Waste Futures - Green Island Landfill Closure

Design Report – September 2023 Update

Dunedin City Council

3 March 2023

→ **The Power of Commitment**

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The Power of Commitment

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Glossary of terms

Abbreviation	Definition
Council	Dunedin City Council or the Council
GIWWTP	Green Island Wastewater Treatment Plant
Ha	Hectares
L/s	Litres per second
m^3/d	Cubic metres per day
m^2	Square metres
m amsl	Metres above mean sea level
mRL	Metres to the Dunedin City Datum. This equates to mean sea level + 100 m
ORC	Otago Regional Council
LDMP	Landfill Development Management Plan – prepared by DCC
LOP	Landfill Operations Plan – prepared by the landfill operator and reflects the requirements of the LDMP with a focus on more day-t-day operations
GIWWTