3/hr capacity, the second with 500 m^3/hr capacity. Valves are incorporated within pipework which enable gas from Zones 1 and 3 to be directed to a SINGLE flare, or to separate flares, depending on gas yields and quality. Currently, all gas extracted is being burnt at the ‘250’ flare, with the ‘500’ flare acting as standby.

The overall quantity and quality of gas entering the 250 flare has declined gradually over time with current flows of approximately 100 m^3/hr and gas concentrations recorded at 23% methane, 23% carbon dioxide and 0.3% oxygen. This represents a decrease of more than a half for the gas flows compared to initial gas yields during July/August 2011. The decline in gas yields has been seen to be relatively steady since April 2012 despite weekly monitoring and rebalancing. This is expected as the gas generation will fall as time passes, but may also be symptomatic of a decrease in extraction efficiency from the installed system.

3.2.3 Gas Modelling

Modelling has been completed using GasSim[1] software to determine the landfill gas generation over time (Source) based on the mass of waste deposited and the assessed composition of the waste. A lateral migration risk assessment has been under taken using a qualitative approach due to the limitations of GasSim for gas migration assessment. Air dispersion assessments have been undertaken as detailed in Chapter 8 (Air Quality and Odour) of the EIS.

GasSim relies on estimated inputs of waste tonnages and definition of waste types to determine the biodegradable portion of the wastes for calculation of Source. There are no records of the wastes deposited at the site hence boreholes records have been used to assess the variation of the wastes deposited. The GasSim model has been zoned, as shown on Drawing Number 32EW5604-00-43. The characteristics of the zones are summarised as follows:

Zone	Key Characteristics
1	Wastes deposited in the zone accounts for approximately 65% of the entire estimated volume of waste on site. The wastes in this area are typically unprocessed, highly odorous and principally comprise non-hazardous mixed construction and demolition (C & D) wastes and household wastes. C & D wastes are noted to contain varying amounts of clay, gravel, concrete, brick, wood, textile, plastic, rubber and metal. Wastes in this area of the site are currently uncapped and unlined. Remediation proposals for this zone comprise capping using a geosynthetic system (low permeability geomembrane or similar) with capping soils. End-use proposals will see this area become a public open space.
1A	The north western tip of this zone contains predominantly inert wastes and this section will be engineered to provide a surface water management pond. As there are limited wastes in this area (with further likely to be removed) it will not be subject to active gas management, although extraction wells will be installed on edge of adjacent Zone 1 to minimise the potential for migration off site.
2A	Much of this zone is covered by c.500 mm thick, reinforced concrete pads, which form an impermeable layer over the wastes and prevent direct rainwater ingress. Wastes are recorded to be unprocessed non-hazardous mixed C & D waste with varying amounts of clay, gravel, brick, concrete, wood, textile, paper, plastic, rubber and metal. Domestic waste also present in this area at varying depths mixed in with C & D materials. Zone 2A contains localised areas of biodegradable wastes. Remediation proposals comprise the retention of the concrete pads (with repairs) over which a sports pitch will be located. Outwith the concrete pads low permeable soils will be placed. End-use proposals will see this area become a public open space, incorporating car parking, a sports pitch and a changing rooms building.
2B	Much of this zone is covered by c.500 mm thick, reinforced concrete pads, which form an impermeable layer over the wastes and prevent direct rainwater ingress. Wastes are recorded to be unprocessed non-hazardous mixed C & D waste with varying amounts of clay, gravel, brick, concrete, wood, textile, paper, plastic, rubber and metal. Waste depths are shallower than, and lower in biodegradability than Zone 2A. Remediation proposals comprise the retention of the concrete pads (with repairs) over which a sports pitch will be located. Outwith the concrete pads low permeable soils will be placed. End-use proposals will see this area become a public open space incorporating a sports pitch.

[1] www.gassim.co.uk/

Zone	Key Characteristics
3	A large part of this area is lined with processed waste materials filling 60% of the existing void space. Wastes in this area comprise processed non-hazardous C & D materials with domestic waste mixed through. C & D wastes contain varying amounts of clay, gravel, concrete, brick, wood, textile, plastic, rubber and metal. The remediation proposals comprise infilling using wastes excavated from other areas of the site to create a suitable profile. The cell will be capped with a low permeability geomembrane or similar, covered with soils. End-use proposals comprise this area being a public open space.
4	Area containing large waste stockpiles, redundant infrastructure and concrete tanks/bays/walls. Various stockpiles are located within the zone, comprising both processed and unprocessed non-hazardous mixed C & D and limited household waste. C & D wastes noted to contain varying amounts of clay, gravel, concrete, brick, wood, textile, plastic, rubber and metal. The remediation proposal is to excavate wastes from this area as far as practicable, to create safe slope profiles and placing low permeable soils above. End-use proposals have this area used as a surface water management pond with paths.

Previous zoning of the site included Zone 5, which includes the site entrance and roads. It is considered from review of ground investigation data that no waste is present in this zone and is not subject to gas modelling. Properties adjacent to this zone will be demolished as part of the works at the site, to facilitate a new site access arrangement and construction of a new Landfill Infrastructure Compound.

The development scheme also encompasses a field adjacent to the L2005 Kerdiffstown Road and is bounded by site Zones 1 and 2A. This field is to be developed for a multi-use sports pitch during the Operational Phase of the works. This field is virgin ground, does not contain waste materials and is therefore not subject to gas modelling.

Waste tonnages and waste type to date

The waste tonnage inputs for the model are based on assessment of the depth of the wastes from site investigation borehole data profiling the depths of wastes encountered. AutoCAD analysis and modelling has been used to estimate waste fill volumes for each of the zones. The volume has been translated into tonnage for the model using a simple 1:1 principle i.e. 1 m^3 = 1 tonne of in place waste.

Definition of waste composition

To assess the biodegradability of the wastes within the zones borehole log waste descriptions were used (2011 site investigations) and a representative sample of borehole logs selected based on:

- Representation for waste areas of higher biodegradability (Zone 1), and of lower biodegradability (majority from Zones 2A and 2B);
- Quality of the recorded descriptions of the wastes and strata; and
- Boreholes which did not hit obstructions and terminate early.

The borehole logs provided relatively detailed descriptions of the waste arising including categories such as municipal waste, wood, paper, plastic, textile, cardboard, clay and gravel. Each of these descriptions had been provided with an assessment of the percentage of that material within each depth profile from the borehole e.g. borehole depth 2 to 4m wood 20%, paper 5% etc. These descriptions and percentages were used to calculate (pro-rata) the overall composition of the full depth of the boreholes.

The following groups of waste were modelled as inert waste (i.e. zero degradability) – soils, clays and gravel, metals and wire, plastics, rubber and ash – as they will have no or insignificant gas generation. Although some of these fractions such as plastics will degrade over-time, this is generally over a time period which will become irrelevant to the objectives of the gas modelling, i.e. over 130 or 150 years. The wastes inputs for the model were entered for the start year 2011 as that was the year of the site investigation which the borehole came from and represents the observation at that time.

The initial runs of the GasSim model produced gas generation estimates which were much higher than the actual landfill gas extraction rates from the site would suggest were feasible. GasSim has been developed for mimicking the landfilling of ‘fresh waste’, and is calibrated by empirical data from active landfills rather than older closed landfills under retrospective investigation as is the case at Kerdiffstown. Therefore, a process of model calibration was deemed to be required to adjust the model to provide results broadly in line with the actual extraction data from the site. The model calibration assumed the rapidly degradable proportion of the waste would have already degraded, and that what is left will be the medium rate and slow rate biodegradable fractions. This calibration gave more realistic model output, as presented in Section 3.2.4, which aligns with the actual gas extraction from the site with appreciation of the current limited coverage of extraction wells.

3.2.4 Model Results

Figure 3.1 provides the calibrated GasSim bulk landfill gas output curves for the entire site (all zones collated) and each of the individual zones.

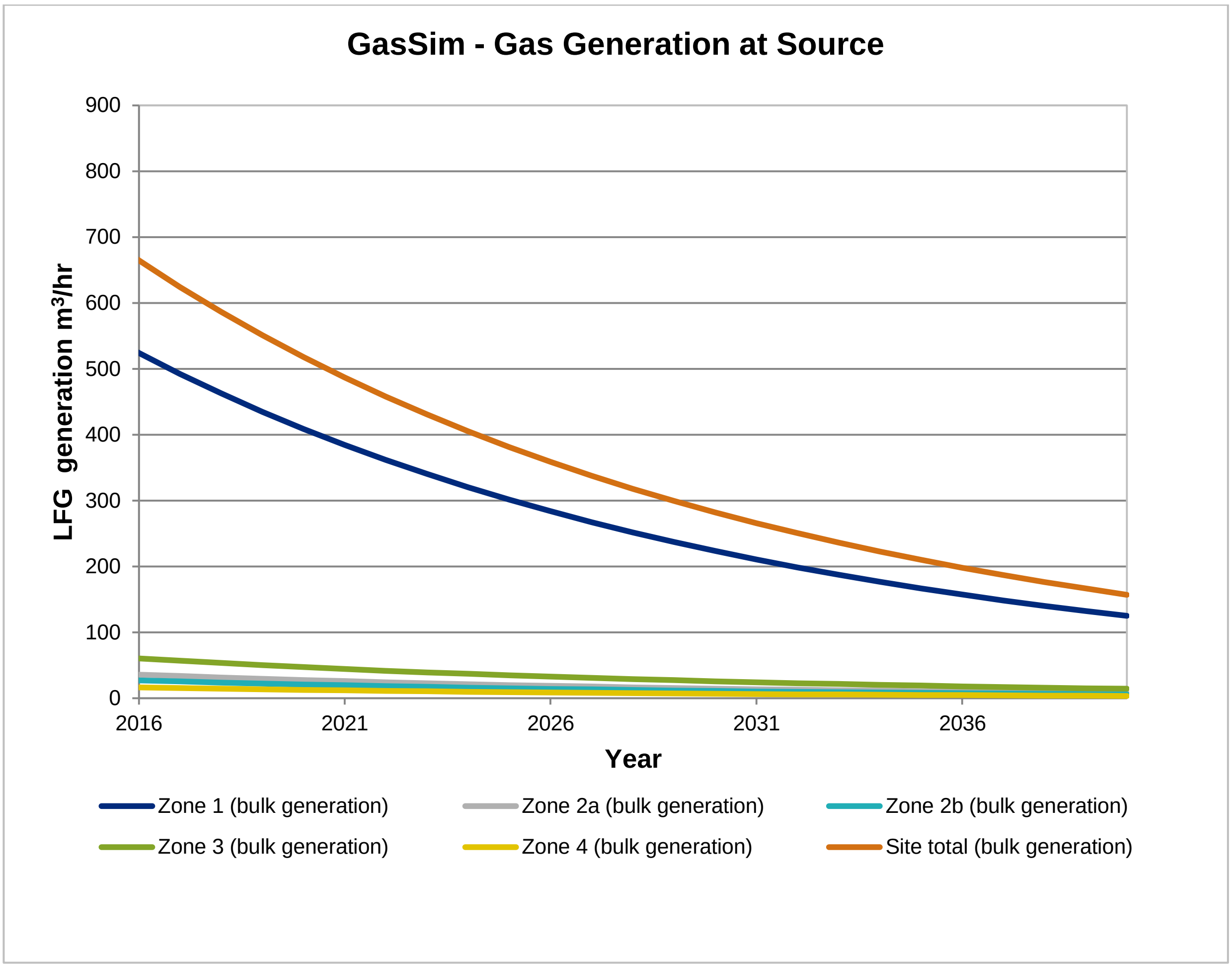

Figure 3.1 : GasSim Gas Output Curves

The majority of the landfill gas is predicted to be produced by Zone 1. This is expected as this zone contains the greatest proportion of the waste (c. 2 million tonnes), and relatively more biodegradable wastes. The next biggest contributor to gas production is Zone 3, which also contains wastes of the higher biodegradability but only contains in the order of 200,000 tonnes of waste.

Zone 1 is currently (2017) extracting approximately 80 m^3/hr of gas from the installed wells from a well coverage area of approximately 25%. Zone 3 is currently (2016) extracting 20 m^3/hr of gas from installed wells which cover all the in-place wastes within that Zone.

The model estimation of approximately 550 m^3/hr (Zone 1 plus Zone 3 for 2017), when compared to actual current on-site extraction rates and current well coverage, is broadly acceptable and potentially provides a slight over-estimation for risk assessment and specification of gas management infrastructure. The extraction efficiency for a site such as Kerdiffstown which does not have full engineered containment across the entire site area is likely to be in the region of 75%. Approximate extrapolation from the above chart suggests that once the full extraction field is installed on Zones 1 and 3 in the order of 400 m^3/hr may be able to be extracted (in 2020 following remediation works).

The GasSim model is provided within Appendix B in hard copy format.

3.3 Pathways

3.3.1 Landfill Gas Migration – General

There are three main processes which cause gases to migrate:

- Differences in gas pressure;
- Differences in gas concentration; and
- By dissolving in water or leachate which subsequently migrates from the landfill, with the dissolved gas coming out of solution.

Of these three mechanisms, pressure differential is usually the dominant mechanism. Within a landfill, continuing degradation of wastes replenishes landfill gas, which results in a positive gas pressure inside the site. Gas will move from zones of high pressure (e.g. within the wastes) to zones of lower pressure (e.g. soil surrounding the site or the atmosphere) until the pressure differential is equalised. Thus within an actively degrading landfill, there is a continuous production of landfill gas and potential for gas migration out of the wastes.

Currently there is no engineered capping on the site, hence gas has ability to vent to atmosphere where it is not controlled by the current gas extraction system, or impeded by presence of thick concrete slabs. Following capping, the potential for horizontal gas migration will increase substantively if no gas control measures are installed at the site. There is also potential for enhanced risk of off-site migration during the remediation phase, if materials are temporarily stockpiled on previously free-venting areas of wastes.

A second mechanism of pressure induced migration is created by changes in atmospheric pressure. Low pressure and falling atmospheric pressure encourages migration of gas, whereas high atmospheric pressure has the opposite tendency. Management of the gas control system will need to be responsive to the potential effects caused by sudden and steep falls in atmospheric pressure which can lead to increased gas migration from the wastes.

Gas will also migrate by diffusion between areas of different gas concentration. For a landfill site, this means there is potential for high concentrations of methane and carbon dioxide to move from the wastes to atmosphere and surrounding soils, and for oxygen and nitrogen in the air and surrounding soils to migrate into the landfill. This mechanism for gas migration becomes significant where there is no pressure difference (typically near the end of the gas producing life of the wastes).

Both carbon dioxide and methane are soluble, with carbon dioxide being approximately 90 times more soluble than methane. Landfill gas can dissolve in leachate in the site, and as leachate migrates away the gases can come out of solution. At Kerdiffstown, this will require methane stripping from leachate prior to its discharge to the public sewer network and monitoring of off-site monitoring boreholes for methane adjacent to unlined areas of the site where leachate may be migrating to groundwater.

During migration, reactions can occur which change the composition of landfill gas. Methane can be subject to microbial oxidation. This reaction causes methane and oxygen to be consumed and generates carbon dioxide and water vapour. This is an important mechanism of methane removal which for passive gas control measures which will need consideration near the end of the gas producing life of the wastes. Carbon dioxide can be removed from soil gas by dissolving in water contained in the soil. The result of these mechanisms occurring is that the composition of gas which has migrated from a landfill site can be substantially different from the composition of gas within wastes. Such mechanisms need to be considered when evaluating results of off-site monitoring, since indications of these processes occurring may provide an early warning of gas migration from the site.

3.3.2 Current Monitoring for Gas Migration

Currently there is limited off-site monitoring of landfill gas. Existing perimeter gas monitoring boreholes are shown in Drawing Number 32EW5604-00-43, comprising a total of eight boreholes on the northern boundary and two on the north-west boundary. To date these boreholes have not detected any significant gas migration as may be expected with the site being uncapped.

It is proposed that additional gas monitoring boreholes will be installed during 2017, in order to assess background readings in advance of the remediation works, to then detect and mitigate gas migration.

3.3.3 Lateral Migration Potential

Logs for existing off-site boreholes (gas and groundwater boreholes) show variable sequences of silt, sand, gravel and clay around the site. Gas migration risk is highest along bands of sand and gravel deposits which have lower permeability silts and clays above and below them, thus concentrating gas movement along the sand and gravel layer. Appendix C summarises the ground conditions encountered in off-site boreholes constructed close to the site perimeter, and provides commentary on gas migration risk for each. This information illustrates that much of the natural geology around the site is conducive to gas movement. The variability of the strata and the presence of sand and gravel layers cannot be defined to the level required to consider the risk of migration through specific routes to specific receptors. It must be assumed that due to the absence of a basal and sidewall liner to prevent migration in all zones (other than Zone 3) there is considered to be a high risk of off-site gas migration requiring suitable gas controls to then be installed. Following installation of new gas monitoring boreholes around the site perimeter, anticipated to be undertaken in 2017, an update to the table in Appendix C will be completed.

To the northern border it is considered that there is less risk of landfill gas migration due to the topography which slopes away from the site, and depth of wastes in contact with the natural strata. Also, the Morell River is present in this direction, the alluvial deposits of which transect the water table and this feature is likely to act as a natural barrier to gas migration.These factors will both limit the potential for landfill gas migration and increase the likelihood that any migrating gas is released through the soil surface.

Gas migration from Zone 3 will be limited due the presence of the engineered liner which will be resistant to gas migration. Migration from Zone 2 (A and B) is considered be limited due to the quantity and nature of the wastes within these areas as not likely to build up the gas pressures required for migration. Migration from Zone 4 will be limited as the vast majority of the wastes will be removed from this zone during remediation with limited gassing potential from existing data, with migration more likely to be vertical through the soils cover.

The migration potential for the landfill gas from the zones is shown in the Conceptual Site Models provided on Drawing Numbers 32EW5604-00-039 to 042 inclusive. These cross sections consider the potential for gas migration prior to and after remediation works and on the introduction of gas control measures proposed in Section 4.

3.4 Receptors

The following current receptors are identified on and around the site. Locations are shown on Drawing Number 32EW5604-00-38.

3.4.1 Buildings

The risk to buildings from landfill gas ingress is associated with the flammability and potential explosion risk of methane. Gas present in soils can enter buildings through cracks or holes in the floor slab, or via services which enter buildings below ground if no protection measures have been incorporated into building design.

Buildings and structures on site which will remain during the remediation works and new buildings to be added on-site for the operation/ aftercare phase relevant for the risk assessment are:

Structure	Gas Protection Measures	Note
EPA Site Offices.	Raised floor slab located over thick concrete pad.	Will be removed following the remediation works.
Security Office – Site Entrance.	Raised above ground, not above areas containing waste.	Will be removed as part of the remediation works.
Security Hut – Zone 1.	Raised above ground.	Will be removed as part of the remediation works.
ESB electrical switch room.	Founded on concrete pad. Louvres in doors and permanently operating fan ensures continuous ventilation of building.	Will remain during aftercare phase.
Two houses are located adjacent to the site entrance, bordering the southern boundary of the site.	Unknown finish and therefore assumed to be susceptible to gas migration.	Due to requirements for a new access to the site and construction of a landfill infrastructure compound, it is proposed that these properties will be removed as part of the remediation works.
Changing room associated with development of public park.	Design measures to take account of gassing ground potential	Developed as part of the end-use design.

As well as the buildings on site (within the site boundary) there are houses and outbuildings close to the north-western, western and southern boundaries of the site which could be vulnerable to landfill gas entry due to migration from the site. The nearest off-site house is located approximately 10m from the site boundary. More buildings and outbuildings are present within 50m of the site boundary. The nearest building associated with Kerdiffstown House is present approximately 110m from the site boundary. It is not considered likely that off-site buildings have been fitted with specific gas protection measures to date.

3.4.2 Residents and Occupiers of Off-site Properties

The risks to people within buildings from landfill gas is associated with flammability and potential explosion risk of methane, and asphyxiation arising from accumulation of carbon dioxide and/or reductions in oxygen. Odours can make houses uninhabitable before gas concentrations reach dangerous levels.

Any on-site work is subject to agreement of detailed health and safety risk assessment and method statement for working, which includes precautions for gas accumulation. Presently there is no identified requirement for gas alarms to be installed in these properties. However, this is required to be reviewed routinely as remediation works progress at the site, with updates to this management plan enacted as necessary.

3.4.3 Underground Services

Underground services on-site and off-site are potentially at risk from landfill gas entry and accumulation, unless the services have been designed to prevent gas ingress. The risk to underground services from landfill gas ingress is associated with the flammability and potential explosion risk of methane. In addition, services can act as pathways for gas to migrate into buildings via service entries.

Locations of known off-site services are outlined on Drawing Number 32EW5604-00-038. The drawing does not show service connections to individual premises. It can be assumed that off-site services do not have specific design features to prevent gas ingress into pipes or surrounding backfill. Locations of surface water drainage and other services on site will be largely amended and augmented during the remediation works.

The remediation and park development proposals incorporate provision of services. This will include electricity supply to the Landfill Infrastructure Compound, the changing rooms building, lights around car parking areas and adjacent paths and floodlights for the sports pitches. Water service connections will be required for the Landfill Infrastructure Compound and the changing rooms building. Gas supplies are not envisaged as being required for these facilities (subject to final design). Any services provided to such site buildings will be designed to limit gas ingress to the service ducts (e.g. surface laid where possible) or designed with measures to prevent gas migration to the buildings (e.g. sealing of ducts prior to entry to facilities).

3.4.4 Utility and Site Workers

The risks to utility workers from landfill gas are associated with flammability and potential explosion risk of methane, and asphyxiation arising from accumulation of carbon dioxide and / or reductions in oxygen. It is likely that practices for working below ground and within buildings will take account of potential risks arising from accumulation of potentially asphyxiant and explosive atmospheres before work commences, although this may not be recognised by individuals working on their own premises.

Any on-site work is subject to agreement of detailed health and safety risk assessment and method statement for working, which includes precautions to be taken against gas accumulation. Any off-site work on utilities and services within the local vicinity of the site should be made aware of the potential risks of migrating gas.

3.4.5 Vegetation

Landfill gas which migrates into soils will tend to displace oxygen from the root zone, and in extreme cases can lead to anaerobic conditions in the soil. This can result in vegetation stress or die off. Deep rooted vegetation is generally more prone to effects of landfill gas presence in soils than shallow rooted.

Currently (2017) there is no evidence to suggest landfill gas is affecting off-site vegetation (along Kerdiffstown Road and within Kerdiffstown House lands).

3.4.6 Summary of Receptor Sensitivity

For the purposes of the development of the gas management plan, the following receptor sensitivities are designated to receptors based on the current situation at the site.

Receptor	Sensitivity	Comments (refer to CSM Drawing Numbers 32EW5604-00-39 to 42)
Buildings on site and occupants and site users	High / Medium	Located directly above, or directly beside source of landfill gas. Likely that there will be migration through the landfill surface, although design of some on-site building such as the site office limits risk.
Grassland / other shallow rooted vegetation (park restoration)	Medium	Likely that there will be migration through the landfill surface. However, relatively high concentrations of migrating gas are required to cause noticeable effects.
Services on-site	High	Located above, or directly beside source of landfill gas, and possibly trenched into waste/capping. Likely that there will be migration through the landfill surface.
Buildings (and occupants) within 50m of site boundary	High	Many buildings located within 50m of site boundary including properties and businesses which abut the boundary. Large thickness of waste along north-western boundary of site giving potential for significant gas movement.
Services within 50m of site	High	Possibility of migrating gases accumulating within services.

Receptor	Sensitivity	Comments (refer to CSM Drawing Numbers 32EW5604-00-39 to 42)
Buildings between 50m and 250m of site perimeter.	Medium	Buildings associated with Kerdiffstown House are approximately 100m from the site boundary, and other properties at this distance. Likelihood of gas migration into this distance is lower as gas likely to be released through soil surface; however, properties will not have been designed with gas protection measures.
Johnstown Garden Centre and Naas Golf Club	Low	Morell River will act as natural barrier to gas migration for Johnstown Garden Centre. Naas Golf Club building is within 250m of the site boundary, but greater than 250m from the waste boundary as the northern tip of Zone 1 which will not contain biodegradable wastes following remediation.
Woodland and individual mature trees, golf course fairways and gardens within 50m of boundary	Low	Trees generally have deeper root penetration than other vegetation, and therefore likely to suffer greater impacts from landfill gas than more shallow rooted species. Relatively high concentrations of migrating gas are required to cause noticeable effects.
Services between 50m and 250m of site perimeter	Medium/ Low	Possibility of migrating gases accumulating within services, lower risk at greater distance.

Measures for mitigating the risk to sensitive receptors are provided in the management plan in Section 4.

3.5 Fugitive Emissions

As well as sub-surface migration there are currently and will be fugitive emissions of landfill gas to atmosphere from the cap and infrastructure, although the proposed gas management will greatly limit these fugitive emissions. Capturing and flaring (thermal treatment) of the landfill gas will provide environmental benefit as it will reduce the global warming potential (GWP) of emitted landfill gas (fugitive methane emissions) to the atmosphere. Methane has a GWP of the order of 21+ times more than carbon dioxide, and during thermal oxidation the methane within the landfill gas will be converted to carbon dioxide. Landfill gas contains other hydrocarbons which will also be treated by the thermal process to deliver management plan improvements.

Zones 2A and 2B are proposed to have passive venting measures due to the anticipated low levels of landfill gas generation within these zones following remediation. Wastes present in Zone 4 suggest minimal landfill gas generation potential, and remediation works comprise the removal of significant quantities of materials from this zone. The quantity of landfill gas generated by these zones is therefore modelled to be relatively low. However, the application of low permeability soils may adjust the degree to which generated landfill gas will laterally migrate to be emitted through discrete structures such as the perimeter venting zones is not fully understood at this stage. These emissions could carry an exposure or explosion risk to site operatives and park users. Therefore, monitoring of the site capping and venting structures for fugitive emissions is proposed within the management plan and, should high emissions be detected, further assessment should be made as to the risk posed action to be taken. The management plan proposals ensure that the design of this passive venting infrastructure provides flexibility for gas management with bio-oxidation or connection to the active gas extraction system being possible.

3.6 Combustion Products

The operation of the flare will lead to point source emissions of combustion products. The emissions to air will disperse into the atmosphere which can act as a pathway to potential receptors. The risk assessment for combustion products is contained within the Air Dispersion Risk Assessment Chapter 8 (Air Quality and Odour) of the EIS.

4. Gas Management Plan

The GasSim estimation of gas generation has been used for broad appreciation of landfill gas management. Details of the proposed landfill gas management and control systems for the aftercare phase are shown on Drawing Number 32EW5604-00-43. These control measures have been developed on a zone specific basis for the site to take account of the differing gassing potential of each zone and their final end-use following remediation works. The current control measures are summarised as follows:

Zone 1 (excl Zone 1A)

- Engineered capping system (geosynthetics);
- Vegetated soils above cap; and
- In-waste vertical landfill gas extraction wells linked to active extraction / landfill gas flaring.

Zones 2A and 2B

- Gas drainage layer overlain by low permeability cap (soils);
- Perimeter gas venting trenches (adaptable to active extraction system if required);
- Park end-use infrastructure designed for gas risk e.g. buildings freely venting, sealed services; and
- Vegetated soils above cap.

Zone 3

- Engineered low permeability basal and sidewall lining system;
- Engineered capping system (geosynthetics);
- Vegetated soils above cap; and
- In-waste vertical landfill gas extraction wells linked to active extraction / landfill gas flaring.

Zone 4

- Low permeability soils; and
- Vegetated soils.

Data will continue to be generated from ground investigations, ongoing monitoring and future pumping trials / operational gas extraction data to be gathered as part of the remediation scheme. As a result the above proposals may be adjusted accordingly, on the basis of further risk assessment and design justification. The gas management proposals will be periodically reviewed to check their suitability and validity, under the responsibility of the Operator.

Other methods for determination of specific landfill gas risk and development of mitigation proposals may be required for all or parts of the site to complement the management plan e.g. detailed design of on-site buildings, public access arrangements and compliance with the ATEX Directive. The detailed design phase will be required to take cognisance of all relevant guidance in this regard and the management plan updated to reflect the risk assessment and mitigation proposed.

4.1 Active Extraction System – Zones 1 and 3

Zones 1 and 3 will continue to generate significant quantities of landfill gas. The GasSim model predicting potential for approximately 400 m^3/hr of bulk gas extraction for Zone 1 and Zone 3 in 2020 and this landfill gas will require active extraction and management. Drawing Number 32EW5604-00-043 shows an indicative layout of the active extraction system, as described in the following sections.

4.1.1 Gas Extraction Wells

Vertical landfill gas extraction wells will be installed in Zone 1 and Zone 3 according to the design shown in Detail 1 on Drawing Number 32EW5604-00-043. It is currently assumed the wells will be installed at minimum 40m spacings towards borders with Kerdiffstown Road and Kerdiffstown House lands, and elsewhere on the zones at maximum 60m spacings. The final well spacings and distribution may change following a pumping trial conducted during the remediation works on Zone 1 and / or gas extraction operational data, offering information on extractable gas yield and the typical zone of influence. Information obtained during the remediation works, to include on-site observations, gas extraction performance data and pumping trial findings should be assessed routinely during the remediation works and inform revisions to the management plan.

It is envisaged that where remediated slope gradients are greater than 1v:3h such as on the northern slope of Zone 1 gas extraction wells will not be able to be installed. In such areas pin wells may be used. Pin wells, were they to be employed, in the management of gas from this part of the site, would typically be installed at 20m spacings as the shallower installation depth of pin wells (c.6m) would not provide as wide a zone of extraction influence as the gas extraction wells. The inclusion of such will be assessed dependent on the actual slopes achieved, gas potential (from pumping trial or operational data) and available and safe drilling methods.

4.1.2 Connecting Pipework

The vertical gas wells will be connected individually to manifolds. The connecting pipework will be designed to ensure that a high velocity is maintained to aid condensate management. As gas generation rates and flows are expected to be relatively low 63mm pipe is likely to be used, but this should be re-assessed based on the pumping trials and gas system operational data.

Connecting pipework is to be laid to maximise falls from the well to the manifold and contra flow conditions i.e. condensate and gas flowing in different directions should be avoided. Pipeline falls shall be a minimum of 1 in 25 where possible. Further review of design proposals to accommodate aspects such as capping stability on the steeper slopes of Zone 1 which may affect the orientation of pipework runs will be required at the detailed design stage for inspection and confirmation during the remediation works.

Connecting pipes are to be joined at the manifold with inlet valves for primary balancing and isolation purposes. Connecting pipe is to be black MDPE to SDR 17.6. Jointing shall be electro-fusion and butt fusion to give strong joints that will not fail.

4.1.3 Manifolds

A manifold system has been chosen as this has the advantage of making gas balancing easier and quicker. The number and location of the manifolds will be subject to the final detailed design once the full number and location of extraction wells has been confirmed. The manifolds will be installed above the capping layer in areas zoned to prevent public access.

The manifolds will be equipped with a gas balancing valve for each gas well, and an isolation valve on the connection to the gas main. Manifolds will include pumped condensate removal where located down gradient from the wells. The manifold chambers will include surface water drain, and ventilation to prevent build-up of landfill gases.

4.1.4 Perimeter Carrier Mains

The carrier mains are proposed to be 250mm diameter MDPE PN10 pipework, which assuming the low flows anticipated from the site (e.g. Zone 1 = c. 400 m^3/hr), will provide flows less than 2 m/s. This will be subject to assessment during pumping trials and the design criteria for all carrier mains is to keep all flows below 6 m/s. Pressure loss calculations should be completed during the final design, to check they are within acceptable levels, dependent on the final extraction system and design.

The mains will be buried or surface laid depending on location and potential for future public access, and laid with suitable falls. Table 4.1 provides a list of ground conditions and required falls for carrier mains.

	Minimum pipework fall
Stable ground, fall and gas flow in same direction	1 in 100
Stable ground, fall and gas flow in opposite direction	1 in 50
Over fill, fall and gas flow in same direction	1 in 50
Over fill, fall and gas flow in opposite direction	1 in 25

Table 4.1 : Ground conditions and recommended pipe falls

4.1.5 Condensate Pumping System

At low points within the carrier mains condensate knock out pots will be installed comprising a water sealed chamber with condensate removal pneumatic pumps, sized and specified for the flow of gas and anticipated condensate quantity. The air supply system for the pumps will be separate from the leachate pumping system. Condensate will either be discharged within Zone 3 (lined cell) or to the leachate treatment system.

4.2 Passive System – Zones 2A and 2B

Zones 2A and 2B have varying depths of waste materials which have relatively lower biodegradability than the wastes within Zones 1 and 3 and are therefore predicted to produce lower quantities of landfill gas. The GasSim model predicts approximately 34 m^3/hr bulk gas production for Zone 2A and 25 m^3/hr for Zone 2B in 2017. These volumes of landfill gas are similar to that for Zone 3, but wastes in these areas are relatively shallow and dispersed over a wider area, hence active gas extraction from these areas would be problematic.

Proposals for passive management fits with outline proposals within the EPA's guidance on the Management of Low Levels of Landfill Gas. This guidance concludes the lower threshold for flaring (low-cal) to be in the region of 25 to 50 m^3/hr at 15 to 30% methane. Site data from drillers borehole logs issued following ground investigations in 2011 record variable and generally low methane content from Zones 2A and 2B with only two exceeding 20% methane. This indicates that extractable gas from these Zones is unlikely to support use of a gas flare and may also negatively impact on the gas extracted from Zones 1 and 3 due to dilution.

The passive system for Zones 2A and 2B includes a gas drainage blanket under low permeability (soils) capping. This gas drainage blanket would comprise a gravel / stone layer to convey any migrating gas to the edges of the zones where it will be vented via trenches. It is proposed that the vent trenches have vertical collection pipework installed at maximum 50m spacing, with perforated pipework extending under the capping, to assist conveyance of gas.

Monitoring is ongoing to enhance the background data for the presence of gas in these zones. This data will be used to further determine the gas generation rate under passive conditions predominantly for informing the detailed design of the changing rooms building and provide appreciation of the suitability of passive venting measures for these zones. The passive venting systems have been designed with adaptability to allow them to be converted to bio-oxidation vents, or a system with slight extraction pressure using rotating aspiromatic cowls, further enhancing to active extraction if data was to support this option in the future.

4.3 Zone 4

Following remediation works Zone 4 will have very limited waste materials left within its footprint. The GasSim model predicts less than 15 m^3/hr of landfill gas production in 2020, and this is based on a worst case assumption of the amount of wastes to remain within this zone. The remediation works comprise placement of low permeable soils which will provide a certain degree of natural biological oxidation for the anticipated low levels of fugitive gas release which may pass through the soils layer.

4.4 Perimeter Monitoring Boreholes

There is currently a limited number of existing perimeter gas monitoring boreholes located around the site. It is proposed to install boreholes specifically for gas monitoring, to be located at or near the site boundary and in proximity to off-site receptors. Provisional locations are shown on Drawing Number 32EW5604-00-043.

The locations and spacings of the boreholes is based on consideration of potential risk from the different zones of the site, the geological setting which is generally conducive to gas migration (refer to Section 3.3.3), the sensitivity of the receptors and their distance from the site boundary. In general the boreholes are shown at 20m spacings on the boundaries with residential properties and Kerdiffstown House, and at 50m spacings at other sections. No additional boreholes are proposed for the site boundaries towards the Morell River as the river limits potential for gas migration, with monitoring continuing on the existing boreholes.

4.5 Landfill Gas Flaring

It is currently proposed to use flaring for the treatment of the landfill gas extracted from the site. Once the site has been remediated and the full gas extraction field is operational it may be possible to install a small scale utilisation scheme at the site. However, presently there is limited certainty on actual extractable gas yield and quality to conclude feasibility and viable economics to support such a scheme. This would be further assessed in the future as technologies develop and a greater understanding of gas yield at the site is determined through the pumping trials.

The existing gas flares at the site will be maintained during the remediation works. As the 250 flare is skid mounted it can be moved around the site to support key extraction areas, to reduce emissions and odour if observed during the remediation works.

The GasSim modelling indicates a flare of approximately 600 m^3/hr capacity will ultimately be required post-remediation works. This presents a slight over-specification of the flare based on the modelling but it is a better approach to assume a larger capacity at this stage. It is also proposed to install a back-up flare unit to maintain control of gas risk should the primary flare be offline for any reason. Post remediation works the gas flares will be located within the landfill infrastructure compound.

Landfill gas wells and extraction field will be progressively installed as the remediation works progress and the flow and quality of extracted gas will be monitored on an on-going basis, as will pumping trials to ascertain sustainable extractable gas quantity and quality. It is envisaged that once the early stages of capping are initiated in Zone 1 and new gas wells installed it should be possible to predict with greater accuracy the actual landfill gas flow and quality which can be extracted from the whole zone. At this stage the flaring system will be constructed within the landfill infrastructure compound.

The primary gas flare will be of an enclosed design providing high temperature flaring, which may or may not be of low-calorific design dependent on the extractable gas yield and quality. The flare will be lined with refractory material on the interior and the flare will be contained within a self-contained unit. The emissions standards the flare shall achieve are set out in Table 4.2 below.

Determinand[2]	Emission standard (mg/m^3)[1]
NOx	150
CO	50
Total VOCs	10

[1] These limits are based on normal operating conditions and load. Temperature: 0°C (273K); pressure: 101.3 KPa; and oxygen: 3%(dry gas)

[2] NOx expressed as NO_2

Table 4.2 : Typical Gas Flare Emissions Standards

The flare will be situated within the new Landfill Infrastructure Compound. The flare will be fitted with telemetry systems to inform of shutdowns. The flare stack height will be suitable to achieve the required air dispersion of the emissions products (at this stage assumed to be 11m). The compound will be securely fenced and locked to prevent public access. The compound will be screened by landscaping, planted shrubs and trees with their distance from the flare, and the other building within the compound considered for potential heat wash effects, with radiative effects typically evident within a 10m zone from a flare, dependent on height. The compound access and sizing has been developed in consideration of the potential need for emergency vehicle access, and access for flare management and maintenance. The indicative compound layout is presented on Drawing Number 32EW5604-00-032.

4.6 Construction Quality Assurance

The outline design principles for the landfill gas management system are provided herein. Detailed design of future landfill gas management infrastructure will be undertaken following pumping trials and detailed topographical surveys to determine appropriate gradients and alignments for pipe routes and manifold locations.

The installation of the requisite management measures will be subject to Construction Quality Assurance and Control. This will provide assurance that the landfill gas infrastructure was constructed as specified in the design and will include inspections, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility.

To enable overall quality management works to the surface water management system will be governed by a comprehensive Construction Quality Assurance (CQA) Plan, prepared for submission to and review by the EPA. CQA is defined as a planned system of activities that provide assurance that the materials used meet design specifications and infrastructure is constructed in accordance with the contract and technical specifications. The CQA Plan will set out:

- Construction quality control (CQC) procedures;
- Technical specification and the conditions of contract drawn up by the designer; and
- Roles and responsibilities for the works. The Construction Environmental Management Plan (CEMP) may also inform and be informed by the CQA Plan.

On completion of the infrastructure works a CQA Report will be prepared, to demonstrate that the system(s) and associated components comply with the specification as set out in the CQA Plan. To align with phasing of the remediation works CQA of landfill gas infrastructure may be embraced within an overarching Remediation CQA Plan, subject to confirmation of procurement approach and detailed design.

4.7 Operations and Maintenance

4.7.1 General

The landfill gas management system will be subject to an operational, preventative maintenance and servicing programme in accordance with the manufacturer's recommendations.

Procedures detailing all the operational and maintenance requirements for the permanent gas flare and utilisation plant will be contained within the operational and maintenance manual, which will be retained in the Site Office. The operational and maintenance manual will include the following:

- System description (construction, process and operational parameters) including full as built drawings, together with a record of all subsequent changes;
- Commissioning measurement data;
- Operating instructions;
- Commissioning into service and out of service procedures;
- Specification for routine operational monitoring;

- Specification for routine field balancing;
- Register of all routine adjustments;
- Record of all non-routine incidents;
- Health and safety instructions for routine operation and further guidance on procedures to adopt in the event of an accident or emergency;
- Detailed inspection programme with inventories and frequencies (including responsibilities for monitoring, inspection and maintenance, daily, weekly and monthly requirements, documentation and recording procedures, procedures for implementing corrective actions);
- Register of fault conditions and corrective actions taken to overcome faults;
- Details of routine repairs and replacements;
- Review requirements for fault conditions and repairs; and
- Inventory of replacement parts and contact details for relevant suppliers and manufacturers.

Personnel responsible for the operation and maintenance of the gas management system are required to be fully conversant with the operational procedures and safety and maintenance programmes.

4.7.2 Flare Maintenance Programme

It is anticipated that flare maintenance will be undertaken via an annual contract by the flare supplier or other qualified maintenance contractor according to the flare manufacturer’s recommendations. Routine inspection and maintenance of the installed flare(s) will be undertaken in accordance with manufacturer’s recommendations, with an indicative programme set out below.

Task	Monthly	Quarterly*	Annually
Check electrical control panel	X		
Check temperature control loop components		X	
Check control of ignition electrode	X		X
Clean UV lamp	X		
Replace UV lamp			X
Check/clean filter in inlet knockout pot		X	
Check/clean/replace filters in gas sampling lines		X	
Check operation of all alarm functions		X	
Check operation of telemetry system		X	
Check flame arrestors		X	
Check/clean motorised valves			X
Check condition of air throttle or damper	X		
Check thermocouples		X	
Check condition of terminal boxes	X		
Check condition of thermal insulation		X	

In the event of a problem being encountered with the operation of the flare, the Site Manager will attempt to identify the problem using the manufacturer’s recommendations on troubleshooting. Should the problem not be rectified through this route, the Site Manager will call out a maintenance contractor to correct the problem, normally within 24 hours of the problem occurring.

4.7.3 General Observations and Landfill Settlement

During monitoring rounds, and at a minimum monthly frequency, a visual assessment of the landfill gas infrastructure should be undertaken and recorded. This should encompass the general condition of the gas management system and site that may affect the efficiency of the system, including:

- The flare and infrastructure located within the Compound;
- The landfill gas wells (including any issues observed during monitoring of wells);
- Perimeter boreholes;
- Manifolds;
- Condensate system;
- Manhole covers;
- Fencing; and
- Surface condition (i.e. signs of settlement).

The assessment and observations should provide detail of the condition of the gas system, listing issues which require attention and maintenance; for example vandalised wells, missing gas taps, corrosion on the compound infrastructure etc.

The observation should include a qualitative assessment of the on-going settlement of the capping profile of the site. Landfills are subject to differential settlement due to the degradation of the waste mass. This settlement can cause issues for landfill gas management including damaging wells and causing the development of low points within the collection pipework which can become flooded with condensate and limit gas extraction. Consolidation and / or scouring of capping soils may also have similar effects or allow preferential pathways to open up for the release of landfill gases through the capping and should also be noted during the assessment. The general observation of the settlement of the site will be supported by an annual topographical survey of the site.

Suitable actions and timescales should be set for corrective action for the above, particularly where it may impact on management and increase landfill gas risk.

4.8 Sampling and Monitoring Plan (Aftercare Phase)

The following section provides proposals for routine monitoring of the site to ensure the performance of the gas management systems. These monitoring proposals are for the aftercare phase once the remediation works are completed where the site and management systems have entered a 'steady state'[2.] Monitoring considerations for the phased remediation of the site are detailed in Section 5.

Provisional monitoring locations, parameters and frequencies are provided in Table 4.3. However, the actual monitoring should be based on the prevailing risk and site behaviour of the site at any particular time.

Monitoring	Location	Frequency	Parameters
In-waste monitoring and gas field balancing	Landfill gas wells/manifolds – includes balancing of wells	Monthly – or as risk defines	CH_4, CO_2, O_2, N_2 and gas balance H_2S CO (note: 50 ppm to be used as trigger for potential fire risk) Relative pressure

[2] Steady State – assuming that no significant gas migration is occurring from the site, and the gas extraction systems are operating full-time without significant downtime for the flare.

Monitoring	Location	Frequency	Parameters
	Landfill gas extraction system for representative sample from each of Zone 1 and Zone 3.	Annual	Trace gases in accordance with English EA guidance LFTGN04
	Leachate extraction well (at least one in Zone 1 and one in Zone 3 for gas monitoring under static conditions).	Monthly	CH_4, CO_2, O_2, N_2 and gas balance H_2S CO (note: 50 ppm to be used as trigger for potential fire risk) Relative pressure
Perimeter	Perimeter boreholes	Monthly – or as risk defines	CH_4, CO_2, O_2, N_2 and gas balance Flow Relative pressure Atmospheric pressure
Flare	Inlet	Automated continuous monitoring	Temperature, CH_4, CO_2, O_2, and gas flow rate
Flare	Inlet	Manual monitoring (monthly)	Inlet pressure CH_4, CO_2, O_2, N_2 and gas balance, H_2S and CO.
	Output	Annual emissions monitoring	NOx, CO and Total VOCs, plus any other species identified by air dispersion assessment. Monitoring in line with EPA Guidance Note on Landfill Flare and Engine Management and Monitoring (AG7)
Surface emissions*	Site wide – capping integrity, edge effects, and vent trenches	Bi-annual – or as risk defines, or in response to observations or complaints	CH_4 with FID If high CH_4 emissions are identified (>100 ppmv over capping or 1,000 ppmv at discrete infrastructure), flux box analysis and trace gas analysis should also be considered to check for exposure risk.
Gas Alarms	As installed – TBC, e.g. compound building	Automated continuous monitoring	CH_4, CO_2, H_2S and CO (or gases identified through risk assessment)
Within buildings on site	e.g. changing room and landfill infrastructure compound buildings if gas alarms not installed	Weekly	CH_4 with FD CO_2, H_2S and CO with GA5000
Topography	Whole site to determine areas of settlement	Annual	Topographical survey.

* refer to UK EA LFTGN07 Guidance for Monitoring Surface Emissions for procedure. Walkover stage only required unless there is a requirement to quantify emissions through flux box analysis.

Table 4.3 : Provisional gas monitoring locations, parameters and frequencies

5. Future Gas Management

5.1 Remediation Phase

The remediation works to be undertaken at the site are likely to be in the order of three to four years duration. During this period, there will be excavation and movement of some wastes to achieve the agreed planning landform. At this stage high level outline remediation phasing plans (Drawing Numbers 32EW5604-00-27 and 32EW5604-00-028) have been developed for achieving the remediation of the site and as such only outline gas management proposals have been developed for this, as the scope and the phasing may change.

During the works additional or replacement interim gas controls may need to be installed to:

- Ensure risk of lateral off-site migration is not increased; and
- Minimise emissions of gas to atmosphere to minimise risk of increasing off-site odours.

The proposals for gas monitoring will need to be bespoke for the remediation works in order to assess the changing nature of the site and associated impacts from gas migration.

Each phase and stage of remedial works will require the contractor appointed to undertake the remediation works to produce a detailed method statement of working which will include assessment of potential environmental, health and safety risks and details of measures to mitigate the gas risks. This will include full development of a detailed phased gas management plan to be approved by the Operator prior to any work taking place. Once approved the Designated Representative will have the responsibly to communicate the method statements and plan to the relevant people involved with the works and ensure compliance with the plan and the method statements. Mitigation measures will need to fulfil the following interconnected objectives:

- Reduce likelihood of increased lateral off-site migration of landfill gas;
- Control gas emissions to air (and hence odours);
- Minimise dust emissions from the site;
- Reduce potential to contaminate surface water run-off with leachate and suspended solids; and
- Minimise attraction of insects such as flies and scavenging birds to the site.

In general with respect to further control of lateral gas migration during remedial works, the following options are available:

- Reduce migration risk by (where possible) not covering existing uncapped areas of wastes with materials, thus preventing risk of increased gas migration from occurring (if feasible, use existing areas of concrete hardstanding as temporary storage areas for materials);
- Conduct regular balancing and adjustment of existing well field to ensure extraction wells are providing sufficient control adjacent to areas where there is a risk of increasing lateral migration of gas;
- If coverage with existing gas wells is determined to be inadequate (for example if FID surveys detect emissions or migration is occurring), install new temporary wells and connecting pipework to existing flare to increase gas capture. Dependent on the issue push wells/pin wells may be able to be deployed rather than full depth wells; and
- Increase frequency of monitoring of off-site boreholes within zone of risk during the particular stage of remedial works, to monitor any changes in off-site migration.

Throughout the period of remediation works monitoring of all off-site boreholes should be conducted at least monthly. During active remedial works, or where materials are moved on to uncapped areas of wastes for temporary storage, more frequent monitoring of off-site boreholes adjacent to affected areas is likely to be required. Frequency will be determined by the risk assessment for each phase of works and incorporated within the method statement for working.

In broad terms the outline gas management approach to be undertaken during remediation works is set out in Table 5.1. Reference should be made to the final proposed gas management scheme in Drawing Number 32EW5604-00-043, and the Outline Remediation Phasing Drawings 32EW5604-00-27 and 32EW5604-00-028.

Activity	Gas Management Proposals
Prior to remediation works.	• Installation of perimeter boreholes. • On-going monitoring of all perimeter wells. Perimeter monitoring data to be collated and used as baseline for detection of migration and increased risk e.g. determination of trends. • Continued extraction from the site via the existing temporary flare system and installed wells.
Works to site entrance and access area, including construction of new Landfill Infrastructure Compound.	• Continued extraction from Zones 1 and 3 via the existing temporary flare system and installed wells. • Continue perimeter borehole monitoring at agreed frequency. • Wells within Zone 3 should be left intact where possible during filling of Zone 3, and extraction maintained on those wells. • Increased perimeter borehole monitoring adjacent to areas where substantial stockpiles have been placed. • Additional temporary extraction to be installed within Zone 3 should monitoring indicate unacceptable risk.
Remediation of slopes in Zone 4, including the removal of wastes. Clean materials to be stockpiled on Zones 2A and 2B for re-use within Zone 4 or elsewhere on site. Waste materials to be disposed of within Zone 3 or Zone 1. Remediation and capping of Zone 1A working progressively onto Zone 1.	• Continued extraction from the site via the existing temporary flare system and all installed operational wells. • Wells within Zone 3 should be left intact where possible during filling and re-profiling of Zone 3, and extraction maintained on those wells. • Increased perimeter borehole monitoring on Zones 2A and 2B adjacent to areas where substantial stockpiles have been placed, as this may increase migration risk. • Additional temporary extraction to be installed within Zone 3 should monitoring indicate unacceptable risk. • Consideration of installation of temporary extraction to be installed within Zones 2A and 2B should monitoring indicate an unacceptable risk. • Installation of extraction wells on completed capping on Zone 1, connected to temporary flare. • Increased monitoring frequency of perimeter boreholes along the L2005 Kerdiffstown Road, adjacent to capping works.
Capping of Zone 3, continued progressive capping of Zone 1 and capping of Zone 4 and formation of surface water ponds.	• Continued extraction from the site via the existing temporary flare system and all installed operational wells. • Continued phased installation of extraction wells within Zone 1 on completion of capping. • Increased monitoring frequency of perimeter boreholes along the L2005 Kerdiffstown Road, adjacent to capping works. • As soon as practical, after capping Zone 3, installation of permanent gas extraction wells to support retained existing wells. Wells to be connected to existing temporary extraction system.

Activity	Gas Management Proposals
	• Pipework installed to allow future changeover to the new extraction system and flare in the landfill infrastructure compound. • Continue increased perimeter borehole monitoring on Zones 2A and 2B adjacent to areas where substantial stockpiles have been placed. • Consideration of installation of temporary extraction to be installed within Zones 2A and 2B should monitoring indicate an unacceptable risk. • First phases of wells in Zone 1 and 3 to be monitored under active extraction via a pumping trial to ascertain achievable long-term extractable yield.
Continued phased capping of Zone 1 and progressive capping of 2B beyond extents of concrete slabs.	• Continued extraction from the site via the existing temporary flare system and all installed operational wells. • Install perimeter venting trenches and associated pipework prior to capping of Zone 2B. Capping with gas drainage layer progressively installed and tied into perimeter vent trench for Zone 2B. • Zone 1: installation of the perimeter extraction mains and manifolds. • Capping to be installed in phases, requiring the corresponding phased decommissioning of currently installed extraction wells to permit cap system installation. • New gas extraction wells to follow as soon as practicable in phases. • Connection of extraction wells to manifolds and perimeter mains. • Pumping trial data to be used to inform capacity and specification of final permanent flare (consider low-calorific flare if suitable). • Final installation and commissioning of permanent flare or operation of temporary flare within compound, pending certainty over extractable yield. • Increased monitoring frequency for all perimeter boreholes. • Consideration of conversion of vertical vents within vent trench to vertical cowls or installation of temporary extraction within Zones 2A and 2B should monitoring indicate an unacceptable risk. • Monitoring of vent trench with FID to check emissions within acceptable levels. • Conversion of vent trench to include bioxidation if venting emissions deemed at an unacceptable level. • Walkovers of installed capping with FID to ensure engineering integrity and acceptable emissions, particularly edge effects where tying in capping with concrete platforms and other infrastructure features.
Final profile and capping for Zone 1 and capping of Zone 2A.	• Continued extraction from the site to the landfill gas compound from all installed operational wells, with connection to permanent flare within landfill infrastructure compound once commissioned. • Continue FID walkover surveys on capped areas to monitor for effects of installation of capping on Zone 1, including tie-ins to Zones 2A and 2B.

Activity	Gas Management Proposals
Final site works – final installation of park infrastructure and planting.	• Connection of extraction system to permanent flare in landfill infrastructure compound if not undertaken in previous phase. • Reduce monitoring frequency back to monthly if appropriate i.e. extraction system operating effectively, gas extraction stable without major fluctuations and no gas migration issues being detected. • FID surveys for cap, infrastructure, vent trenches to check for gas issues. • Site enters Aftercare Phase for gas management, and monitoring schedule in Section 4.8.

Table 5.1 : Remediation Phase activities and gas management proposals

5.2 Operational Phase

Gas management proposals for the Operational Phase at the site are likely to follow that identified for the Remediation Phase, augmented by the addition of the new gas management system and requirements of specific guidance on flares and surface emissions. This will be informed by the added background data, confirmation of detailed design, pumping trials, operational data and IED Licence. This section will be updated accordingly.

6. Action Plan

The following Action Plan provides the outline for processes to be followed when incidents associated with the gas management system arise.

Incident	Actions
Landfill gas detected in perimeter boreholes above trigger levels (1% methane and 1.5% carbon dioxide)	• Report incident to Site Manager. • Consider results in relation to gas risk to receptors. • Consider emergency response and evacuation if situation presents unacceptable risk. • Increase monitoring frequency of subject borehole and neighbouring boreholes. • Check adjacent gas management infrastructure (extraction wells or vent trench) for issues. • Check service ducts and service access points within vicinity for gas (be mindful of risks of confined spaces). • Check replenishing rate - concentration and flow after evacuating borehole. • Increase suction on neighbouring extraction wells to see if linkage, and if this resolves the problem (over sufficient time). • Consider installation of additional gas extraction (Zone 1 and 3) wells in area affected if problem persists. • Consider modifications to gas management (Zones 2A and 2B) e.g. aspiramatic cowls or connection to active extraction if migration is detected from passive zones. • If problem persists, or if gas monitoring indicates increasing trend then undertake FID survey of properties, evacuating property if found to be unacceptable risk. • Install gas monitoring and alarms within properties affected once issue resolved.
Gas Flare Shut Down	• Report incident to Site Manager. • Back-up flare should be operated. • Check cause of failure and re-ignite if possible. • Set to vent mode (if available) and re-balance site wells, or re-balance using back-up flare if issue due to poor gas quality or flow. • Check extraction systems for air ingress issues during balancing, shut off sections subject to unacceptable air ingress, then re-ignite. • Monitor perimeter boreholes, and other related infrastructure for migration effects from flare shut-down or adjustment to gas field • Monitoring gas internal and external to site on a daily basis if flare shut down persists for more than a day, call flare supplier to trouble shoot, modifications or repairs to flare as required. • Once issue is fixed re-balance site.

Incident	Actions
Gas extraction system compromised (gas wells, manifolds or carrier mains)	• Report incident to Site Manager. • Isolate leak via the extraction system valves. • Mark out and fence off safety zone, consider restricting public access to area of the site. • Rectify cause with supplies and tools on site if possible, if not order relevant parts or specialist contractor assistance to fix. • Increase perimeter monitoring frequency on adjacent perimeter monitoring wells to check for migration. • Consider increasing suction on adjacent gas extraction wells to alleviate any issues. • Once issue is fixed re-balance site.
Capping compromised (gas emissions detected during FID survey, air ingress or gas escape noted, settlement, or erosion issues etc.)	• Report incident to Site Manager. • Mark out and fence off safety zone, consider restricting public access to area of the site. • Balance site in affected area to allow maximum suction without drawing in excess air (Zones 1 and 3). • Arrange for repair of the cap. • Once issue is fixed re-balance site.
Landfill fire detected (trigger 100ppm CO)	• Report incident to Site Manager and emergency services if appropriate. • Only take the following steps if safe to do so: • Mark out and fence off safety zone, consider restricting public access to area of the site. • Take laboratory sample to confirm analysis. • Check extraction pressures of wells within local vicinity, and gas concentrations of extracted gases. Refer to UK Industry Code of Practice Management and Prevention of Sub-Surface fires (C&P Environmental) for guidance. • If confirmed fire then restrict gas extraction from affected area. • Increase monitoring and balancing in the affected area to see if the issue can be alleviated. Balance affected area of site to keep oxygen levels as low as possible. Note: high CO results may persist in the waste mass after the fire is extinguished. • Change balancing approach to ensure similar problems do not occur in future and that oxygen is not drawn into the site where the fire was located.

Following incidents occurring at the site the Action Plan should be updated to ensure that the document is kept relevant.

Appendix A. Relevant Guidance Documents

Below is a non-exhaustive list of guidance. Review of this and prevailing best practice should be made on future updates to this Management Plan:

Guidance	Year
Guidance Note on Landfill Flare and Engine Management and Monitoring (AG7)	2012
Policy: Monitoring of Stack Emissions at EPA Licensed Sites	2012
Basic Air Monitoring Checklist for Licensees	2011
Management of Low Levels of Landfill Gas	2011
Guidance Note on Site Safety Requirements for Air Emissions Monitoring (AG1)	2010
Odour Impact Assessment Guidance for EPA Licensed Sites (AG5)	2010
Air Guidance Note - Surface VOC Emissions Monitoring on Landfill Facilities (AG6)	2010
Climate Change Research Programme (CCRP) 2007-2013: Report Series No. 3 - Estimates of Methane Recovery in Landfill Gas Flaring and Utilisation	2009
Summary Report - Independent Assessment of Landfill Gas Emissions and Management Systems at 29 EPA Licensed Landfills in the Republic of Ireland	2009
Air Guidance Note on the Implementation of I.S. EN 14181 (AG3)	2008
Annual Surveillance test (AST) Report summary format - AG3	2008
Air Emissions Monitoring Guidance Note #2 (AG2)	2007
Landfill Manual - Guidance note of Landfill Monitoring	2003
Landfill Manuals Landfill Monitoring	2003
Landfill Site Design	2000
Landfill Manuals Investigations for Landfills	1995
Landfill Manuals Landfill Operational Practices	1997
Landfill Manuals Landfill Restoration and Aftercare	1999
The Safety, Health and Welfare at Work (Construction) Regulations 2013 SI 291	2013
The Safety, Health and Welfare at Work Act	2005
ATEX 1999/92/EC Directive, the Worker Protection Directive (also known as the ‘ATEX 137’ Directive), concerned with the “minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres”	1999
ATEX 94/9/EC Directive, the ATEX ‘Product’ Directive, concerned with the manufacture of equipment and protective systems designed for use in potentially explosive atmospheres	1994

The UK landfill industry has also developed a series of Industry Codes of Practice (ICoPs), comprising guidelines on compliance with ATEX regulations with respect to landfill gas, leachate, drilling and general landfill operations, including the undertaking of area classifications / zoning around landfill infrastructure.

Available [Online] from www.esauk.org/reports_press_releases/esa_reports/dsear_guidance.html [accessed 9 December 2016].

Appendix B. GasSim Model

[Refer to Hard Copy for CD Rom]

Project Details

Project Name	**Kerdiffstown Landfill**
Client	Kildare County Council
Model	c:\users\scooke\documents\kerdiffs data\final gassim\kerdiff 2016 v4.gss
Model Date	09/03/2017 13:47:07
Comments	Start Year 2011 Operation Period 7 Simulation Period 150 Iterations 100 Confined Migration Pathway

Waste Composition

Year	*Composition*
2011	Kerdiffstown half degradability
Newspapers	
User Defined 1	SINGLE(5.0)
User Defined 2	SINGLE(1.5)
User Defined 3	SINGLE(5.0)
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(48.5)
Hemi-Cellulose (%)	SINGLE(9.0)
Decomposition (%)	SINGLE(17.5)
Magazines	
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(42.3)
Hemi-Cellulose (%)	SINGLE(9.4)
Decomposition (%)	SINGLE(46.0)
Other paper	
Domestic	SINGLE(18.2)
Civic Amenity	SINGLE(3.3)
Commercial	SINGLE(28.8)
Industrial	SINGLE(8.8)
User Defined 1	SINGLE(5.0)
User Defined 2	SINGLE(1.5)
User Defined 3	SINGLE(5.0)
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(87.4)
Hemi-Cellulose (%)	SINGLE(8.4)
Decomposition (%)	SINGLE(49.0)
Liquid cartons	
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(57.3)
Hemi-Cellulose (%)	SINGLE(9.9)
Decomposition (%)	SINGLE(64.0)
Card packaging	
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(57.3)
Hemi-Cellulose (%)	SINGLE(9.9)
Decomposition (%)	SINGLE(64.0)
Other card	
Water (%)	SINGLE(30.0)
Cellulose (%)	SINGLE(57.3)
Hemi-Cellulose (%)	SINGLE(9.9)
Decomposition (%)	SINGLE(64.0)
Wood	
Domestic	SINGLE(2.8)
Civic Amenity	SINGLE(11.2)
Commercial	SINGLE(3.3)
Industrial	SINGLE(5.0)
User Defined 1	SINGLE(31.0)
User Defined 2	SINGLE(11.0)
User Defined 3	SINGLE(31.0)
Water (%)	SINGLE(20.0)
Cellulose (%)	SINGLE(21.0)
Hemi-Cellulose (%)	SINGLE(11.0)
Decomposition (%)	SINGLE(37.5)
Textiles	
Domestic	SINGLE(1.8)
Civic Amenity	SINGLE(2.3)
Commercial	SINGLE(1.1)
Industrial	SINGLE(0.3)
User Defined 1	SINGLE(11.0)
User Defined 2	SINGLE(2.0)
User Defined 3	SINGLE(11.0)
Water (%)	SINGLE(25.0)

Cellulose (%)	SINGLE(20.0)
Hemi-Cellulose (%)	SINGLE(20.0)
Decomposition (%)	SINGLE(25.0)
Disposable nappies	
Domestic	SINGLE(2.3)
Civic Amenity	SINGLE(2.9)
Water (%)	SINGLE(20.0)
Cellulose (%)	SINGLE(25.0)
Hemi-Cellulose (%)	SINGLE(25.0)
Decomposition (%)	SINGLE(50.0)
Other misc. combustibles	
Domestic	SINGLE(7.1)
Civic Amenity	SINGLE(4.2)
Commercial	SINGLE(10.4)
Industrial	SINGLE(17.7)
User Defined 2	SINGLE(1.0)
Water (%)	SINGLE(20.0)
Cellulose (%)	SINGLE(25.0)
Hemi-Cellulose (%)	SINGLE(25.0)
Decomposition (%)	SINGLE(50.0)
Garden waste	
Domestic	SINGLE(14.2)
Civic Amenity	SINGLE(32.1)
Commercial	SINGLE(9.8)
Industrial	SINGLE(4.7)
Water (%)	SINGLE(65.0)
Cellulose (%)	SINGLE(25.7)
Hemi-Cellulose (%)	SINGLE(13.0)
Decomposition (%)	SINGLE(62.0)
Other putrescible	
Domestic	SINGLE(19.8)
Civic Amenity	SINGLE(14.8)
Commercial	SINGLE(10.4)
Industrial	SINGLE(6.8)
Water (%)	SINGLE(65.0)
Cellulose (%)	SINGLE(55.4)
Hemi-Cellulose (%)	SINGLE(7.2)
Decomposition (%)	SINGLE(76.0)
10mm fines	
Domestic	SINGLE(5.4)
Civic Amenity	SINGLE(1.2)
Commercial	SINGLE(1.9)
Industrial	SINGLE(0.5)
Water (%)	SINGLE(40.0)
Cellulose (%)	SINGLE(25.0)
Hemi-Cellulose (%)	SINGLE(25.0)
Decomposition (%)	SINGLE(50.0)
Sewage sludge	
Sewage Sludge	SINGLE(100.0)
Water (%)	SINGLE(70.0)
Cellulose (%)	SINGLE(14.0)
Hemi-Cellulose (%)	SINGLE(14.0)
Decomposition (%)	SINGLE(75.0)
Composted organic material	
Composted Organic Material	SINGLE(100.0)
Water (%)	SINGLE(30.0)
Cellulose (%)	UNIFORM(7.47, 9.59)
Hemi-Cellulose (%)	UNIFORM(7.47, 9.59)
Decomposition (%)	SINGLE(57.0)
Incinerator ash	
Commercial	SINGLE(0.2)
Industrial	SINGLE(25.5)
Incinerator Ash	SINGLE(100.0)
Water (%)	SINGLE(30.0)
Cellulose (%)	TRIANGULAR(0.5, 0.7, 1.5)
Hemi-Cellulose (%)	TRIANGULAR(0.5, 0.7, 1.5)
Decomposition (%)	SINGLE(57.0)
Non degradable	
Domestic	SINGLE(28.4)
Civic Amenity	SINGLE(28.0)
Commercial	SINGLE(34.1)
Industrial	SINGLE(30.7)
Inert	SINGLE(100.0)
User Defined 1	SINGLE(48.0)
User Defined 2	SINGLE(83.0)

User Defined 3	SINGLE(48.0)
Water (%)	SINGLE(0.0)
Cellulose (%)	SINGLE(0.0)
Hemi-Cellulose (%)	SINGLE(0.0)
Decomposition (%)	SINGLE(0.0)
Calcium Sulphate (%)	
Domestic	TRIANGULAR(0.2, 0.35, 2.3)
Civic Amenity	TRIANGULAR(0.2, 0.35, 2.3)
Composted Organic Material	TRIANGULAR(0.2, 0.35, 2.3)
Incinerator Ash	TRIANGULAR(0.2, 0.35, 2.3)
Residues from MRF	TRIANGULAR(0.2, 0.35, 2.3)
Recycling Schemes	TRIANGULAR(0.2, 0.35, 2.3)
Chemical Sludge	TRIANGULAR(0.2, 0.35, 2.3)
Industrial Liquid Waste	TRIANGULAR(0.2, 0.35, 2.3)
Iron (%)	
Domestic	TRIANGULAR(0.3, 4.8, 8.2)
Civic Amenity	TRIANGULAR(0.3, 4.8, 8.2)
Commercial	TRIANGULAR(0.3, 4.8, 8.2)
Industrial	TRIANGULAR(0.3, 4.8, 8.2)
Inert	TRIANGULAR(0.3, 4.8, 8.2)
Liquid Inert	TRIANGULAR(0.3, 4.8, 8.2)
Sewage Sludge	TRIANGULAR(0.3, 4.8, 8.2)
Composted Organic Material	TRIANGULAR(0.3, 4.8, 8.2)
Incinerator Ash	TRIANGULAR(0.3, 4.8, 8.2)
Residues from MRF	TRIANGULAR(0.3, 4.8, 8.2)
Recycling Schemes	TRIANGULAR(0.3, 4.8, 8.2)
Chemical Sludge	TRIANGULAR(0.3, 4.8, 8.2)
Industrial Liquid Waste	TRIANGULAR(0.3, 4.8, 8.2)
User Defined 1	TRIANGULAR(0.3, 4.8, 8.2)
User Defined 2	TRIANGULAR(0.3, 4.8, 8.2)
User Defined 3	TRIANGULAR(0.3, 4.8, 8.2)
2012	Kerdiffstown half degradability
2013	Kerdiffstown half degradability
2014	Kerdiffstown half degradability
2015	Kerdiffstown half degradability
2016	Kerdiffstown half degradability
2017	Kerdiffstown half degradability
Justification:	[Changed] Not Justified

Trace Gases

No Combustion Products Selected

Zone 1

Infiltration	SINGLE(720.0)
Justification:	[Changed] Not Justified

Waste Input

Year	Amount Depositied (t)
2011	SINGLE(2.15E+06)
Justification:	[Changed] Not Justified

Waste Breakdown

2011

User Defined 1	SINGLE(100.0)
Justification:	[Default] Default Value

Trace Gases

No Trace Gases Selected

Waste Moisture Content

Degradation rate - Filling Phase	Average
Justification:	[Changed] Not Justified
Degradation rate - after change	Average
Justification:	[Changed] Not Justified
Waste Density	UNIFORM(0.8, 1.2)
Justification:	[Default] Default Value
Leachate Head	SINGLE(1.0)
Justification:	[Default] Default Value
Hydraulic Conductivity	LOGUNIFORM(1.00E-09, 1.00E-05)
Justification:	[Default] Default Value

Engineered Controls

Cap Composite	
First Layer:	
Cap Thickness	SINGLE(0.6)
Cap Hydraulic Conductivity	SINGLE(1.00E-09)
Second Layer:	
Cap 2 Thickness	SINGLE(0.03)
Cap 2 Hydraulic Conductivity	SINGLE(1.00E-09)
Justifications	
Cap	[Changed] Not Justified

Cap Thickness	[Changed]	Not Justified
Cap Hydraulic Conductivity	[Changed]	Not Justified
Liner	None	
Justifications		
Liner	[Default]	Default Value
Liner Thickness	[Changed]	Not Justified
Liner Hydraulic Conductivity	[Changed]	Not Justified
Justification:	[Default]	Default Value
Methane Oxidation %	SINGLE(10.0)	
Justification:	[Default]	Default Value
Land Raise Depth	SINGLE(20.0)	

Geosphere

Ground Surface (mAOD)	100
Water Table (mAOD)	80
Geosphere Moisture Content	SINGLE(5.0)
Geosphere Porosity	SINGLE(10.0)

Zone 2a

Infiltration	SINGLE(720.0)
Justification:	[Changed] Not Justified

Waste Input

Year Amount	Depositied (t)	
2011	SINGLE(4.12E+05)	
Justification:	[Changed]	Not Justified

Waste Breakdown

2011

User Defined 2	SINGLE(100.0)	
Justification:	[Default]	Default Value

Trace Gases

No Trace Gases Selected

Waste Moisture Content

Degradation rate - Filling Phase	Average	
Justification:	[Changed]	Not Justified
Degradation rate - after change	Average	
Justification:	[Changed]	Not Justified
Waste Density	UNIFORM(0.8, 1.2)	
Justification:	[Default]	Default Value
Leachate Head	SINGLE(1.0)	
Justification:	[Default]	Default Value
Hydraulic Conductivity	LOGUNIFORM(1.00E-09, 1.00E-05)	
Justification:	[Default]	Default Value

Engineered Controls

Cap	*SINGLE* Clay	
Cap Thickness	SINGLE(0.6)	
Cap Hydraulic Conductivity	SINGLE(1.00E-09)	
Justifications		
Cap	[Changed]	Not Justified
Cap Thickness	[Changed]	Not Justified
Cap Hydraulic Conductivity	[Changed]	Not Justified
liner	None	
Justifications		
Liner	[Default]	Default Value
Liner Thickness	[Changed]	Not Justified
Liner Hydraulic Conductivity	[Changed]	Not Justified
Justification:	[Default]	Default Value
Methane Oxidation %	SINGLE(10.0)	
Justification:	[Default]	Default Value
Land Raise Depth	SINGLE(5.0)	

Geosphere

Ground Surface (mAOD)	100
Water Table (mAOD)	80
Geosphere Moisture Content	SINGLE(5.0)
Geosphere Porosity	SINGLE(10.0)

Zone 2b

Infiltration	SINGLE(720.0)
Justification:	[Changed] Not Justified

Waste Input

Year	Amount Depositied (t)
2011	SINGLE(3.12E+05)
Justification:	[Changed] Not Justified

Waste Breakdown

2011

User Defined 2	SINGLE(100.0)

Justification: [Default] Default Value

Trace Gases

No Trace Gases Selected

Waste Moisture Content

Degradation rate - Filling Phase	Average	
Justification:	[Changed]	Not Justified
Degradation rate - after change	Average	
Justification:	[Changed]	Not Justified
Waste Density	UNIFORM(0.8, 1.2)	
Justification:	[Default]	Default Value
Leachate Head	SINGLE(1.0)	
Justification:	[Default]	Default Value
Hydraulic Conductivity	LOGUNIFORM(1.00E-09, 1.00E-05)	
Justification:	[Default]	Default Value

Engineered Controls

Cap	*SINGLE* Clay	
Cap Thickness	SINGLE(0.6)	
Cap Hydraulic Conductivity	SINGLE(1.00E-09)	
Justifications		
Cap	[Changed]	Not Justified
Cap Thickness	[Changed]	Not Justified
Cap Hydraulic Conductivity	[Changed]	Not Justified
liner	None	
Justifications		
Liner	[Default]	Default Value
Liner Thickness	[Changed]	Not Justified
Liner Hydraulic Conductivity	[Changed]	Not Justified
Justification:	[Default]	Default Value
Methane Oxidation %	SINGLE(10.0)	
Justification: [Default] Default Value		
Land Raise Depth	SINGLE(5.0)	

Geosphere

Ground Surface (mAOD)	100	
Water Table (mAOD)	80	
Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	
Zone 3		
Infiltration	SINGLE(720.0)	
Justification:	[Changed] Not Justified	

Waste Input

Year	Amount Depositied (t)	
2011	SINGLE(2.49E+05)	
Justification:	[Changed]	Not Justified

Waste Breakdown

2011		
User Defined 3	SINGLE(100.0)	
Justification:	[Default]	Default Value

Trace Gases

No Trace Gases Selected

Waste Moisture Content

Degradation rate - Filling Phase	Average	
Justification:	[Changed]	Not Justified
Degradation rate - after change	Average	
Justification:	[Changed]	Not Justified
Waste Density	UNIFORM(0.8, 1.2)	
Justification:	[Default]	Default Value
Leachate Head	SINGLE(1.0)	
Justification:	[Default]	Default Value
Hydraulic Conductivity	LOGUNIFORM(1.00E-09, 1.00E-05)	
Justification:	[Default]	Default Value

Engineered Controls

Cap	Composite	
First Layer:		
Cap Thickness	SINGLE(0.6)	
Cap Hydraulic Conductivity	SINGLE(1.00E-09)	
Second Layer:		
Cap 2 Thickness	SINGLE(0.03)	
Cap 2 Hydraulic Conductivity	SINGLE(1.00E-09)	
Justifications		
Cap	[Changed]	Not Justified
Cap Thickness	[Changed]	Not Justified
Cap Hydraulic Conductivity	[Changed]	Not Justified

liner	*SINGLE* Liner	
Liner Thickness	SINGLE(0.03)	
Liner Hydraulic Conductivity	SINGLE(1.00E-09)	
Justifications		
Liner	[Changed]	Not Justified
Liner Thickness	[Changed]	Not Justified
Liner Hydraulic Conductivity	[Changed]	Not Justified
Justification:	[Default]	Default Value
Methane Oxidation %	SINGLE(10.0)	
Justification:	[Default]	Default Value
Land Raise Depth	SINGLE(8.0)	

Geosphere

Ground Surface (mAOD)	100
Water Table (mAOD)	80
Geosphere Moisture Content	SINGLE(5.0)
Geosphere Porosity	SINGLE(10.0)

Zone 4

Infiltration	SINGLE(720.0)	
Justification:	[Changed]	Not Justified

Waste Input

Year	Amount Depositied (t)	
2011	SINGLE(1.92E+05)	
Justification:	[Changed]	Not Justified

Waste Breakdown

2011

User Defined 2	SINGLE(100.0)	
Justification:	[Default]	Default Value

Trace Gases

No Trace Gases Selected

Waste Moisture Content

Degradation rate - Filling Phase	Average	
Justification:	[Changed]	Not Justified
Degradation rate - after change	Average	
Justification:	[Changed]	Not Justified
Waste Density	UNIFORM(0.8, 1.2)	
Justification:	[Default]	Default Value
Leachate Head	SINGLE(1.0)	
Justification: [Default] Default Value		
Hydraulic Conductivity	LOGUNIFORM(1.00E-09, 1.00E-05)	
Justification:	[Default]	Default Value

Engineered Controls

Cap	*SINGLE* Clay	
Cap Thickness	SINGLE(0.6)	
Cap Hydraulic Conductivity	SINGLE(1.00E-06)	
Justifications		
Cap	[Changed]	Not Justified
Cap Thickness	[Changed]	Not Justified
Cap Hydraulic Conductivity	[Changed]	Not Justified
liner	None	
Justifications		
Liner [Default] Default Value		
Liner Thickness	[Changed]	Not Justified
Liner Hydraulic Conductivity	[Changed]	Not Justified
Justification:	[Default]	Default Value
Methane Oxidation %	SINGLE(10.0)	
Justification:	[Default]	Default Value
Land Raise Depth	SINGLE(2.0)	

Geosphere

Ground Surface (mAOD)	100
Water Table (mAOD)	80
Geosphere Moisture Content	SINGLE(5.0)
Geosphere Porosity	SINGLE(10.0)

Site Characteristics

Proportion to CO2 [%]	SINGLE(50.0)	
Justification: [Default] Default Value		
Proportion to CH4 [%]	SINGLE(50.0)	
Justification:	[Default]	Default Value

Cellulose Decay Rates

Slow Moderate Fast			
Dry	SINGLE(0.013)	SINGLE(0.046)	SINGLE(0.076)
Average	SINGLE(0.046)	SINGLE(0.076)	SINGLE(0.116)
Wet	SINGLE(0.076)	SINGLE(0.116)	SINGLE(0.694)

Saturated	SINGLE(0.013)	SINGLE(0.046)	SINGLE(0.076)
User Defined 1	SINGLE(0.046)	UNIFORM(0.046, 0.076)	UNIFORM(0.076, 0.116)
User Defined 2	UNIFORM(0.046, 0.076)	UNIFORM(0.076, 0.116)	UNIFORM(0.116, 0.694)
Justification:	[Default]	Default Value	

Gas Plant

No Flares/Engines in use

Engine/Flare Order	[Default]	Default Value

Trace Gas Plant

No Trace Gases Selected

Justification:	[Default]	Default Value

Global Impact

Bulk Gases

Global Warming Potential

Carbon Dioxide [t]:	1	
Methane [t carbon dioxoide]:	21	
Hydrogen [t carbon dioxide]:	0	
Justification:	[Default]	Default Value

Ozone Depletion Potential

Carbon Dioxide [t trichlorofluoromethane]:	0	
Methane [t trichlorofluoromethane]:	0	
Hydrogen [t trichlorofluoromethane]:	0	
Justification:	[Default]	Default Value

Lateral Migration

Bulk Gases

Air Diffusion Coefficients

CO2 Dispersivity	SINGLE(0.1613)	
CH4 Dispersivity	SINGLE(0.2192)	
H2 Dispersivity	#UNDEFINED?	
Justification:	[Default]	Default Value

Geosphere

Cell Zone 1

Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	

Cell Zone 2a

Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	

Cell Zone 2b

Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	

Cell Zone 3

Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	

Cell Zone 4

Geosphere Moisture Content	SINGLE(5.0)	
Geosphere Porosity	SINGLE(10.0)	
Justification:	[Changed]	Not Justified

Appendix C. Perimeter Borehole Log Summary

Borehole	Strata Description	Gas Generation Potential
EMW01	Clay to 7.3 metres.	Low permeability will inhibit gas movement.
EMW02	Clay to 4.0 metres, sand from 4.0 to 5.5 metres, clay to end of borehole at 6.0 metres.	Confined sand layer has potential to allow gas migration, although sand layer is likely to be saturated so gas migration other than by dissolution is unlikely.
EMW03	Sand and gravel to 4.0 metres, clay to 14.0 metres, gravel from 14.0 to 16.5 metres, clay from 16.5 metres to end of borehole at 17.5 metres.	Sand and gravel layers will allow migration of gas. Gas migrating through the upper layer has ability to dissipate to atmosphere. The lower sand layer is confined but below the water table, so gas migration other than by dissolution is unlikely.
EMW04	Sand and gravel to 3.4 metres, clay to base of borehole at 7.0 metres.	Sand and gravel layers will allow migration of gas. Gas migrating through the upper layer has ability to dissipate to atmosphere.
EMW05	Clay to 2.0 metres, sand and gravel from 2.0 metres to 3.5 metres, clay from 3.5 metres to base of borehole at 6.0 metres.	The sand and gravel layer will allow movement of gas. The sand layer is confined, so there is greater potential for horizontal movement of gas although sand layer is likely to be saturated so gas migration other than by dissolution is unlikely.
EMW06	Sand and gravel to 5.9 metres, clay from 5.9 metres to base of borehole at 7.3 metres.	Sand and gravel layers will allow migration of gas. Gas migrating through the upper layer has ability to dissipate to atmosphere.
EMW07	Clay to 3.0 metres, sand and gravel from 3.0 to base of borehole at 6.0 metres.	The sand and gravel layer will allow movement of gas. The sand layer is confined, so there is greater potential for horizontal movement of gas although sand layer is likely to be saturated so gas migration other than by dissolution is unlikely.
EMW08	Sand to 1.0 metres, clay from 1.0 to 2.0 metres, sand and gravel from 2.0 metres to base of borehole at 5.0 metres.	Sand and gravel layers will allow migration of gas. Gas migrating through the upper layer has ability to dissipate to atmosphere. The lower sand layer is confined but likely to be saturated, so gas migration other than by dissolution is unlikely.
EMW09	Sand and gravel to 19.0 metres. Boulders or weathered bedrock from 19.0 metres to base of borehole at 20.5 metres.	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers.
EMW10	Gravel to 2.3 metres, sand and gravel from 2.3 metres to base of borehole at 20.5 metres.	A large thickness of sand and gravel will allow migration of landfill gas. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers, although the top clay layer will impede dissipation to atmosphere and encourage further lateral migration of gas.
EMW18	Sandy Gravelly clay to 3.2 metres, fine to coarse sandy gravel with occasional cobbles to base of borehole at 6.2.	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers.
EMW19	Clay to 2.0 metres, gravelly clay to 3.0 metres, sandy gravel to 3.9 followed by sand to 8.0, gravelly clay to 8.7 metres, boulder to 9.3 metres followed	The sand and gravel layer will allow movement of gas. The lower sand layer is confined, so there is greater potential for horizontal movement of gas but likely to be saturated, so gas migration other than by dissolution is unlikely.

Borehole	Strata Description	Gas Generation Potential
	by sandy gravel to 10.0 metres. Returns of rock to base of borehole at 15.4 metres.	
EMW20	Fine to coarse sandy gravel with occasional cobbles to base of borehole at 6.1 metres	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers.
EMW21	Made ground to 2.4 metres followed by sandy gravelly clay to 4.9 metres, fine to coarse Sandy gravel with occasional cobbles to base of borehole at 6.7 metres	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers.
EMW22	Sandy slightly gravelly clay with some cobbles to 3.6 metres very sandy slightly gravelly clay with some cobbles and boulders to 15.5 metres, boulders to 16.0 metres followed by returns of sandy gravel to 19.5 metres with bedrock to base of borehole at 24.6 metres	A large thickness of sand and gravel will allow migration of landfill gas through the wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers. Sand and gravel layer is confined at base by bedrock.
EMW23	Clay to 1.8 metres, Sandy gravel to 10.5 metres, Sand from 10.5 to 11.2 metres followed by sandy gravel to 14.8 metres	The sand and gravel layer will allow movement of gas. The lower sand layer is confined, so there is greater potential for horizontal movement of gas.
EMW29	Soft clay to 0.8 metres followed by sandy gravel to 4.5 metres. Sandy gravelly clay to base of borehole at 8.0 metres	The sand and gravel layer will allow movement of gas, although groundwater is close to ground surface at this location, which limits the extent of unsaturated zone through which gas can move.
EMW30	Sandy gravelly clay to 1.8 metres followed by gravelly sand to 10.0 metres followed by sandy gravel to base of borehole at 14.0 metres	A large thickness of sand and gravel will allow migration of landfill gas through a wide cross-sectional area. Migrating gas will tend to dissipate throughout the volume of sand and gravel, rather than migrating along discrete confined layers.

Appendix A4.6 Surface Water Management Plan

Kerdiffstown Landfill Remediation Project (KLRP)

Kildare County Council (KCC)

Surface Water Management Plan

32EW5604/DOC/0042 | 2

30 June 2017

Kerdiffstown Landfill Remediation Project (KLRP)

Project No:	32EW5604
Document Title:	Surface Water Management Plan
Document No.:	32EW5604/DOC/0042
Revision:	2
Date:	30 June 2017
Client Name:	Kildare County Council (KCC)
Client No:	
Project Manager:	Rhianna Rose
Author:	Patryk Ciesla
File Name:	\\Iedub1-fil001\ji\Sustainable Solutions\Kerdiffstown Landfill\4 - Documents\4.3 - Draft Documents\32EW5604 L Additional Design Work\4 Surface Water\KLRP_SWMP Rev 2.docx

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Contents

1. Introduction

1.1 Background

The site of the proposed Project, is located in County Kildare, approximately 3km north-east of central Naas, approximately 400m north-west of Johnstown village and in close proximity to the strategically important M7/N7 corridor. The site is located in close proximity to a number of residential and commercial receptors as well as being a short distance away from the larger settlements of Johnstown and Naas. In addition to the above, the site neighbours a number of recreational land uses, specifically Palmerstown House Estate and Naas Golf Course to the north-east and north-west respectively.

The site occupies approximately 30 hectares and is a former sand and gravel quarry which was progressively backfilled by a number of operators from the 1950s onwards. In January 2011 a major fire developed in a mound of waste material in the northern part of the site. This required intervention of a number of state agencies including Kildare County Council and the Environmental Protection Agency (EPA). The site was under the control of Kildare Fire Service until late February 2011, when it was handed over to the care of the EPA. Since 2011, measures have been taken to secure the site and limit environmental impact.

In April 2015 the Minister for the Environment, Community and Local Government, Alan Kelly TD, announced that funding would be made available for the remediation of the landfill site, and that Kildare County Council would take control of the site and commence remediation.

The objective in remediating the site in terms of surface water management is to:

- Take all necessary and reasonable measures to prevent and limit future leachate impact upon groundwater and surface water receptors and reduce/control the future production of leachate from the site; and
- Reduce contaminant loads discharging to groundwater.

Linked to the overarching objectives of the project is the aim to provide a future landform and end use appropriate for the site and of potential benefit to the local community. To that end, the intended end-use for the site is public access parkland and recreational use.

1.2 Aims and Objectives

This Surface Water Management Plan has been prepared in support of a planning application and industrial emissions licence for the remediation and operational (end-use) phases, outlined as follows:

- *Development / Remediation* – The works required to re-profile the site including excavation of waste and other materials for deposition on site to achieve the proposed final landform. The works will also include the installation of landfill infrastructure such as capping, landfill gas, leachate and surface water management. A second stage of remediation will comprise the works required to restore the site to the proposed park end use, including planting and landscaping, installation of sports pitches, changing rooms, car parks and associated services.
- *Operational / Aftercare* – The life cycle stage of the site following the remediation works when the site will be used for public access parkland and recreation. The responsibility for the management of the site and the landfill infrastructure systems as well as park operation and maintenance will be retained by Kildare County Council (KCC).

At all stages the aim of the management plan is to:

- Develop a strategy for surface water management ensuring that the site is compliant with relevant regulations and best practice at all stages (during development/ remediation and operation / aftercare);
- Ensure that the management plan is based on the current site operations and development, data arising from the site and foreseen future proposals for changes to the site;
- Ensure safety of site operatives and contractors working on site;

- Not increase the future flood risk to land or properties outside the site boundary;
- Avoid adverse impacts and increased pollution risk to local streams and rivers;
- Prevent the escape of excessive sediment that may arise in the initial years following remediation works;
- Be sufficiently flexible to control surface water throughout different phases of the remediation works;
- Integrate with other environmental control systems to be employed as part of the remediation works;
- Be compatible with final restoration and after-use of the site; and
- Reduce potential environmental impact of the site throughout its whole life.

Section 2 of Annex 1 of the 1999 EU Landfill Directive outlines surface water control requirements which are applicable for all classes of landfill sites. The specific requirements with regards to surface water management are:

- Control water from precipitations entering into the landfill body;
- Prevent surface water from entering into the landfilled waste;
- Collect contaminated water and leachate; and
- Treat contaminated water and leachate collected from the landfill to the appropriate standard required for discharge.

This Directive was transposed into Irish law by the Waste Management Licensing Regulations 2004 (S.I. 395 of 2004) and the Waste Management Act 1996 (as amended). The development of the site, comprising remediation works, takes cognisance of the Directive as far as reasonably practicable, whilst applying Best Available Techniques (BAT) where appropriate.

Relevant guidance and best practice documents referred to in the development of this management plan are listed in Appendix A.

1.3 Roles and Responsibilities

This management plan is a live document where site use and operations, monitoring and performance data informs regular updates to the proposals and procedures within the document in order to mitigate the risks posed by surface water. The following provides definition of some of the terms used within the management plan:

- *Operator* – Kildare County Council, who hold responsibility and liability for the operation and maintenance of the surface water management system;
- *Site Manager* – the individual representing the Operator on site during the remediation works and operation of the park/ aftercare of the site; and
- *Designated Representative* – the entity or individual appointed by the Operator to undertake management of the surface water management system for a defined phase of its lifecycle.

The Operator will have full responsibility to ensure that surface water is properly managed on site in accordance with relevant regulations, guidance and best practice at all times and that all activities are fully documented in the Site File.

1.4 Risk Assessment

The control, collection and disposal of surface waters is required to prevent pollution of the environment. By controlling waters from precipitation and surface run-off from entering the waste body the system will also serve to minimise the production of leachate.

The Detailed Qualitative Risk Assessment (DQRA) and operational risk assessments confirm that measures are required to manage surface waters.

2. Surface Water Management Measures

2.1 Design Philosophy

The philosophy and methodology applied to the surface water drainage design is set out in Appendix B, with existing site conditions and future proposals set out below.

2.2 Existing Site Drainage

2.2.1 Site Characteristics

The site is uncapped and as such surface water is not currently collected for formal discharge. The site is classified into zones, with the key surface water management characteristics set out in the table below.

Zone	Key Characteristics
1	Wastes deposited in the north-west area which account for approximately 65% of the entire estimated volume of waste on site. Wastes in this area of the site are currently uncapped and unlined. Rainfall mostly infiltrates into the ground, waste and also runs off to the adjacent ground. No surface water collection system is in place over this zone.
2A	Much of this zone is covered by reinforced concrete pads, which form an impermeable layer over underlying wastes and prevent direct rainwater ingress. In the small area without concrete slabs, rainfall infiltrates into the ground and waste. No surface water collection system is in place over this zone.
2B	Much of this zone is covered by reinforced concrete pads, which form an impermeable layer over the wastes and prevent direct rainwater ingress. In the small area without concrete slabs, rainfall infiltrates into the ground and waste. No surface water collection system is in place over this zone.
3	This zone comprises a lined cell, filled with processed waste materials. The cell has a remaining void capacity to be infilled during the proposed remediation works. The existing waste mass has been temporarily capped using a geomembrane liner, with run-off directed to perimeter trench and directed to an unlined pond located within Zone 4.
4	This zone contains large waste stockpiles, redundant infrastructure including concrete tanks, bays, walls and pads. The pads form an impermeable layer over local pockets of wastes and prevent direct rainwater ingress. No surface water collection system is in place over this zone. A small pond is present discharging surface water run-off from Zone 3 to groundwater.

Previous zoning of the site included Zone 5 which has not shown waste to be present hence is considered as outwith remediation proposals. A large part of this zone currently has houses present with one known to have a septic tank present within the bounds of the property. A further property located to the south-east of the site also has a septic tank which may be discharging to land within the site boundary. Drainage from the site access road is collected in buried pipes and discharges to a settlement tank and directed to the Canal Feeder located to the south of the site. Drainage from a property located to the south of the site discharges via the site road drainage system and settlement tank to the Canal Feeder.

To facilitate construction of an additional pitch as part of the Operational Phase a property and adjoining field located off Kerdiffstown Road and outwith the previous site boundary is to be sought as part of a Compulsory Purchase Order. The land is located immediately adjacent to the site between Zone 1 (to north) and Zone 2A (to south). This land is greenfield and has an approximate ground level of 98mOD. There is no surface water collection system in place over this area with rainfall water infiltrating to the ground.

Foul and grey waters drainage from the existing site offices is collected in a septic tank and removed from site on a regular basis.

The layout of the site is shown on Drawing Number 32EW5604-00-001.

2.2.2 Watercourses / Receptors

The closest watercourse to the site is the Morell River which lies to the north-east of the site. A second small local stream is Canal Feeder located to the south of the site.

The Morell River generally flows northwards within 40m of the site boundary and discharges into the River Liffey approximately 7km northwest of the site. The summary flow statistics downloaded from EPA for existing hydrometric station near the weir adjacent to Kerdiffstown House (gauging station ref. 09044) indicates an annual minimum daily flow rate of 0.059m^3/s and Q95 (95 percentile flow) of 0.119m^3/s (a statistical measure of flow rate based on long-term flow records).

The Hartwell River joins the Morell River upstream from the site. This is not shown on OS mapping but has been surveyed to record this connection. This is shown on the figure below.

The Canal Feeder stream is located approximately 150m south of the site. This generally flows in westward direction and discharges into the Grand Canal, which is located approximately 2km west of the site.

Other surface water features in the area include the Rathmore Stream and the lakes/ponds at Palmerstown House Estate and Golf Course. The Rathmore Stream lies southeast of the site and joins with the Morell River upstream. The lakes / ponds at Palmerstown House Estate and Golf Course are located 100m to the east. The plan showing location of watercourses is shown in Figure 2.1 below.

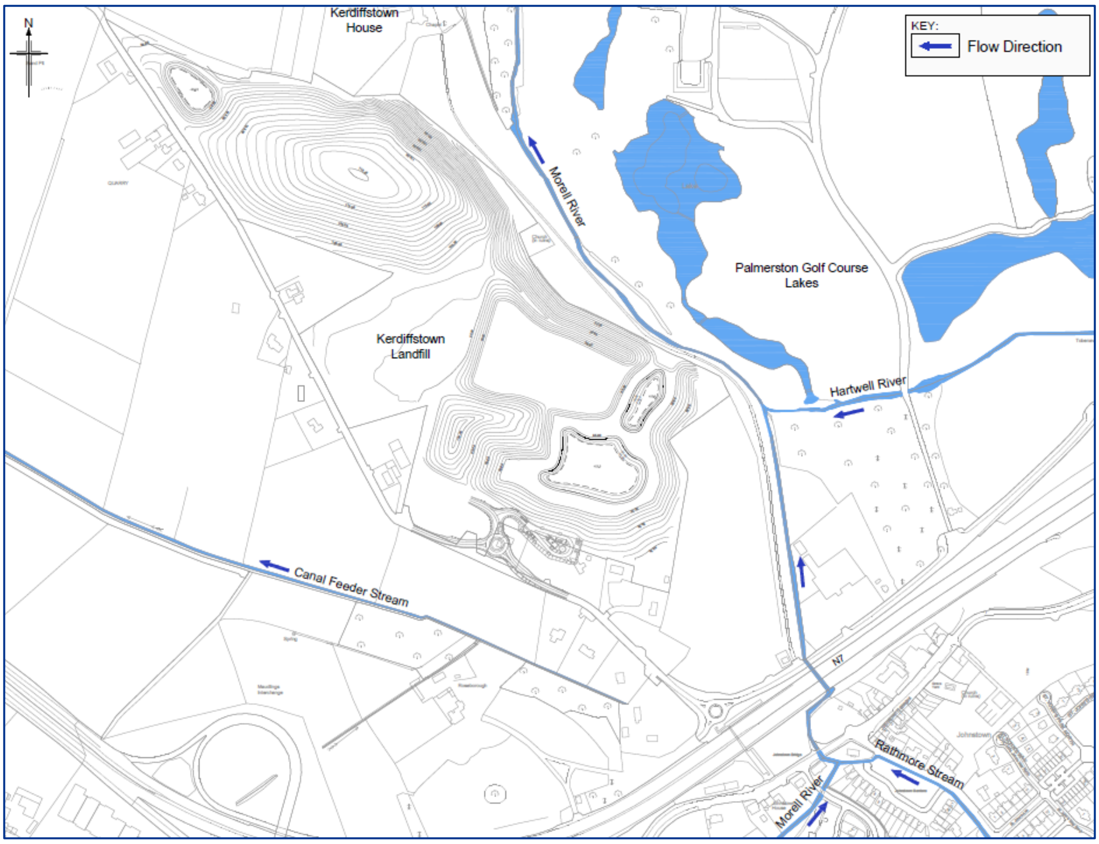

Figure 2.1: Existing watercourses

There is only one existing discharge point from the site into the Canal Feeder Stream in the form of the overflow from the settlement tank adjacent to the site entrance. There is currently no direct discharge from the site to the Morell River.

2.2.3 Surface Water Quality

The Morell River and Canal Feeder Stream are classified as moderate watercourses under Water Framework Directive classification. Baseline water quality monitoring is currently undertaken monthly at several locations on the Morell River and Canal Feeder Stream to determine any detrimental impacts potentially caused by the landfill site. An extended suite of sampling is undertaken on bi-annual basis for an increased number of locations and parameters. Surface water run-off samples are also collected on-site from the oil interceptor located adjacent to the site entrance.

Details of surface water quality are detailed in the Environmental Impact Statement, Chapter 14 Water – Hydrology. Findings are also presented in monthly monitoring reports.

2.3 Remediation Works Measures

Remediation works are to be undertaken in a phased basis, over a period of approximately 3.5 years. This is subject to a number of assumptions. The outline phasing of works is set out in Table 2.1 below.

Phase of Works	Surface Water Management Proposals
Works to site entrance and access area, including construction of new landfill infrastructure compound.	• On-going surface water monitoring around the site. • Re-align existing drainage pipe from adjacent property, around site boundary to reconnect to a buried pipe discharging to Canal Feeder. • Relocate existing or construct new septic tank for property to south-east of the site. • Construct surface water drainage provisions as detailed in the Management Plan within the new landfill infrastructure compound. • Install drainage from new site office (to be connected in future). • Install temporary septic tank for drainage from site office. • Install foul water sewer pipe and connection to public sewer network, via Johnstown Pumping Station.
Remediation of slopes in Zone 4, including the removal of wastes. Clean materials to be stockpiled on Zones 2A and 2B for re-use within Zone 4 or elsewhere on site. Waste materials to be disposed of within Zone 3 or Zone 1.	• Construct surface water management ponds in Zone 4, and install geomembrane liner. • Monitor run-off from placement of low permeability soils to Zone 4. • Install surface water open channels and ditches to connect to pond on completion of remediation over slope areas. • Construct outfall from pond 3 for future discharge.
Capping of Zone 3.	• Install permanent capping system (geosynthetic) in Zone 3. • Install perimeter surface water drainage system. • Monitor run-off from Zone 3.
Progressive capping of Zones 2A and 2B beyond extents of concrete slabs.	• Install silt fences on north / north-east perimeter to Zone 2B. • Retention of the concrete yard slabs, with placement of low permeability capping layer (soils) on areas outwith the slabs. • Place cover soils and vegetation over capping system. • Locate drainage systems from concrete slabs and direct to surface water system (with intermediate controls, e.g. silt trap). • Install new surface water drainage channels around completed areas.

Phase of Works	Surface Water Management Proposals
Re-grading wastes in Zone 1 to achieve proposed landform.	• Install silt fences on north perimeter to Zone 1. • Construct perimeter swale / catchment ditch. • Inspection of reprofiling works to identify any indications of leachate presence. • Increased monitoring frequency for surface water receptors along northern perimeter. • As areas of waste are exposed, construct temporary separation bunds for management of surface water. • Utilise silt buster or similar system for run-off. • Construct and line temporary ponds as necessary. • Capping system (geosynthetic) to be installed in phases. • Place cover soils and vegetation over capping system. • Install surface water management system as soon as practicable. • Monitor surface water management system for contamination (i.e. silt). • Construct soakaway adjacent to pond 1. • Enter 3 month period for monitoring of run-off to obtain baseline data.
Works within additional field to incorporate into park area for multi-use sports pitch. Ground re-profiling, demolition of existing building, installation of pitch and landscaping.	• Undertake minor ground re-profiling works to allow surface water to drain to perimeter ditches and swale. • Install surface water ditches and connect to open channels in Zone 1 and Zone 2A. • Install reed bed.
Final site works – installation of park infrastructure and planting.	• Install drainage from changing rooms building and connect to rising main, for discharge to public sewer network. • Clean surface water management ponds of all silt, install stone drainage layer (with supporting geotextile) and plant ecological enhancements. • Commission off-site discharge locations (soakaway and to Morell River). • Site enters Aftercare Phase for surface water management and monitoring.

Table 2.1 : Outline Remediation Works Phasing Proposals

<u>Surface Water Management Ponds 2 and 3</u>

The surface water run-off volume from Catchment Zone 1 will be retained within two ponds (2 & 3) in the south-eastern side of the site. Both ponds will become park water features with a permanent pool of water to provide attenuation and treatment of surface water run-off. Attenuation storage will be provided by freeboard above the permanent water level. A flow control system (e.g. orifice plate, hydrobrake or throttle pipe) will be installed at the outfall from pond 3 to limit the discharge rate to the maximum permissible rate of 51.07l/s. Following the remediation works the installed impermeable geomembrane liner will be cleaned of any silt deposits, with a stone layer placed above the liner for protection during maintenance / emptying operations and top soil/growing medium over the stone to encourage plant growth and provide ecological enhancement. The storage ponds will be designed to encourage settlement of solids which can be removed from the base of the retention area. In addition access points will be provided to each pond to facilitate future maintenance (vegetation management and sedimentation removal).

Surface Water Management Pond 1

The surface water run-off flows from Catchment Zone 2 will be gravitated and stored in pond 1 in the north-west corner of the site. The attenuation storage volume provided in the pond is sufficient to prevent flooding due to rainfall events. The bed and slopes of the pond will be lined with an impermeable heavy duty liner geomembrane with a stone layer placed on the top of the liner. The flows from this storage pond will be discharged into a new soakaway located west of the pond.

Ground investigations in this area have identified ‘waste’, though largely comprising inert and/ or construction and demolition (C&D) waste. Remediation proposals comprise the reduction in waste extents in this area. A key design element for the function of the soakaway is groundwater levels in this proposed location. Assessment of the remediation profile suggests that the ground would be between 10m and 12m above groundwater levels hence suitable for installation of a soakaway. Ground conditions comprise overburden which is layered hence horizontal permeability from the soakaway into the soils will be greater than vertical permeability, with the effect that water in the soakaway will likely across rather than down. The ability to percolate vertically will be influenced by the degree of interconnection between the layers. Borehole logs in this area do not show any perched water above the groundwater table which suggests that there is reasonable downward movement of infiltration.

With this indication of possible horizontal movement of water waste cannot be present in the proximity of the soakaway. Borehole EMW12 shows the base of the waste at being at around 84.4mOD compared to the current designed base of the soakaway at circa 87 to 88mOD. However, the soakaway will be positioned approximately 60m from borehole EMW12 hence water would have to move a reasonable distance to effect the waste. The regional groundwater flow direction is also away from the waste and the various ground investigation logs in this part of the site do not show any evidence of perched groundwater further discounting the possibility of water from the soakaway migrating to the waste deposits. Remediation works will identify and classify the wastes in this area and remove to ensure that a sufficient ‘buffer’ exists between the soakaway and remaining waste deposits in Zone 1, with levels confirmed during detailed design.

The soakaway should be filled with granular material and lined with geotextile to prevent migration of fines into the soakaway and ingress of backfill material during and after surface reinstatement. Alternatively the soakaway could take the form of perforated concrete manhole ring units placed within a square pit with sides about twice the selected ring unit diameter and granular material backfill placed between the rings and the sides of the pit. The granular material must be separated from the surrounding soil by a suitable geotextile. The top surface of the granular fill should also be covered with geotextile.

Road and Hardstanding Drainage

Oil interceptors will be required during landfill remediation works to serve temporary working areas (e.g. potential laydown area, fuelling station, temporary car park and wheel wash area). These interceptors will be removed on completion of restoration works.

2.4 Future Surface Water Management Proposals

2.4.1 Surface Water Catchment Zones

The proposed remediation works comprises re-profiling of the site to generate a suitable profile for capping and surface water management to be effected. Based on the design proposals, the site has been divided into smaller sub-catchments in order to determine surface water flow paths, the direction of flows, locations for storage ponds and discharge points. This assessment determined that three main catchment zones are prevalent. These are approximated as shown in Figure 2.2 below and will be based on the final topography achieved through the remediation works. (Note that the boundary shown in the below figure is not the final proposed project boundary)

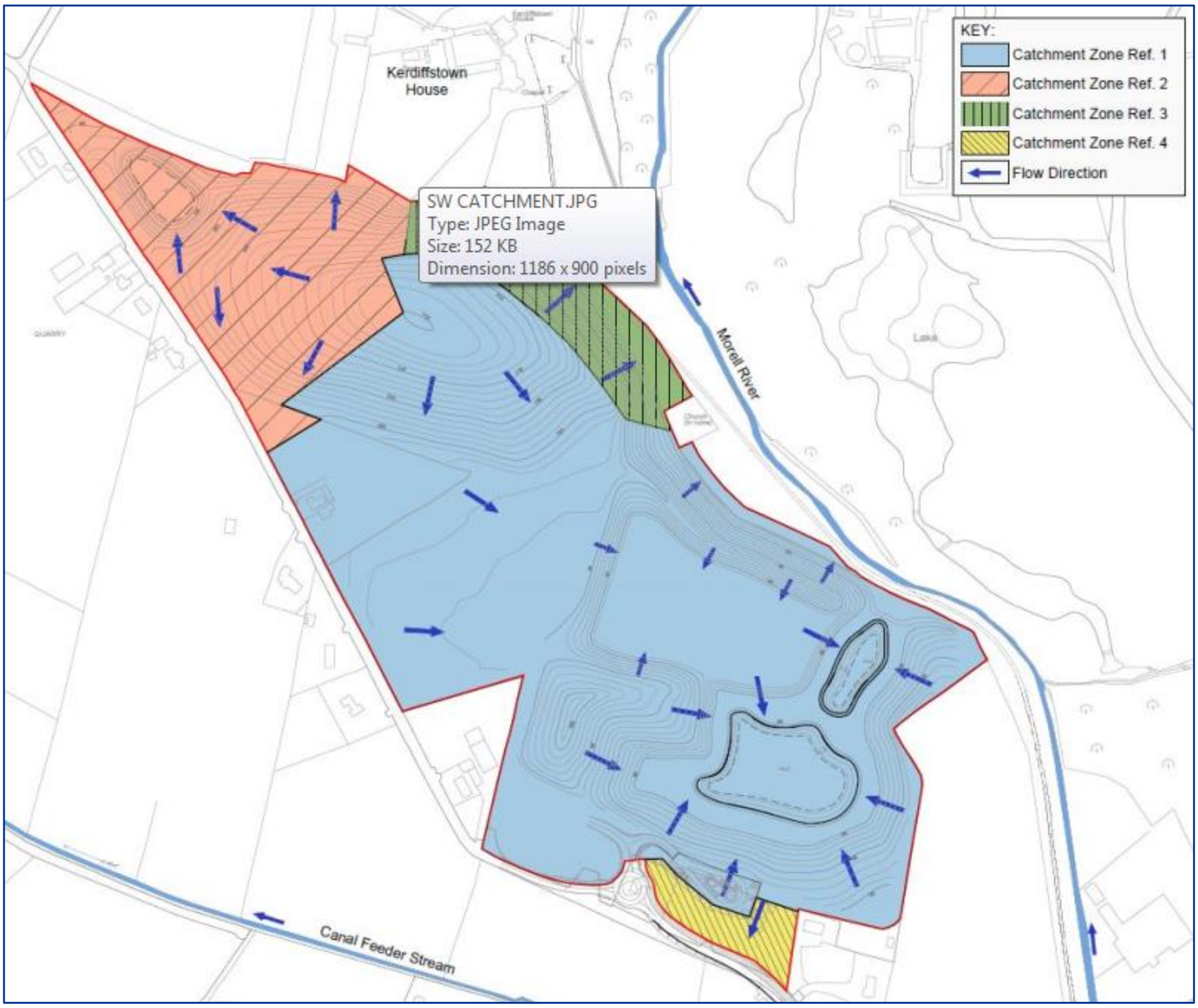

Figure 2.2: Outline Surface Water Catchment Zones

This approximation of catchment zoning indicates that most of the surface water captured on the site, as shown as Catchment Zone 1, can flow by gravity via system of open channels and perimeter ditches to the south-eastern area of the site, for collection and discharge. Due to topographic constraints a limited area to the north-west of the site (Catchment Zone 2) cannot be readily drained to the south east and requires an alternative solution. Similarly, steep slopes to the north of the site (Catchment Zone 3) fall to a low level preventing sustainable drainage options to be used to drain back into the site. Catchment Zone 4 represents an area of land currently comprising residential properties and gardens, which falls away from the site and is located outwith the licensed boundary containing no landfill infrastructure. As a result Catchment Zone 4 does not form part of the site catchment or surface water management proposals.

2.4.2 Surface Water Run-off Rates

The peak rainfall run-off rates have been estimated based on the rainfall intensity depths attached in Appendix C. A climate change factor of 10% was applied to all rainfall intensities as recommended in the Sustainable Drainage Guidance for Ireland. The estimated design peak flow rates were then used to determine indicative sizes, gradients and alignment of the drainage system required to convey surface water flows. The peak design run-off flow rates can be found in the summary table in Appendix E.

2.4.3 Fluvial Flood Extent

The online Office of Public Works (OPW) National Flood Hazard Mapping contains historical flood information and shows a number of flood events on the Morell River, in the area of Johnstown east of the site. The flood report and flood risk map are attached in Appendix D for reference.

The map indicates that the site is located just outside the fluvial flood risk zone. However, an area located to the north extents of the site boundary aligning with the access road to Kerdiffstown House is positioned within the 0.1% AEP (annual exceedance probability) and 1% AEP fluvial flood events which represents areas at risk of 1 in 1000 and 1 in 100 year flood events respectively.

Remediation works proposals are not required in this area, although realigning of the road to Kerdiffstown House is likely in order to provide surface water management and future maintenance access to the site.

2.4.4 Outline Drainage Strategy

The proposed concept drainage design comprises surface water management measures for the remediation and post-remediation works phases to mitigate the risk of environmental pollution and flooding. The design and sizing of the drainage components is based on the proposed pre-settlement remediation profile, estimated peak run-off rates, specific requirements in each zone and the permissible discharge rate from the site.

The drainage system for the site will include a network of open ditches, channels and swales to intercept and control surface water run-off generated from the capped and restored landfill areas and direct it towards storage ponds. The ditches will be supplemented with culverts and road drainage as required. The proposed drainage plan and cross sections are shown on Drawing Numbers 32EW5604-00-044 and 046. The strategy for the management of surface water run-off embraces the anticipated phasing of the remediation works.

During site remediation, construction of perimeter, temporary bunds will enable separation of working areas from restored areas. However, it is anticipated that until initial vegetation coverage, comprising grass, fully germinates silty run-off from capping soils may still be prevalent and require control. As a result the surface water management design proposals do not permit surface water discharge until such time as it can be shown through monitoring that water quality is stable and clean, with sufficient background data to support this assessment. Monitoring proposals are discussed further in Section 3.

2.4.5 Surface Water Management Proposals

Table 2.2 sets out proposals for surface water management at the site according to the zonal categorisation for areas containing waste. The specific details, locations and levels of infrastructure will require to be confirmed as remediation works progress.

Zone	Remediation and End-Use Proposals	Surface Water Management Proposals
1	The remediation proposals for this zone comprise capping using a geosynthetic system (low permeability geomembrane or similar) with capping soils. End-use proposals will see this area become a public open space.	Catchment Zone 1: Open ditches and channels, with buried pipes to traverse paths, tracks and roads as necessary. Discharging via Zone 2B infrastructure to surface water management ponds 2 and 3. Catchment Zone 3: Infiltration swale constructed on toe of re-profiled slopes, discharging to groundwater.
1A	The remediation proposals for this zone comprise re-profiling to create a suitable landform and capping using a geosynthetic system (low permeability geomembrane or similar) with capping soils. End-use proposals will see this area as public open space.	Catchment Zone 2: Surface water management pond (1), providing retention and linking to a soakaway, discharging to groundwater. Open ditches and channels directing run-off to pond.

Zone	Remediation and End-Use Proposals	Surface Water Management Proposals
2A	The remediation proposals comprise the retention of the concrete pads (with repairs) over which a sports pitch will be located. Outwith the concrete pads a low permeable cap (soils) will be placed. End-use proposals will see this area become a public open space, incorporating car parking, a sports pitch and a changing rooms building.	Catchment Zone 1: Open ditches and channels, with buried pipes to traverse paths, tracks and roads as necessary. Sports pitch drainage to connect to channels. Road drainage to include silt and oil interceptors. Discharging to ponds 2 and 3.
2B	The remediation proposals comprise the retention of the concrete pads (with repairs) over which a sports pitch will be located. Outwith the concrete pads a low permeable cap (soils) will be placed. End-use proposals will see this area become a public open space, incorporating a sports pitch and paths.	Catchment Zone 1: Open ditches and channels, with buried pipes to traverse paths and tracks as necessary. Sports pitch drainage to connect to channels. Discharging to surface water management ponds 2 and 3. Drainage from perimeter bund (north) to be collected via open channel and French drain (as topography and levels dictate) to discharge to pond 1.
3	The remediation proposals zone comprise re-profiling to create a suitable landform and capping using a geosynthetic system (low permeability geomembrane or similar) with capping soils. End-use proposals will see this area as public open space.	Catchment Zone 1: Open ditches and channels, with buried pipes to traverse paths and tracks as necessary.
4	Remediation proposals comprise excavation of identified wastes as far as practicable, to create safe slope profiles. Low permeable soils will be placed over re-profiled slopes. End-use proposals will see this area used for surface water management ponds with paths.	Surface water management ponds (2 & 3), providing retention and, discharging to Morell River.

Table 2.2: Surface Water Management Proposals

2.4.6 Discharge Rates and Key Discharge Points

The estimated discharge rate (Q_{BAR}) is based on the outline remediation works design drawings is provided in Appendix F for reference.

The topographical features of the site define the direction of flow paths and locations at which water can be discharged from the site. Generally surface water flows from Catchment Zone 1 can be gravitated via a system of open channels and perimeter ditches to the south-eastern area of the site, where the water will be retained within attenuation ponds and discharged via a new outfall structure to the Morell River.

Surface water from the north-west part of the site (i.e. Catchment Zone 2) will flow northwards and westwards, and cannot be readily captured for transfer to the south-east area of the site. The surface water run-off from Catchment Zone 2 will therefore be discharged into an attenuation pond in the western corner of the site with an overflow discharging to a soakaway.

The ground profile at the toe of the north slopes, represented as Catchment Zone 3 prevents drainage to the attenuation ponds in the south-east corner of the site. The surface water run-off from this limited catchment area will be discharged into an infiltration swale located along the mound toe, with waters permitted to discharge to groundwater.

2.4.7 Surface Water Storage Requirements

Attenuation storage will be required as surface water management ponds 2 and 3, located in the south-east area of the site, and surface water management pond 1 in the north-west area, in order to temporarily retain water within the site during periods when storm water run-off exceeds the allowable discharge rate. The use of attenuation ponds will also protect the site against flooding and the river from detrimental impacts due to high flows from the site. In addition, the attenuation ponds will permit settlement of suspended solids from the drainage system.

Estimation of surface water storage requirements is based on peak run-off rates and the restricted discharge rate from the site. The storage volumes designed to provide protection to the site against flooding and mitigate the risk of detrimental impact on the discharge locations (where applicable) are summarised in Table 2.3.

Catchment Zone	Storage volume (m^3)	Storage Provision	Discharge Point	Receiving Receptor
Catchment Zone 1	16,783	Ponds 2 & 3	Morell River	Surface water
Catchment Zone 2	2,452	Pond 1	Soakaway	Groundwater
Catchment Zone 3	614	Swale	Infiltration Swale	Groundwater

Table 2.3: Surface Water Storage Volumes and Discharge Locations

The proposed outline site layout with storage ponds is shown on Drawing Number 32EW5604-00-044.

<u>**Surface Water Management Ponds 2 and 3**</u>

The surface water run-off volume from Catchment Zone 1 will be retained within two ponds (2 & 3) in the south-eastern part of the site. Both ponds will become park water features with a permanent pool of water to provide attenuation and treatment of surface water run-off. Attenuation storage will be provided by freeboard above the permanent water level. A flow control system (e.g. orifice plate, hydrobrake or throttle pipe) will be installed at the outfall from pond 3 to limit the discharge rate to the maximum permissible rate of 51.07l/s. Following the remediation works the installed impermeable geomembrane liner will be cleaned of any silt deposits, with a stone layer placed above the liner for protection during maintenance / emptying operations and top soil/growing medium over the stone to encourage plant growth and provide ecological enhancement. The storage ponds will be designed to encourage settlement of solids which can be removed from the base of the retention area. In addition access points will be provided to each pond to facilitate future maintenance (vegetation management and sedimentation removal).

A sampling and monitoring point will be provided downstream of the outlet from pond 3 to allow for water quality monitoring. A penstock will be installed in the manhole downstream of the sampling and monitoring point to allow for isolation and containment of flows in the event of suspected or confirmed contamination of surface water in the ponds, preventing discharge to the Morell River. This penstock will be controlled using a SCADA (Supervisory Control and Data Acquisition) automation control system based on data reported from the sampling point. During normal operational conditions this penstock will remain open to allow flows to be discharged to the Morell River. Further information on monitoring proposals is detailed in Section 3.

The position of the proposed outfall structure to the Morell River is restricted by the extent of the existing rock armour that stretches approximately 80m along the adjacent riverbank. The outfall is proposed to be constructed beyond the northern extents of the rock armour with the discharge pipework to the river laid at an angle to avoid disturbance to the opposite river bank. The proposed orientation of discharge pipework and position of the outfall is shown on Drawing Number 32EW5604-00-044 with typical outfall detail shown on Drawing Number 32EW5604-00-046.

Surface Water Management Pond 1

The surface water run-off flows from Catchment Zone 2 will be gravitated and stored in pond 1 in the north-west corner of the site. The attenuation storage volume provided in the pond is sufficient to prevent flooding due to rainfall events. Following the remediation works the installed impermeable geomembrane liner will be cleaned of any silt deposits with a stone layer placed above the liner for protection during maintenance / emptying operations.

A new soakaway will be constructed immediately adjacent to the pond. The soakaway will be constructed using large diameter concrete rings or similar and filled with appropriately sized granular material with the top surface of the granular fill covered with a filter geotextile to retain fines.

Monitoring will be undertaken in pond 1 to verify quality of discharge. A penstock will be installed in the underground manhole downstream of the pond to allow for isolation and containment of flows in the event of suspected or confirmed contamination of water within the pond. During normal operating conditions this penstock will remain open to allow flows to be discharged to the soakaway.

Infiltration Swale

Run-off from Catchment Zone 3 will be collected in an infiltration swale, constructed along the toe of the re-profiled slope beyond the capping system as a shallow, flat-bottomed drainage feature to convey run-off to ground. Swales may be planted with grasses and other vegetation to provide a level of pollution control and treatment for smaller storm events. The extent of the swale is constrained by a historic shrine and graveyard and gardens of Kerdiffstown House. The location and detail of the proposed infiltration swale are shown on Drawing Numbers 32EW5604-00-044 and 32EW5604-00-045. The water retained in the swale will infiltrate into the ground. The proposed infiltration swale is located outside 1 in 1000 year fluvial flood extent and will be constructed at an elevation above the 1 in 1000 year flood level. An access track will be provided adjacent to the swale to facilitate future maintenance.

During extreme rainfall events it is anticipated that surface water flows may overtop the swale onto adjacent land. However, this will not increase any run-off volume that is currently discharged onto this land as the additional run-off volume resulting from the site will be retained within the swale. The proposed swale may require installation of intermediate bunds along its length to compensate for the reduction in ground profile along its length allowing sub-catchment management.

2.4.8 Road and Hardstanding Drainage

Any new roads and hardstandings which are to be built or retained within the site as part the remediation works and / or end-use development (i.e. access roads to car parking, changing rooms, and landfill infrastructure compound) will require permanent drainage to collect surface water flows. The surface water flows will be collected by a system of road gullies and underground drainage pipework with the flows discharged to ditches and then to pond 2. As run-off from such roads and hardstandings have the potential to contain silt, oil and fuel washed off roads silt and oil interceptors will be provided to separate these contaminants from the surface water, prior to entering pond 2, and preventing pollution of the Morell River.

All oil interceptors, road gullies and silt traps that will remain post-remediation will require regular maintenance to sustain their long-term performance. This is discussed further in Section 3.

Run-off from the proposed new roundabout at the site entrance external to the site will be collected by new road gullies and discharged into the existing road drainage on Kerdiffstown Road. The flows from the existing road drainage are discharged to the Morell River to the south of the site. During detailed design it is considered that a silt and oil interceptor may be installed as part of the road improvement works that will be required on Kerdiffstown Road.

2.4.9 Landfill Infrastructure Compound Drainage

Surface water from the compound will be collected by system of road gullies and underground pipework which will be supplied with silt and oil interceptor(s). These flows will be discharged to the main road drainage. However due to the risk of run-off from the compound containing contaminants due to leachate spillages the drainage system from the compound will also be provided with an isolation point before discharge into the main road drainage. An isolation penstock will be installed within a manhole and the surface water run-off will be retained within the storage manhole until mitigation works have been carried out. Contaminated surface water may need to be transported off-site for disposal during this period until the normal operation has been restored.

Contingency plans to address leaks from valves and tankers used in the management of leachate in the Landfill Infrastructure Compound are outlined in the Leachate Management Plan.

2.5 Foul Water and Grey Waters Drainage Strategy

2.5.1 Guidance

Design considerations for foul and grey waters generated from the site post-remediation are outlined in Appendix B. The site is proposed to be used as a public open space/ park with three multi-use sports pitches.

The following technical specifications have been used as references in the determination of options for the future treatment and discharge of foul and grey waters from the changing rooms and site compound office:

- Wastewater Code of Practice;
- Sewers for Adoption;
- Sewers for Scotland;
- BS EN 752 Drain and Sewer Systems Outside Buildings;
- BS EN 12056-2 Gravity Drainage Systems Inside Buildings; and
- Theory of Simplified Sewerage (web link: http://www.efm.leeds.ac.uk/CIVE/Sewerage/manual/docs/chap2.pdf).

The Greater Dublin Regional Code of Practice provides guidance for the design and construction of sewers in the Greater Dublin Area. Where sufficient data or particular elements were not available within this document, it was supplement through the use of Sewers for Scotland in conjunction with Sewers for Adoption as is typical.

A full list of guidance used for the surface water management proposals is detailed in Appendix A.

2.5.2 Proposals

A packaged pumping station (PS) is proposed to be located adjacent to the changing rooms building. The PS will pump sewage from the changing rooms through a 150mm (internal diameter) barrier MDPE pipe rising main. The approximate proposed route of the rising main is shown on Drawing Number 32EW5604-00-049.

A packaged mass rate pump will be located adjacent to the site office in the landfill infrastructure compound. The pump will inject flows from the site office into the rising main taking flows from the changing rooms via a 100mm (internal diameter) buried pipe. A telemetry control link will be installed between the pumping station at the changing rooms and the one at the site office to ensure to the optimal operation of the pumps.

The sewage rising main will break via an air valve. From the air valve chamber, the foul and grey water will gravitate to Johnstown Wastewater Pumping Station (WwPS), discharging to the public local sewer network. The sewage pipe will run parallel to the leachate main (refer to the Leachate Management Plan). The proposed route of the sewerage gravity main is shown on Drawing Number 32EW5604-00-049. he transfer main shall be a fully welded 150mm (internal diameter) barrier MDPE pipe. The minimum depth of cover to the crown of the pipe will be 900mm in field areas, increasing to 1200mm beneath roads.

The gravity sewerage pipework route consists of the following major sections:

1. A section along the boundary of the waste mass;
2. A section through a grass field;
3. A section under a minor road;
4. A section under a major three-lane motorway (N7);
5. A section under the Morell River; and
6. A section to Johnstown WwPS.

The final design of the sewerage rising main and gravity main shall be in accordance with relevant guidance such as Sewers for Scotland technical specification, BS EN 752 Drain and Sewer Systems Outside Buildings and BS EN 12056-2 Gravity Drainage Systems Inside Buildings. The pumping stations at the changing rooms building and the site compound shall be in accordance with relevant technical specifications.

Rainfall collected by roof drainage from buildings on the site such as the changing rooms will be discharged to the road drainage system.

There is an opportunity to re-use this water on site (e.g. for flushing toilets) which will be determined at detailed design stage.

2.6 Water Quality

Surface water flows from the site may contain an increased concentration of suspended solids, oil and fuels. In addition surface water flows are at risk of contact with contaminated waste and leachate which may result in the increased elevation of ammoniacal nitrogen, chloride, suspended solids, nitrate, iron and Total Organic Carbon. Therefore the surface water run-off from the site will require appropriate management and control measures throughout the remediation works and development of the park as the end-use. The primary control measure is to not permit surface water discharge from the site during remediation works, unless it can be shown to be free from contamination. The quality of the discharged water will require to comply with discharge parameters to be agreed with the EPA. Monitoring requirements are further outlined in the EIS, Chapter 14 Water – Hydrology.

2.6.1 Remediation Phase

Surface Water Quality and On Site Treatment

The remediation works will comprise excavation and re-profiling of waste, resulting in open areas of waste. The works are to be phased to reduce exposed working areas, both from excavation and filling locations, with surfaces covered with inert soils at the end of each working day as a minimum. Rainfall coming into contact with waste may generate contaminated run-off or leachate. Therefore segregation of surface water from open areas of waste and leachate will be required through use of temporary bunds and/or ditches. The precise position and general arrangement of required bunds will be confirmed during detailed design phase once the phasing and sequence of the proposed restoration works have been confirmed.

The areas for pond construction to be utilised in the end-use design will be used temporary lined condition for storage of run-off during the construction works. Further temporary ponds may be constructed at locations adjacent to working areas to assist with management of run-off if the phasing and timing works require additional storage volumes.

Any contaminated run-off will be captured and contained separately. This water will not be discharged from the site unless monitoring shows discharge to be acceptable. Water will be required for on-site purposes such as dust suppression. Any waters confirmed to be contaminated and considered as unsuitable for treatment or re-use on site will require to be removed from the site. Depending on procurement strategies for the construction works this may be achieved through road tanker removal. Alternatively, on agreement with Irish Water, the water may be discharged to sewer in accordance with the Leachate Management Plan.

Identification of leachate outbreaks from the waste mass will require to be remediated by installation of stone filled drains, to direct the leachate back into the waste mass. Procedures are detailed in the Leachate Management Plan.

Immediately following capping works completed areas will be susceptible to erosion by surface water run-off. During rainfall events increased sediments may be carried in the surface water run-off as a result of this erosion. This effect is likely to continue until the surface are fully grassed and stable making them less susceptible to erosion. To mitigate this siltation fencing will be provided at the perimeter of completed areas / ditches to catch silt as far as practicable. Silt buster or other similar tank arrangements may also be utilised by contractors undertaking the works to remove silt prior to discharge to the ponds and reduce the loading to the ponds and requirement to clean in the future. Despite these measures surface water run-off collected by perimeter ditches is still likely to carry suspended solids content which will need to be contained and managed such that it is not discharged from the site. The flows will be directed to the retention ponds located in the south-eastern part of the site. The retention ponds will be designed to encourage settlement of solids. Stone bunds / baffle boards along the base of the retention pond may be required to improve settlement. The suspended medium and coarse silts will settle out of the water to the bottom of the ponds and can then be removed from the base of the retention area.

The contractor(s) undertaking earthworks at the site will be required to be responsive to potentially changing conditions across the site and adopt a proactive approach to managing silt removal.

In addition to these contamination risks, the use of plant and construction materials (including, but not limited to, cement, oil and fuel) may lead to contamination if these are not adequately controlled during the restoration period. During remediation works contractor(s) will be required to put in place a strategy to ensure that no oil and fuel spills from machinery and plant reach the watercourse or groundwater. Silt traps and oil interceptors will be required to serve any areas which are designated as temporary laydown areas, fuelling stations, temporary car parks and potential wheel wash areas. These interceptors will be removed on completion of works.

If any temporary haul roads are required during the restoration phase then these will be provided with a channel drain on one side of the road connecting back to the main perimeter drains. The roads will be coated with a binder to prevent the release of silt during time of rainfall.

Construction of an outfall on the Morell River is to be undertaken during low flow conditions. Construction of a cofferdam may be required during outfall construction to protect the Morell River and provide a safe working environment. Mitigation for construction works is outlined in the EIS, Chapter 14 Water – Hydrology.

Surface Water Monitoring

Monitoring of surface water will be undertaken at the storage ponds for verification purposes. As water is likely to be required during remediation works, such as for dust suppression, contamination from waste will be the key characteristics to check such that these are not made airborne during dust suppression activities.

During remediation works, sampling of adjacent surface water locations will continue at the following locations (as a minimum):

- Upstream and downstream of the future discharge location on the Morell River;
- Each storage pond; and
- Infiltration swale.

The minimum monitoring frequency is proposed to be monthly, increasing to weekly when immediately adjacent to remediation works areas. Monitoring staff and site operatives will monitor the efficiency of the surface water management during works on a daily basis and report evidence of any potential contamination, excessive sedimentation or any other factors that may compromise the efficiency of the system to the site manager.

The details of chemical analysis for the weekly and monthly sampling will cover key contaminants associated with typical landfill operations, including total suspended solids (TSS), chloride, ammoniacal nitrogen, nitrate, iron, chemical oxygen demand (COD), electrical conductivity (EC), pH and total organic carbon (TOC). The full details including allowable discharge concentrations and typical monitoring suites are provided in the Monitoring and Control Management Plan.

2.6.2 Operational Phase

Surface Water Quality and On Site Treatment

Following completion of remediation works surface water run-off will not come into contact with waste materials. However, water may still contain some suspended solids and possibly oil, fuel and silt washed off roads.

Silt fences installed around the site as part of the remediation works will remain in place until the vegetation within the site is well established and perimeter ditches and swales grassed. Once it has been established that sediment retention techniques are no longer required silt fences may be removed.

All oil interceptors, road gullies and silt traps that serve permanent access road, car park and hardstandings will remain in place due to the potential risk of oil, fuel and silt being washed off these areas. This water would require separation from surface water. All oil interceptors, road gullies and silt traps that will remain post-remediation will require regular inspection and maintenance to sustain long-term performance.

Surface Water Monitoring and Sampling Plan

The sampling and monitoring of surface water discharges will be required post restoration works to confirm that the run-off quality complies with the discharge parameters agreed with the EPA. Auto-sampling points will be provided at the outlets from pond 1 in the northwest corner of the site, discharging to groundwater, and pond 3 in the south-eastern area, discharging to the Morell River.

A flow meter will also be installed at the sampling point on the outlet from pond 3 to record discharge rates to the Morell River. This data will be maintained via data logger and linked to the site office, located within the landfill infrastructure compound.

Monitoring of the infiltration swale at the northern perimeter of the site will also be undertaken. Sampling upstream and downstream of the outfall to the Morell River will continue (as a minimum).

The frequency of monitoring at all locations is to be monthly as a minimum, with the auto-sampling points recording data more frequently. The frequency of the monitoring of the Morell River may be reduced following sufficient data to support ongoing assessment, to quarterly and six-monthly periods.

The details of chemical analysis for the monthly sampling will cover key contaminants associated with the former landfill site including TSS, chloride, ammoniacal nitrogen, nitrate, iron, COD, EC, pH and TOC. A more comprehensive analytical suite should be employed annually to include trace organics and metals. The full details of the monitoring suites are provided in the Monitoring and Control Management Plan.

2.7 Construction Quality Assurance

The outline design principles for the surface water management system are provided herein. Detailed design of future surface water management facilities will be undertaken following a detailed topographical survey to determine appropriate gradients and alignments.

The installation of the requisite management measures will be subject to Construction Quality Assurance and Control. This will provide assurance that the surface water management system was constructed as specified in the design and will include inspections, verifications, audits and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility.

To enable overall quality management works to the surface water management system will be governed by a comprehensive Construction Quality Assurance (CQA) Plan, prepared for submission to and review by the EPA. CQA is defined as a planned system of activities that provide assurance that the materials used meet design specifications and infrastructure is constructed in accordance with the contract and technical specifications. The CQA Plan will set out:

- Construction quality control (CQC) procedures;
- Technical specification and the conditions of contract drawn up by the designer; and
- Roles and responsibilities for the works. The Construction Environmental Management Plan (CEMP) may also inform and be informed by the CQA Plan.

On completion of the infrastructure works a CQA Report will be prepared, to demonstrate that the system(s) and associated components comply with the specification as set out in the CQA Plan. To align with phasing of the remediation works CQA of surface water infrastructure may be embraced within an overarching Remediation CQA Plan, subject to confirmation of procurement approach and detailed design.

2.8 Surface Water Management Review

Management of surface water will be maintained under review by Site Management to ensure that, as far as is reasonably practicable, the surface water collection, treatment and disposal system will have sufficient capacity to handle the maximum predicted flow rates.

Further review may be necessary following agreement with Irish Water for the sewer connection to Johnstown Pumping Station, agreed in principle (February 2017).

If the review process identifies potential shortfalls in the provision of surface water management facilities at the site, action will be taken to upgrade the system capability. Proposed changes shall be discussed with the EPA prior to implementation.

3. Installation, Monitoring and Maintenance

3.1 Installation Plan

Phased development of drainage works will take place as re-profiling and remediation (capping) works progress on the project as shown on Drawing Numbers 32EW5604-00-027 and 028. The remediation works will include a network of open ditches and channels that will capture and control any surface water run-off generated from the capped areas towards the surface water management ponds. These ditches will be supplemented with herringbone drainage, pipework and culverts as required. It is recorded that drains cannot be installed across steep slopes (1:2.5 to 1:3) due to required use of geogrid in capping soils to provide stability to the system.

During the operation of the surface water management ponds inspections will be carried out to ensure that the system is operating as designed and has not been contaminated with leachate.

Post remediation works inspections of drainage channels will continue. Recording of data relating to the volume discharged to the Morell River and quality thereof and the water quality present in ponds 2 and 3 will be logged in the site manager's office, and reviewed to determine any detrimental changes.

Records from the construction works and testing will be retained in the Site File.

3.2 Monitoring Plan

Routine monitoring of the site to assess the performance of the surface water management system will be undertaken. Monitoring staff will carry out checks of infrastructure each time the gas and groundwater monitoring boreholes are sampled. Observations will be recorded, and evidence of contamination such as excessive sedimentation or any other factors that may compromise the efficiency of the system will be reported to the Site Manager prior to leaving the site.

Details of the monitoring programme/plan for the site are set out in the Monitoring and Control Management Plan and cover (as a minimum):

- Surface water monitoring (on-site: levels; quality; quantities);
- Surface water monitoring (off-site: quality; flows to River);
- Surface water infrastructure inspections; and
- Surface water infrastructure maintenance programmes.

3.3 Maintenance

The surface water drainage system will require long term maintenance and upkeep including:

- Inspections and maintenance of silt and oil traps;
- Inspections and maintenance of swales, ditches and reed beds;
- Inspections and maintenance of road gullies and underground drains, and repairs if required;
- Inspections and maintenance of discharge point, outfall and isolation penstocks; and
- Maintenance of auto-sampling system.

In order to maintain the effectiveness of the surface water system following identification of defects action will be taken to remove any obstructions to flow.

4. Action Plan

4.1 Overview

As identified in Section 2 reductions in infiltration will be achieved by progressive phases of capping works, across areas of the landfill. The surface water management scheme is also important in providing a collection system for surface water run-off that will reduce the loading on the leachate collection and disposal system (see also Leachate Management Plan).

It is proposed that the Surface Water Management Plan and Surface Water Action Plan would be regularly reviewed, and updated where necessary, to ensure that sufficient surface water management options are available to adequately control run-off at the site, and to prevent any uncontrolled escape of surface water into the surrounding environment.

4.2 Action Plan

The maintenance, monitoring and sampling procedures, and action plan will be maintained throughout construction and post-remediation works. However, in the event of suspected or confirmed contamination of surface water the following action plan should be in place:

- Identify which catchment area is affected and close the relevant penstock at the outlet from pond 3 and/or 1 to allow for isolation and containment of discharge flows within the site.
- Contingency measures to be put in place:
  - Undertake sampling and analysis to confirm suspected contamination.
  - Identify source of pollution and isolate the area of concern.
  - EPA to be informed as soon as possible.
  - Where appropriate undertake actions to remove contaminated water for site treatment and ensure that the source of pollution has been eliminated. Temporary pumping operations might be required to remove/pump contaminated water for site treatment.
  - Agree any other necessary actions with EPA.
- Following emergency response plan and successful removal/treatment of contaminated water and source of pollution, increased monitoring and sampling of surface water is to be put in place. The frequencies and chemical analysis requirements are to be in line with the Monitoring and Control Management Plan.

5. Work Instructions

5.1 Maintaining Surface Water Infrastructure

Work instructions for the Site Manager and Site Operatives are as follows:

5.1.1 Duty of Site Manager

- Ensure that all constructed engineering works prevent the uncontrolled escape of surface water into the surrounding environment;
- Manage any controlled pumping into the surface water system;
- Ensure any pumps employed to deal with the management of the surface water system are sized accordingly to deal with predicted ingress;
- Review and approve the CQA Plan for each phase of remediation works (if required) with particular regard to the control and management of surface water;
- Consider both surface water management during remediation works and the long term control and management from completed parts of the site;
- Regularly inspect bunded areas for ponding liquids and remove as necessary;
- Ensure that routine monitoring of surface water is undertaken in accordance with the guidelines detailed within this management plan;
- Ensure that data loggers are working appropriately and are maintained according to manufacturer's recommendations;
- Ensure that regular checks of the surface water management system are undertaken;
- Review monitoring data to determine any reduction in frequency;
- Ensure that any notifications required by this management plan are submitted to the EPA; and
- Ensure that the Action Plan detailed within this management plan is implemented.

5.1.2 Duty of the Site Operative

- Ensure any pumps employed in the management of surface water are serviced and fully operational;
- Ensure discharge points of any pumps are placed in the correct position of the installed surface water system;
- Maintain all surface water ditches with regards to debris and litter to ensure water runs freely;
- Inspect the surface water ponds for debris and litter and remove as necessary;
- Inform the Site Manager of any blockages, overflow or abnormal operation of installed surface water collection system immediately;
- Ensure that all pumps are placed on a drip tray for environmental protection of virgin ground;
- Do not use pumps for surface water management if previously used for the control and management of leachate unless they have been appropriately cleaned.
- When using the water bowser for surface water management always ensure that there is no contamination from the tanker body prior to use.

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Appendix A. Relevant Guidance Documents

Below is a non-exhaustive list of guidance. Review of this and prevailing best practice should be made on future updates to this Management Plan:

Guidance	Year
Sustainable Drainage Guidance for Ireland (www.uksuds.com/irish_suds)	-
WRc Sewers for Adoption (7th Edition)	2013
Irish Water Code of Practice for Wastewater Infrastructure	2016
IS EN 752 Drain and Sewer Systems Outside Buildings	2008
CIRIA Report C753 - The SuDS Manual	2007
IS EN 12056-2 Gravity Drainage Systems Inside Buildings	2000
CIRIA Report C692 Environmental Good Practice on site (third edition)	2010
Civil Engineering Specification for the Water Industry (7th Edition)	2011
Sewers for Scotland (3rd Edition)	2015
Scottish Water Standard and Specifications for Waste Water Pump Stations	2015
Theory of Simplified Sewerage: (www.efm.leeds.ac.uk/CIVE/Sewerage/manual/docs/chap2.pdf)	2016
EPA Final Draft BAT Guidance Note on Best Available Techniques for the Waste Sector: Landfill Activities	2011
EPA Landfill Manual - Guidance note of Landfill Monitoring	2003
EPA Landfill Site Design	2000
EPA Landfill Manuals Investigations for Landfills	1995
EPA Landfill Manuals Landfill Operational Practices	1997
EPA Landfill Manuals Landfill Restoration and Aftercare	1999
EPA Landfill Manuals Landfill Monitoring	2003
UK Environment Agency Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer	2015
The Safety, Health and Welfare at Work Act	2005
The Safety, Health and Welfare at Work (Construction) Regulations 2013 SI 291	2013
ATEX 94/9/EC Directive, the ATEX 'Product' Directive, concerned with the manufacture of equipment and protective systems designed for use in potentially explosive atmospheres	1994
ATEX 1999/92/EC Directive, the Worker Protection Directive (also known as the 'ATEX 137' Directive), concerned with the "minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres"	1999

Standard Type:

IS Irish Standard
BS British Standard
IS EN European Standard adopted as an Irish Standard
BS EN European Standard adopted as a British Standard
WIS UK Water Industry Specification
EPA Environmental Protection Agency
CIRIA Construction Industry Research and Information Association

Appendix B. Drainage Design Philosophy & Methodology

Surface Water Design Input Data

The rainfall intensity depths have been obtained via the EPA from the Met Éireann Meteorological Service (weather station at Casement). These data is shown in Appendix C.

1. Key Design Parameters

The following key design parameters have been adapted in the assessment of the surface water strategy for the proposed restoration site:

- Discharge rate from the landfill remediation site should be limited in line with the recommendations in Sustainable Drainage Guidance for Ireland (maximum discharge rate of Q_{BAR} or 2 l/s/ha, whichever is the greater). However if the catchment is less than 2.5ha, the discharge rate will be dictated by the minimum orifice size of 75mm which will control the outflow to 5l/s).
- 10% climate change factor is to be applied to all rainfall intensities as per Sustainable Drainage Guidance for Ireland.
- The capacity of the surface water drainage system (including storage system) will be designed in line with Sustainable Drainage Guidance for Ireland (durations from 15 minutes to 48 hours are to be assessed). If no relevant information can be found in the Irish SUDS guidance then CIRIA C753 SUDS Manual is to be utilised. It is currently assumed that the drainage system and associated storage/sedimentation ponds are to be designed for no flooding for a 1 in 100 year, 6 hour duration storm event.
- A minimum freeboard allowance of 150mm is to be provided for open channels / ditches and 500mm for storage ponds.
- Flows from site (post-remediation) should be discharged to the Morell River if possible.

2. Design Constraints

The key constraints to be managed from the perspective of surface water management and drainage were identified through initial design and consultations with relevant stakeholders. The key constraints are divided into the following sections:

- Topography
  - Ground profile and existing watercourses: the topography defines the direction of surface water flow paths and location at which water can be discharged. In addition the position of discharged points is restricted by location of the existing watercourses.
- Environment
  - Discharge quality: this is determined by the nature of the ground that the surface water run-off has travelled over. The potential for an increased concentration of suspended solids in surface water resulting from remediation works will require appropriate controls. Any surface water that was in contact with contaminated waste and leachate will require treatment on site. In addition surface water run-off from roads and car park may contain silt, oil and fuels which will require appropriate control and management measures. Without these controls, impacts could include a reduction in water quality and could negatively affect ecology and habitats across the site and local watercourses.
  - Discharge quantity: the discharge rate from the development site to watercourse will need to be restricted to protect and minimise detrimental effect on the river. The size of any soakaways will depend on the permissible infiltration rate. Therefore surface water run-off will require provision of retention area/s within the development site.
  - Discharge permit: EPA consents will be required for discharge of surface water from the development site into the river and for the construction of a new outfall. Monitoring controls will be required in order to demonstrate compliance with the agreed discharge parameters.

- Historic shrine and graveyard: restricting positioning of perimeter ditches.
- Site of archaeological interests possibly located within additional land for additional pitch (end-use).
- Ecology: existing copse in the northern part of the site will restrict the construction of perimeter ditches.
- Contaminated waste mound and proposed capping and restoration layer: this will restrict the positioning of the drainage system.

- Existing Infrastructure
  - Existing service and infrastructure within the development site: existing underground and/or uncharted services, existing concrete retaining wall, and underground obstructions within the former landfill site will restrict the construction of the drainage system.
  - Existing services in the private access road to Kerdiffstown House: these will restrict the position of discharge pipework to the Morell River.
  - Rock armour along the bank of the Morell River.
- Construction
  - Remediation works phasing may impact on the surface water management proposals.
- Operations
  - Location of gas control and leachate treatment infrastructure.
- Access Road
  - Restricted space within the development site to accommodate access tracks for future maintenance.
  - Proposed roads within the site requiring underground drainage system.

The SWMP sets out the strategy and drainage proposals taking cognisance of site constraints.

3. Design Outputs

Catchment Areas

The approximate catchment areas for each zone are shown as follows.

Catchment Zone	Area (ha)
Catchment Zone 1	22.90
Catchment Zone 2	5.40
Catchment Zone 3	2.0
Catchment Zone 4	0.52
Total Catchment Area	**30.82***

* Total Catchment Area represents that within the site boundary. However, Catchment Zone 4 is greenfield only with overland flow away from the site, hence the area applicable for this surface water management plan is 30.30ha.

Discharge Rates

The discharge rate from the proposed restoration site should be limited to Q_{BAR} or 2 l/s/ha, whichever is greater, in order to ensure that the surface water run-off from the site does not have a detrimental impact on the downstream river network and increase the risk of flooding. The estimated Q_{BAR} from the whole site catchment is 68.73l/s, equivalent to 2.23 l/s/ha. The greenfield run-off estimation calculation and results is attached in Appendix F for reference.

Discharge via a new outfall structure to the Morell River would be at a maximum rate of 51.07l/s (permissible Q_{BAR} rate per approximate Catchment Zone 1 area of 22.90ha).

Foul and Grey Waters Design Input Data

1. Assumptions

The end-use design accounts for two multi-use sports pitches, with a changing rooms building available for use. There will be four changing rooms, with a capacity of 30 people each. A typical layout of a building shows that each changing room may have two toilets, two washbasins and four showers. There will also be four rooms for referees / first aid, each comprising one shower, one toilet and one washbasin. Further there is outline provision for three additional public toilets in the building. In total design has been based on the following:

- 15 toilets;
- 15 washbasins; and
- 20 showers.

2. Peak Daily Flow

Showers
On average, a shower would use 0.16 l/s. Assuming the worst case water usage scenario, when all 20 showers are all in use at once, the water consumption for the showers would be 3.2 l/s.

Toilets
A typical WC would use approximately 0.1 l/s. The most conservative water usage scenario would be that all 15 toilets are used at once. Therefore, the total water consumption for the toilets would be 1.5 l/s if all of the toilets are flushed simultaneously.

Washbasins
An average tap would require 0.08 l/s. If all of the taps are running simultaneously, that will be 1.12 l/s.

Peak Daily Flow
The maximum daily peak flow would occur when all of the toilets, washbasins and showers are used at the same time. Thus, the instantaneous peak flow for the changing rooms building would be approximately 6 l/s.

3. Average Daily Flow

The wastewater peak factor can be estimated as follows:

$$k_1 = \frac{peak\ daily\ flow}{average\ daily\ flow}$$

Where $k_1 = peak\ factor$.

A suitable design value for k_1 is 1.8, therefore the average daily flow can be calculated as follows:

$$Average\ daily\ flow = \frac{peak\ daily\ flow}{k_1} = \frac{6\ l/s}{1.8} \cong 3.3\ l/s$$

The sewerage pipe is designed for the average daily flow of 3.3 l/s. The nominal diameter of the pipe is calculated as per BS EN 12056-2, which dictates that for a hydraulic capacity of 3.3 l/s, the nominal diameter of the pipe should not be less than 100mm and 60mm for vents. Sewage design dictates pipes should not be less than 150mm in diameter hence the rising main sewage pipe shall be a fully welded 150mm (internal diameter) barrier MDPE pipe. The minimum depth of cover to the pipe crown will be 900mm.

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4. Site Compound Office

It is proposed that that the site office will have two toilets – one male and one female, providing two toilets and two washbasins. The peak flow would occur when all of the facilities are used at once, hence would be the sum of the water usage per second of all of the facilities. Therefore, the peak daily flow for the site compound office would be 0.36 l/s.

The average daily flow would then be:

$$Average\ daily\ flow = \frac{peak\ daily\ flow}{k_1} = \frac{0.36\ l/s}{1.8} = 0.2\ l/s$$

Due to the low flows and short distance of pipe, this rising main sewage pipe shall be a fully welded 100mm barrier MDPE pipe. The minimum depth of cover to the pipe crown will be 900mm.

5. Design Constraints

The key constraints to be managed from the perspective of foul and grey water management were identified through initial design and consultations with relevant stakeholders. The key constraints are divided into the following sections:

- Topography
  - Ground profile and existing watercourses: the topography defines the direction of foul water flow paths and location at which water can be discharged. In addition the position of discharged points is restricted by location of the existing foul water network / treatment works.

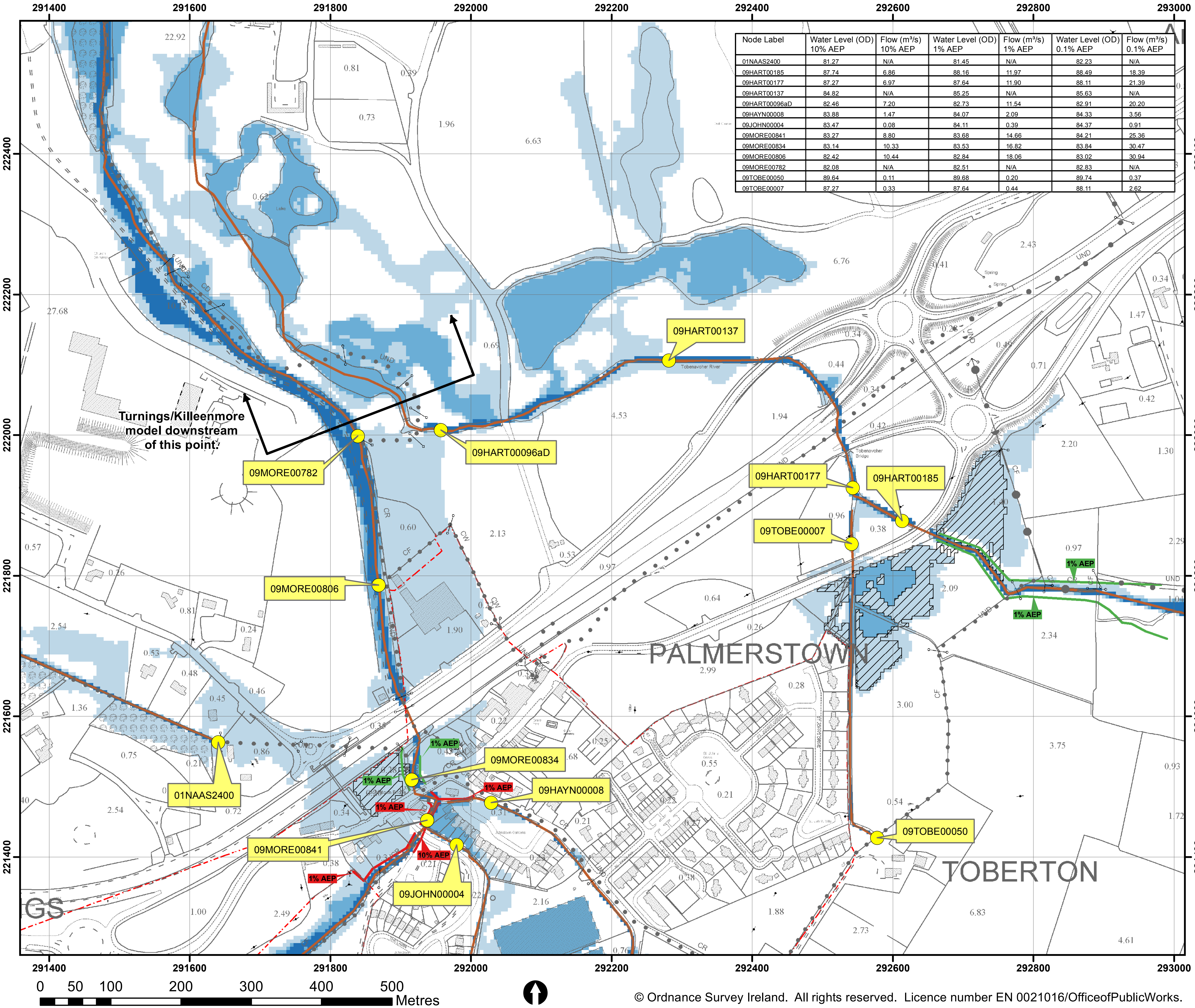
Appendix C. Rainfall Data

Met Eireann
Return Period Rainfall Depths for sliding Durations
Irish Grid: Easting: 291400, Northing: 222100,

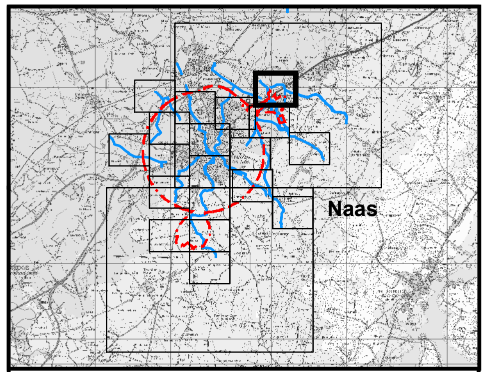
	Interval		Years													
DURATION	6months,	1year,	2,	3,	4,	5,	10,	20,	30,	50,	75,	100,	150,	200,	250,	500,
5 mins	2.6,	3.7,	4.4,	5.3,	6.0,	6.5,	8.2,	10.2,	11.5,	13.4,	15.1,	16.4,	18.4,	20.0,	21.3,	N/A ,
10 mins	3.6,	5.2,	6.1,	7.5,	8.4,	9.1,	11.5,	14.2,	16.0,	18.7,	21.0,	22.8,	25.7,	27.9,	29.7,	N/A ,
15 mins	4.2,	6.1,	7.2,	8.8,	9.8,	10.7,	13.5,	16.7,	18.9,	21.9,	24.7,	26.8,	30.2,	32.8,	35.0,	N/A ,
30 mins	5.6,	8.0,	9.3,	11.3,	12.6,	13.7,	17.1,	21.0,	23.6,	27.3,	30.6,	33.2,	37.2,	40.3,	42.8,	N/A ,
1 hours	7.4,	10.5,	12.1,	14.5,	16.2,	17.5,	21.7,	26.5,	29.6,	34.0,	38.0,	41.0,	45.8,	49.4,	52.5,	N/A ,
2 hours	9.8,	13.6,	15.7,	18.7,	20.8,	22.3,	27.5,	33.3,	37.1,	42.4,	47.1,	50.7,	56.3,	60.7,	64.2,	N/A ,
3 hours	11.5,	15.9,	18.2,	21.7,	24.0,	25.8,	31.6,	38.0,	42.3,	48.2,	53.4,	57.4,	63.6,	68.4,	72.3,	N/A ,
4 hours	13.0,	17.8,	20.3,	24.1,	26.6,	28.6,	34.8,	41.8,	46.4,	52.8,	58.4,	62.7,	69.3,	74.4,	78.7,	N/A ,
6 hours	15.3,	20.8,	23.7,	27.9,	30.8,	33.0,	40.0,	47.9,	52.9,	60.0,	66.2,	71.0,	78.3,	83.9,	88.5,	N/A ,
9 hours	18.0,	24.3,	27.5,	32.4,	35.6,	38.1,	46.0,	54.7,	60.4,	68.2,	75.1,	80.4,	88.4,	94.6,	99.7,	N/A ,
12 hours	20.2,	27.1,	30.7,	36.0,	39.5,	42.1,	50.7,	60.2,	66.3,	74.8,	82.1,	87.8,	96.4,	103.0,	108.4,	N/A ,
18 hours	23.8,	31.6,	35.7,	41.7,	45.6,	48.6,	58.3,	68.8,	75.6,	85.0,	93.2,	99.4,	108.9,	116.1,	122.1,	N/A ,
24 hours	26.7,	35.3,	39.8,	46.3,	50.6,	53.9,	64.3,	75.7,	83.0,	93.1,	101.9,	108.6,	118.7,	126.4,	132.8,	154.5,
2 days	32.3,	41.8,	46.6,	53.5,	58.1,	61.5,	72.4,	84.1,	91.5,	101.7,	110.4,	117.1,	127.1,	134.7,	140.9,	161.9,
3 days	37.0,	47.3,	52.5,	59.9,	64.7,	68.3,	79.7,	91.9,	99.5,	110.0,	119.0,	125.7,	135.9,	143.6,	149.8,	171.0,
4 days	41.4,	52.3,	57.8,	65.6,	70.7,	74.5,	86.4,	99.0,	107.0,	117.7,	126.9,	133.9,	144.3,	152.1,	158.4,	179.9,
6 days	49.2,	61.4,	67.4,	76.0,	81.5,	85.6,	98.4,	112.0,	120.4,	131.8,	141.5,	148.8,	159.7,	167.8,	174.4,	196.6,
8 days	56.3,	69.6,	76.1,	85.3,	91.2,	95.6,	109.3,	123.7,	132.6,	144.6,	154.7,	162.3,	173.7,	182.2,	189.0,	212.0,
10 days	62.9,	77.2,	84.2,	94.0,	100.3,	105.0,	119.4,	134.5,	143.9,	156.4,	167.0,	174.9,	186.7,	195.5,	202.6,	226.3,
12 days	69.2,	84.4,	91.8,	102.2,	108.8,	113.8,	129.0,	144.7,	154.5,	167.5,	178.5,	186.7,	198.9,	208.0,	215.3,	239.7,
16 days	81.1,	98.1,	106.2,	117.6,	124.9,	130.3,	146.7,	163.8,	174.3,	188.3,	200.0,	208.8,	221.7,	231.3,	239.1,	264.8,
20 days	92.4,	110.9,	119.8,	132.1,	139.9,	145.7,	163.4,	181.5,	192.7,	207.5,	220.0,	229.2,	242.9,	253.0,	261.1,	288.1,
25 days	106.0,	126.2,	135.8,	149.2,	157.6,	163.9,	183.0,	202.5,	214.4,	230.2,	243.4,	253.2,	267.7,	278.4,	286.9,	315.3,

NOTES:
N/A Data not available
These values are derived from a Depth Duration Frequency (DDF) Model
For details refer to:
'Fitzgerald D. L. (2007), Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Eireann, Dublin',
Available for download at www.met.ie/climate/dataproducts/Estimation-of-Point-Rainfall-Frequencies_TN61.pdf

Appendix D. Flood Risk Map & Local Flood Report



Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 1% AEP	Flow (m³/s) 1% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
01NAAS2400	81.27	N/A	81.45	N/A	82.23	N/A
09HART00185	87.74	6.86	88.16	11.97	88.49	18.39
09HART00177	87.27	6.97	87.64	11.90	88.11	21.39
09HART00137	84.82	N/A	85.25	N/A	85.63	N/A
09HART00096aD	82.46	7.20	82.73	11.54	82.91	20.20
09HAYN00008	83.88	1.47	84.07	2.09	84.33	3.56
09JOHN00004	83.47	0.08	84.11	0.39	84.37	0.91
09MORE00841	83.27	8.80	83.68	14.66	84.21	25.36
09MORE00834	83.14	10.33	83.53	16.82	83.84	30.47
09MORE00806	82.42	10.44	82.84	18.06	83.02	30.94
09MORE00782	82.08	N/A	82.51	N/A	82.83	N/A
09TOBE00050	89.64	0.11	89.68	0.20	89.74	0.37
09TOBE00007	87.27	0.33	87.64	0.44	88.11	2.62



IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

- 10% Fluvial AEP Event
- 1% Fluvial AEP Event
- 0.1% Fluvial AEP Event
- Modelled River Centreline
- AFA Extents
- Embankment
- Wall
- Defended Area
- 1% AEP / 1% AEP — Standard of Protection of Flood Defence (Walls / Embankments)
- Node Point
- Node ID — Node Label

FINAL

REV:	NOTE:	DATE:
01	Amendments made to wire grid.	20/09/16

EASTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

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Map:
Naas Fluvial Flood Extents

Map Type: EXTENT
Source: FLUVIAL
Map Area: HPW
Scenario: CURRENT
Drawn By : C.C. **Date :** 20 September 2016
Checked By : T.D. **Date :** 20 September 2016
Approved By : G.G. **Date :** 20 September 2016
Drawing No. :
E09NAA_EXFCD_F1_20
Map Series : Page 20 of 21
Drawing Scale : 1:5,000 @ A3

OPW National Flood Hazard Mapping

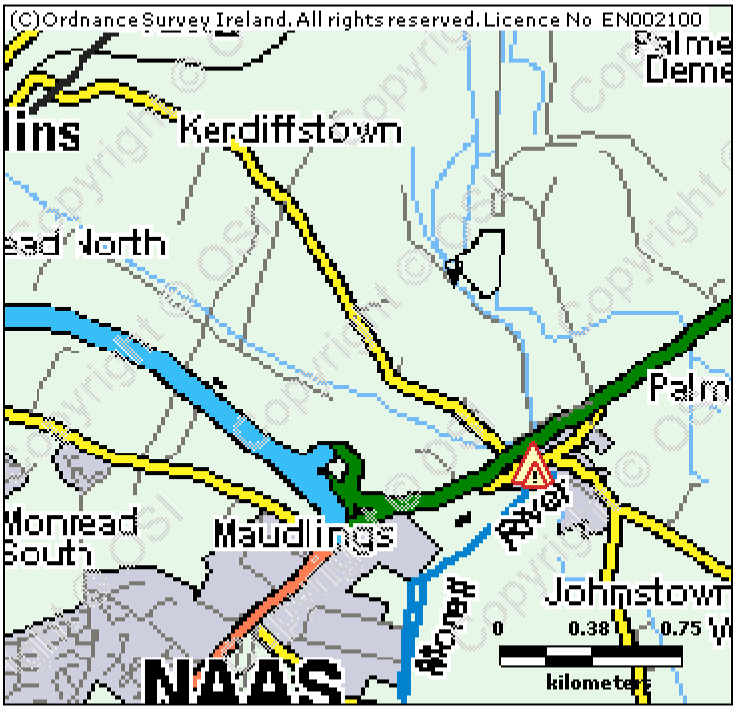
Summary Local Area Report

This Flood Report summarises all flood events within 2.5 kilometres of the map centre.

The map centre is in:

County: Kildare

NGR: N 912 219



Map Scale 1:31,079

Map Legend
Flood Points
Multiple / Recurring Flood Points
Areas Flooded
Hydrometric Stations
Rivers
Lakes
River Catchment Areas
Land Commission *
Drainage Districts *
Benefiting Lands *

* Important: These maps do not indicate flood hazard or flood extent. Thier purpose and scope is explained in the Glossary.

4 Results

1. Monread Sallins Co Kildare 30th Nov 2009 — Start Date: 29/Nov/2009

   County: Kildare — Flood Quality Code: 3

   Additional Information: Reports (2) More Mapped Information

2. Morell Johnstown Nov 2000 — Start Date: 05/Nov/2000

   County: Kildare — Flood Quality Code: 2

   Additional Information: Reports (2) More Mapped Information

3. Morell Johnstown June 1993 — Start Date: 10/Jun/1993

   County: Kildare — Flood Quality Code: 3

   Additional Information: Reports (2) More Mapped Information

4. Morell Johnstown Recurring — Start Date:

   County: Kildare — Flood Quality Code: 3

   Additional Information: Reports (2) More Mapped Information

OPW *National Flood Hazard Mapping*

Summary Local Area Report

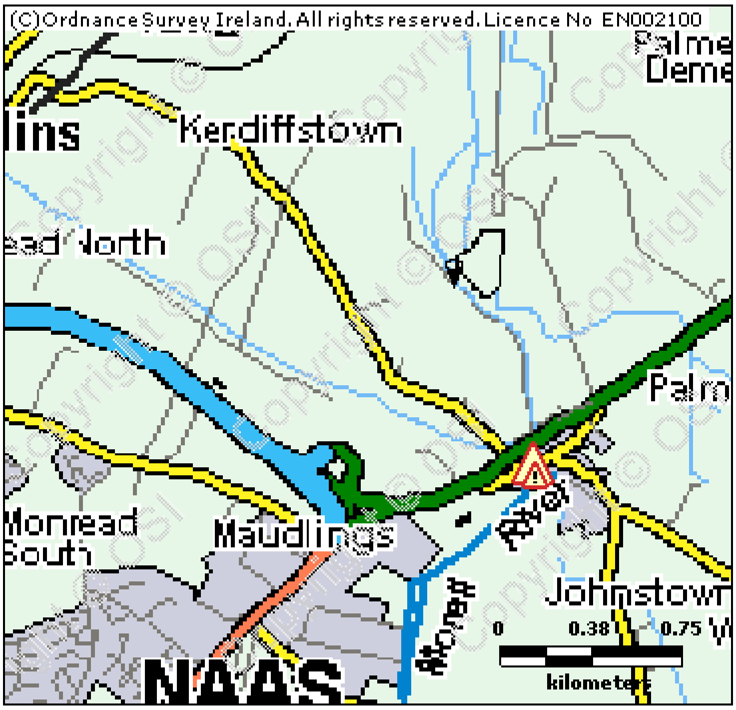
This Flood Report summarises all flood events within 2.5 kilometres of the map centre.

The map centre is in:

County: Kildare

NGR: N 912 219

This Flood Report has been downloaded from the Web site www.floodmaps.ie. The users should take account of the restrictions and limitations relating to the content and use of this Web site that are explained in the Disclaimer box when entering the site. It is a condition of use of the Web site that you accept the User Declaration and the Disclaimer.



Map Scale 1:31,079

Map Legend
Flood Points
Multiple / Recurring Flood Points
Areas Flooded
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Land Commission *
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Additional Information: Reports (2) More Mapped Information

4. Morell Johnstown Recurring — Start Date:
County: Kildare — Flood Quality Code:3
Additional Information: Reports (2) More Mapped Information

Appendix E. Peak Run-off Rates

Peak run-off rates and open channels summary table									
Channel reference	Catchment Area (ha)	Flow rate (m^3/s)	Gradient 1 : X (m)	Base width (m)	Channel Depth (m)	Channel bank slope	Top channel width (m)	Length (m)	Gravel lining (Y/N)
CH01	2.49	0.245	172	0.50	0.40	1 in 3	2.90	138.00	N
CH02	2.68	0.254	172	0.50	0.40	1 in 3	2.90	162.00	N
CH03	1.15	0.188	150	0.50	0.40	1 in 3	2.90	314.00	N
CH04	2.75	0.451	87	0.45	0.43	1 in 3	3.03	391.00	Y
CH05	4.16	0.390	150	0.50	0.45	1 in 3	3.20	361.00	N
CH06	0.57	0.047	300	0.45	0.30	1 in 3	2.20	166.00	N
CH07	3.90	0.639	80	0.45	0.50	1 in 3	3.45	98.00	Y
CH08	6.90	0.983	300	0.55	0.65	1 in 3	4.45	269.00	N
CH09	3.00	0.344	300	0.50	0.50	1 in 3	3.50	347.00	N
CH10	7.60	0.851	40	0.50	0.46	1 in 3	3.26	242.00	Y
CH11	0.91	0.149	500	0.50	0.40	1 in 3	2.90	380.00	N
CH12	0.73	0.120	300	0.50	0.35	1 in 3	2.60	84.00	N
CH13	15.23	1.610	150	0.50	0.70	1 in 3	4.70	197.00	Y
CH14	0.52	0.085	80	0.50	0.30	1 in 3	2.30	217.00	N
CH15	0.72	0.059	100	0.50	0.30	1 in 3	2.30	254.00	N
CH16	0.29	0.033	150	0.50	0.30	1 in 3	2.30	107.00	N
CH17	0.55	0.090	200	0.50	0.35	1 in 3	2.60	143.00	N
CH18	1.91	0.313	200	0.50	0.45	1 in 3	3.20	184.00	N
CH19	0.19	0.009	300	0.10	0.25	1 in 3	1.60	118.00	N
CH20	1.33	0.065	300	0.45	0.30	1 in 3	2.25	210.00	N

Appendix F. Q_{BAR} Calculations

HR Wallingford
Working with water

Greenfield runoff estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Patryk Ciesla
Site name:	Kerdiffstown Landfill Remediation Project
Site location:	Kerdiffstown Landfill

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance “Preliminary rainfall runoff management for developments”, W5-074/A/TR1/1 rev. E (2012) and the SuDS Manual, C753 (Ciria, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site coordinates

Latitude:	53.24040° N
Longitude:	6.62838° W
Reference:	5902657
Date:	2017-03-09T08:29:34

Methodology	IH124

Site characteristics

Total site area (ha)	30.82

Methodology

Qbar estimation method	Calculate from SPR and SAAR
SPR estimation method	Calculate from SOIL type

	Default	Edited
SOIL type	2	2
HOST class	---	---
SPR/SPRHOST	0.3	0.3

Hydrological characteristics

	Default	Edited
SAAR (mm)	831	831
Hydrological region	12	12
Growth curve factor: 1 year	0.85	0.85
Growth curve factor: 30 year	2.13	2.13
Growth curve factor: 100 year	2.61	2.61

Notes:

(1) Is Q_{BAR} < 2.0 l/s/ha?

(2) Are flow rates < 5.0 l/s?

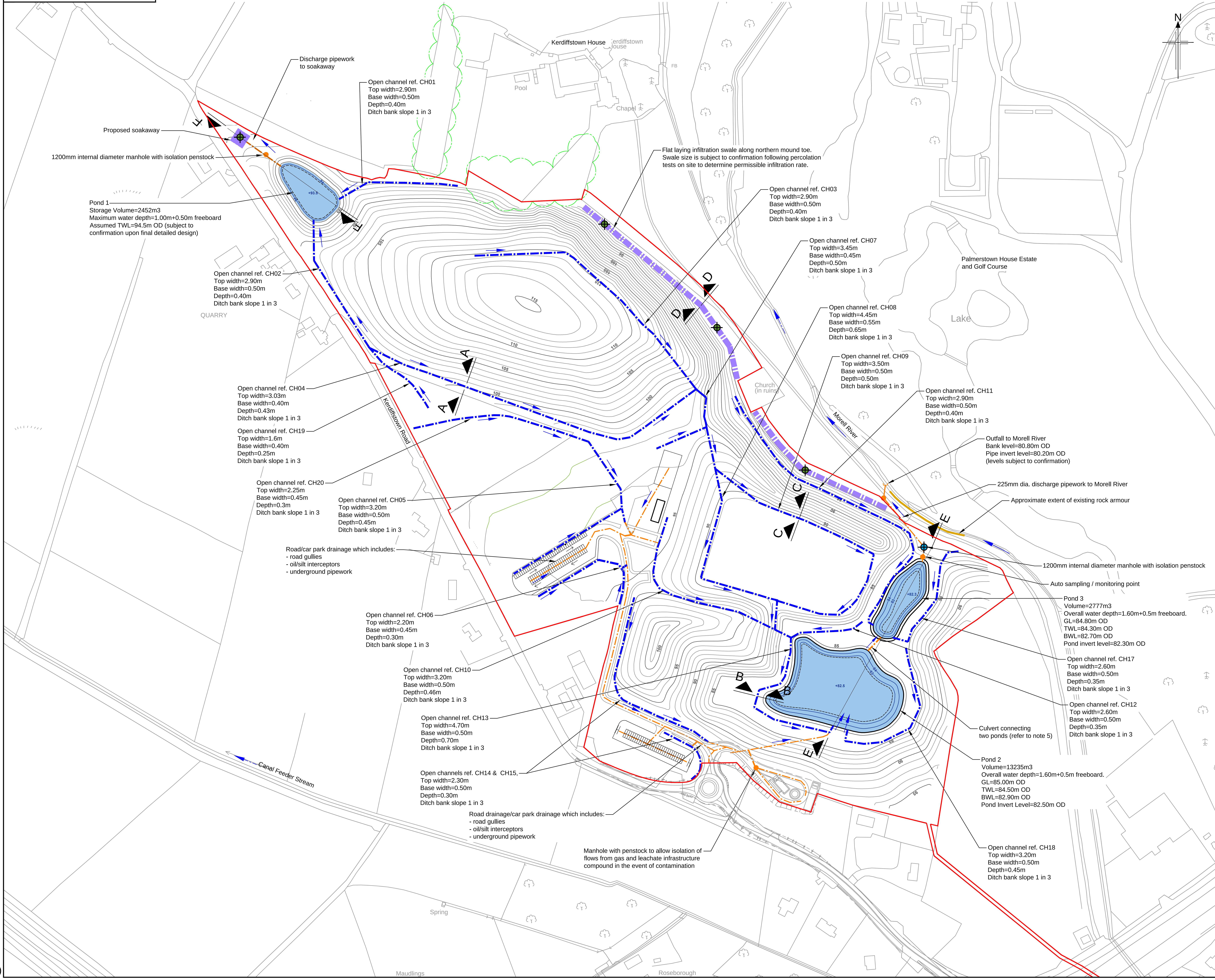
(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite may be a requirement for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Qbar (l/s)	68.65	68.65
1 in 1 year (l/s)	58.35	58.35
1 in 30 years (l/s)	146.23	146.23
1 in 100 years (l/s)	179.18	179.18

32EW5604-00-044-2



KEY:

- Licence boundary
- Approximate extent of existing rock armour
- Proposed storage pond
- Proposed ditch/open channel
- Proposed infiltration swale/trench
- Proposed underground pipework
- Proposed manhole / chamber
- Proposed outfall
- Direction of flows
- Proposed soakaway
- Surface water emission point
- Ground emission point
- Existing Copse (mature trees)
- GL Ground Level
- TWL Top Water Level
- BWL Bottom Water Level

NOTES:

1. All levels are to metres OD (Malin Head) unless stated otherwise.
2. All dimensions are in millimetres unless stated otherwise.
3. This drawing should be read in conjunction with the Surface Water Management Plan.
4. The size and shape of the proposed soakaway is to be confirmed during detailed design phase.
5. The size and general arrangement of culvert between Pond 2 and Pond 3 is to be confirmed during detailed design phase.
6. For section details refer to Drawings 32EW5604-00-045 and 32EW5604-00-046. (In Surface Water Management Plan).
7. Drainage from upgraded road will tie into the existing road.

0 50 100 150 200 m

SCALE 1 : 2000

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
2	07/08/2017	EIAR SUBMISSION	AR	CD	CD	RR
1	30/06/2017	EIAR SUBMISSION	KMA	CD	CD	RR
0	14/12/2016	EIS SUBMISSION	VT	PHC	AHK	RR

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Jacobs, Merrion House, Merrion Road, Dublin 4
Tel:+353(1)269 5666
www.jacobs.com

Client

Kildare County Council
Comhairle Contae Chill Dara

Project

KERDIFFSTOWN LANDFILL
REMEDIATION PROJECT

Drawing title

SURFACE WATER MANAGEMENT PLAN
OUTLINE DRAINAGE LAYOUT

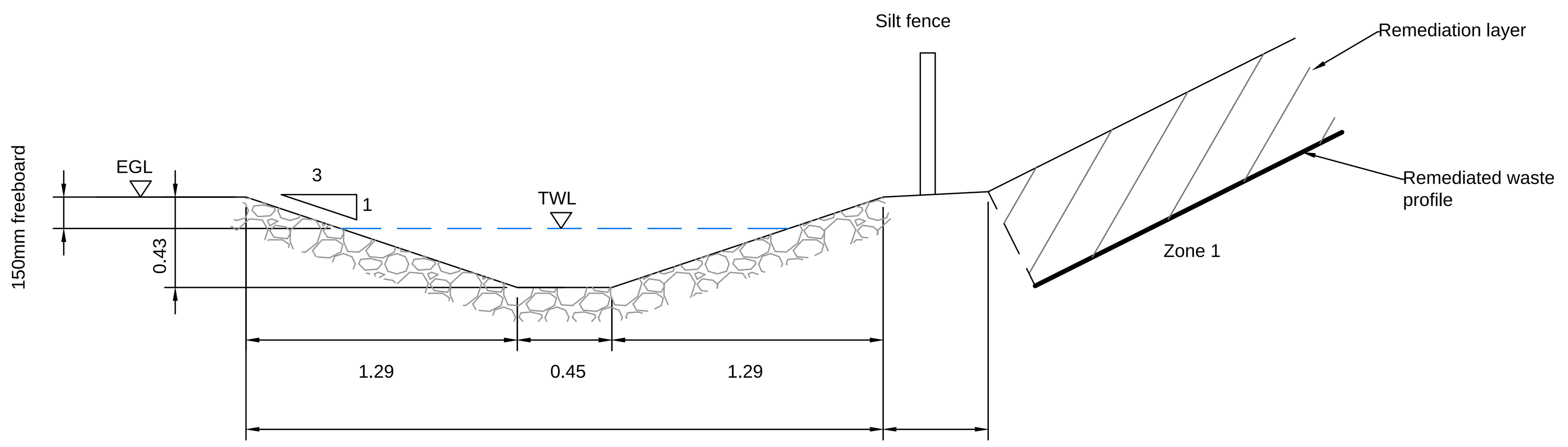
Drawing status

EIAR SUBMISSION

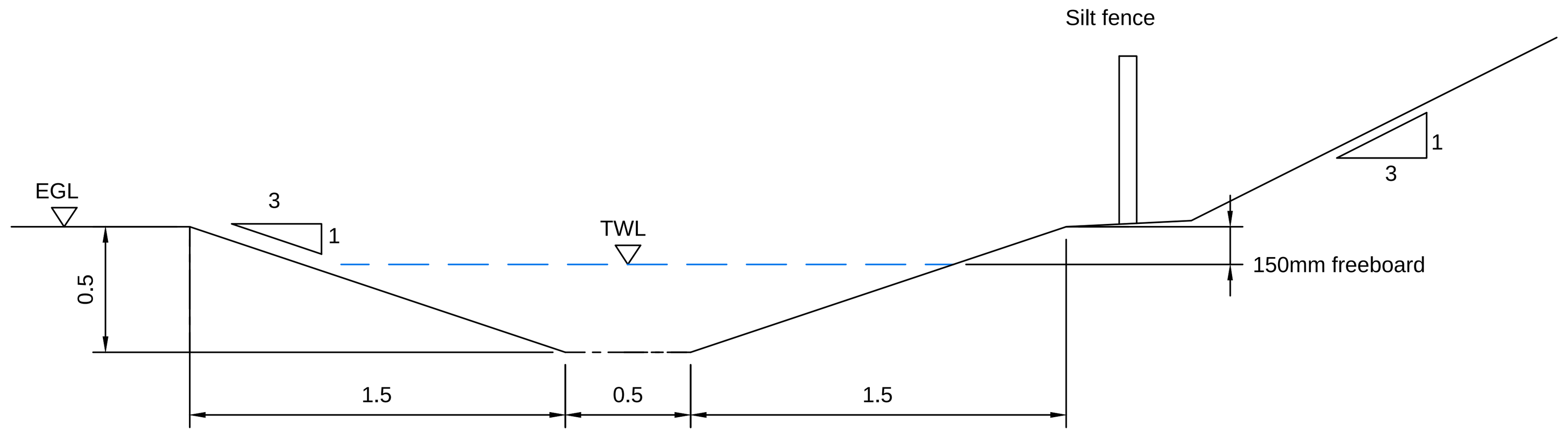
Scale	1:2000 @A1	DETAILS SHOWN ARE NOT FOR CONSTRUCTION PURPOSES HENCE DRAWING SHOULD NOT BE SCALED
Jacobs No.	32EW5604	
Client no.	6286	

Drawing number: 32EW5604-00-044

Rev: 2



SECTION A-A CHANNEL REF. CH04
TYPICAL DRAINAGE CHANNEL SECTION
(WITH GRAVEL LINING)
SCALE 1:25



SECTION C-C - CHANNEL REF. CH09
TYPICAL DRAINAGE CHANNEL SECTION
(WITHOUT GRAVEL LINING)
SCALE 1:25

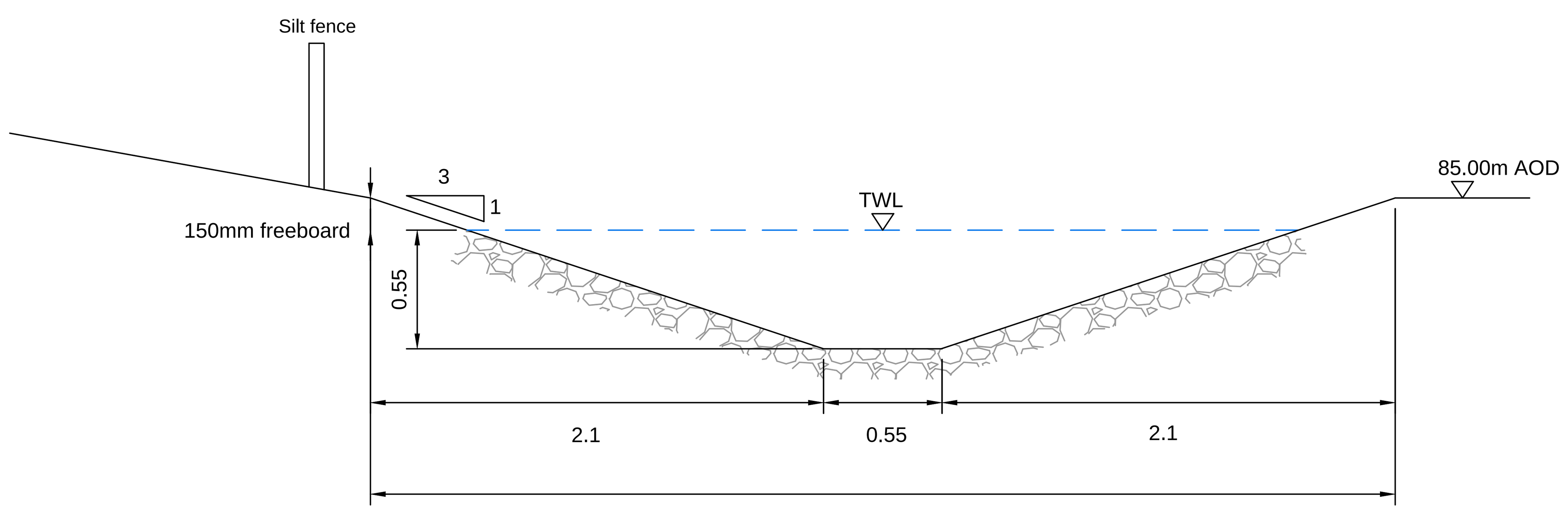
KEY:

EGL Existing Ground Level

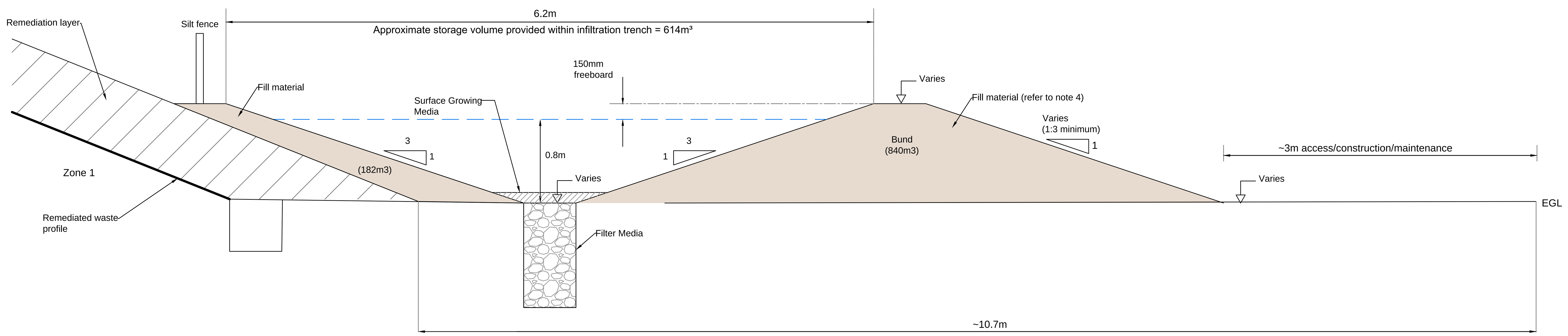
TWL Top Water Level

NOTES:

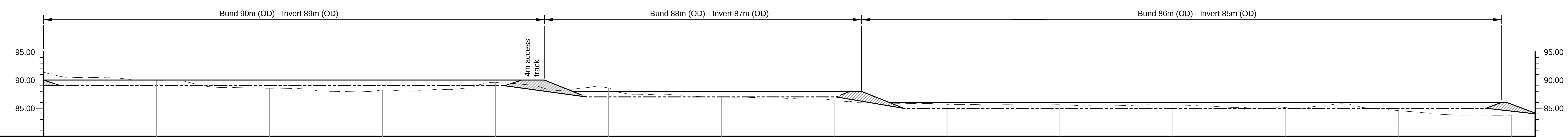
1. All levels are in metres OD (Malin Head).
2. All dimensions are in millimeters unless stated otherwise.
3. Silt fence to remain in place until the vegetation within restoration areas and mounds have been well established and perimeter ditches grassed.
4. The details of the proposed bund will be confirmed during detailed design. The bund material will need to prevent seepage along plane between fill and existing ground.



SECTION B-B - CHANNEL REF. CH13
TYPICAL DRAINAGE CHANNEL SECTION
(WITH GRAVEL LINING)



SECTION D-D - INFILTRATION SWALE INDICATIVE DETAIL
SCALE 1:25



Chainage (m)	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	264.164
Existing Ground Level m(OD)	91.413	89.963	88.556	88.242	89.614	88.603	86.987	86.456	85.694	85.593	85.586	85.098	84.575	83.762	84.133

INFILTRATION SWALE - INDICATIVE LONG SECTION
SCALE 1:500

0 10 20 30 40 50m
SCALE 1 : 500

0 0.5 1.0 1.5 2.0 2.5 m
SCALE 1 : 25

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
2	07/08/2017	EIAR SUBMISSION	AR	CD	CD	RR
1	30/06/2017	EIAR SUBMISSION	AR	CD	CD	RR
0	14/12/2016	DRAFT EIS SUBMISSION	VT	PHC	AHK	RR

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Client
Kildare County Council
Comhairle Contae Chill Dara

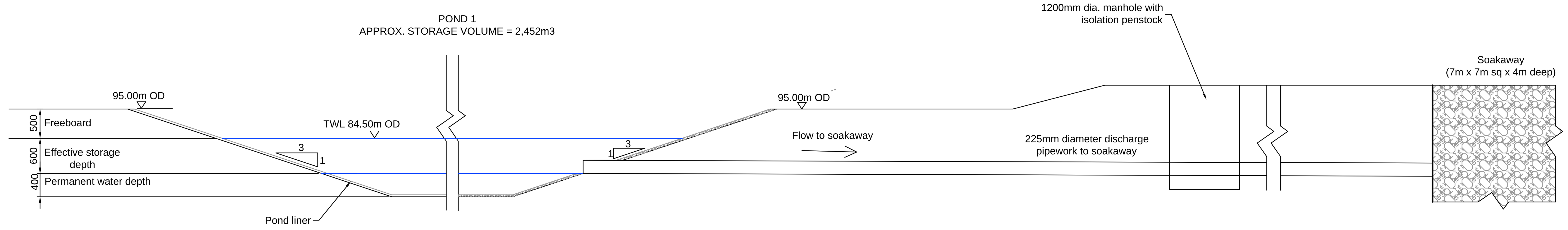
Project
KERDIFFSTOWN LANDFILL
REMEDIATION PROJECT

Drawing title
SURFACE WATER MANAGEMENT PLAN
CHANNEL AND INFILTRATION
SWALE DETAILS

Drawing status
EIAR SUBMISSION

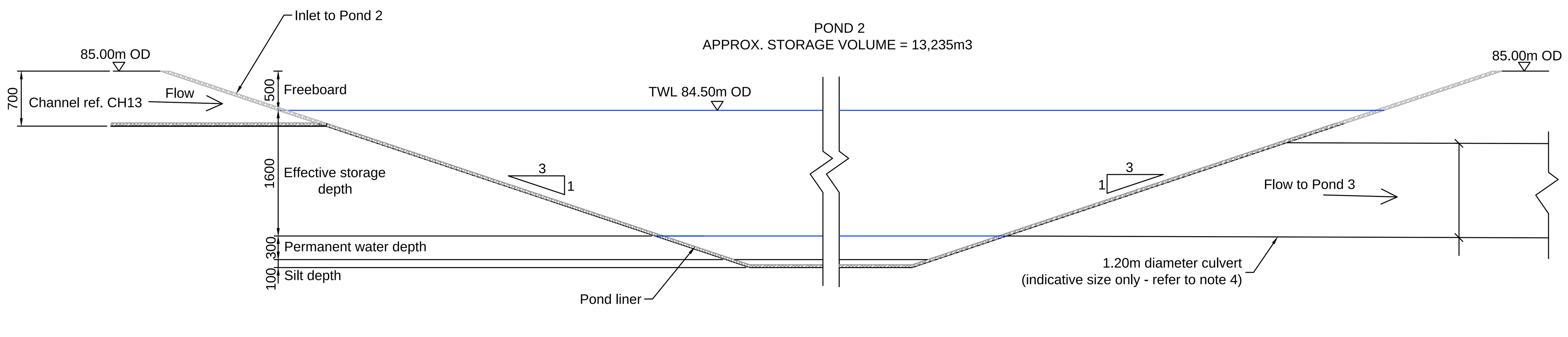
Scale	AS SHOWN — DO NOT SCALE
Jacobs No.	32EW5604
Client No.	6286

Drawing number 32EW5604-00-045 Rev 2



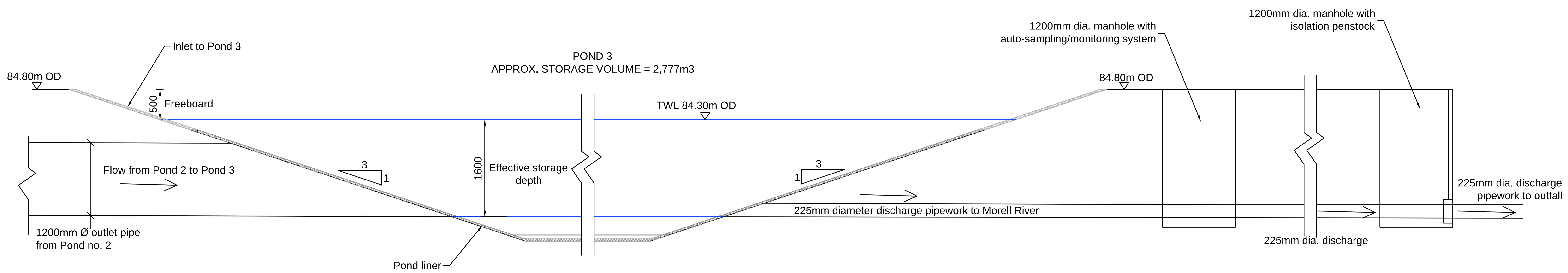
SECTION F-F - POND 1

SCALE (1:50)



SECTION E-E - POND 2

SCALE (1:50)



SECTION E-E (continuation) POND 3

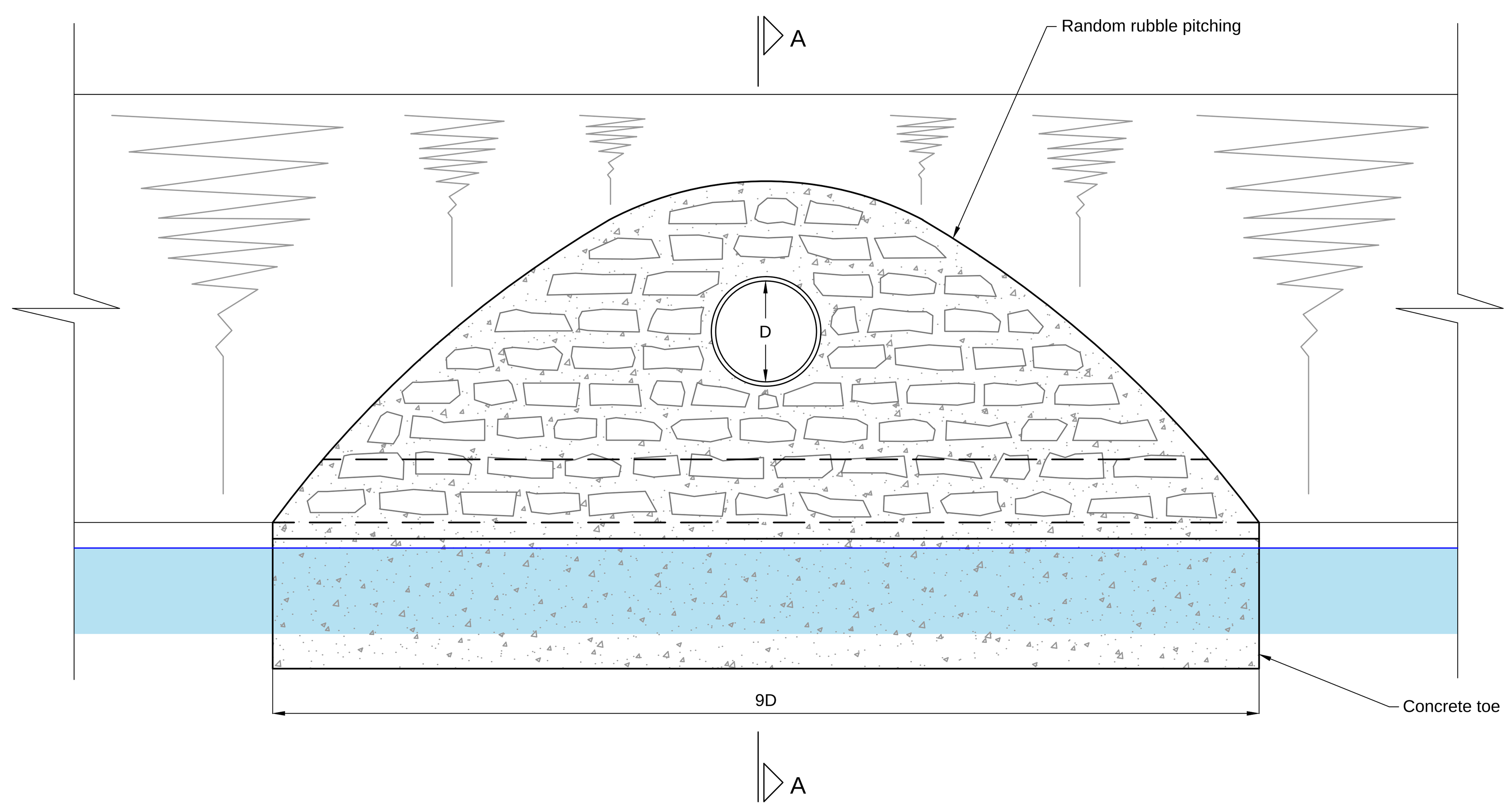
SCALE (1:50)

0 1 2 3 4 5 m

SCALE 1 : 50

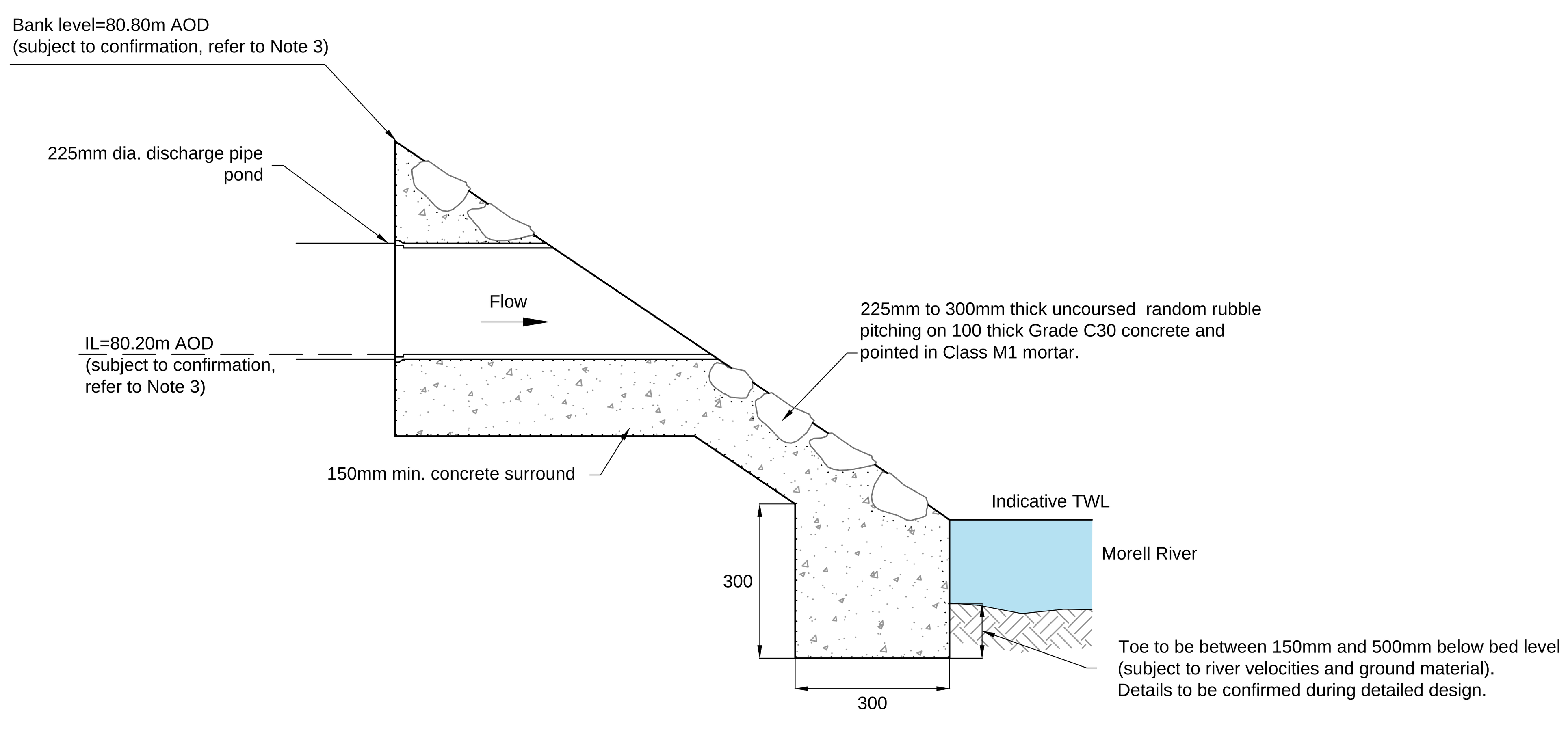
0 0.1 0.5 1.0 m

SCALE 1 : 10



TYPICAL OUTFALL FRONT ELEVATION

(SCALE 1:10)



SECTION A-A

(SCALE 1:10)

NOTES:

1. All levels metres OD (Malin Head) unless stated otherwise.
2. All dimensions are in millimeters unless stated otherwise.
3. Both ponds to be lined with an impermeable heavy duty geomembrane with a stone layer placed on top of the liner to protect it during maintenance/emptying operations. Specification for stone layer to be confirmed in detailed design. A growing medium/top soil to be placed on top of the stone layer to provide ecological enhancement (details to be confirmed during detailed design by environmental engineers and landscapers).
4. The size and general arrangement of culvert between Pond 2 & Pond 3 is to be confirmed during detailed design phase.

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
2	07/08/2017	EIAR SUBMISSION	AR	CD	CD	RR
1	30/06/2017	EIAR SUBMISSION	AR	CD	CD	RR
0	14/12/2016	DRAFT EIS SUBMISSION	VT	PHC	AHK	RR

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Client

Kildare County Council
Comhairle Contae Chill Dara

Project

KERDIFFSTOWN LANDFILL
REMEDIATION PROJECT

Drawing title

SURFACE WATER MANAGEMENT PLAN
POND AND OUTFALL DETAILS

Drawing status

EIAR SUBMISSION

Scale	AS SHOWN @ A1	DETAILS SHOWN ARE NOT FOR CONSTRUCTION PURPOSES HENCE DRAWING SHOULD NOT BE SCALED
Jacobs No.	32EW5604	
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Drawing number: 32EW5604-00-046

Rev: 2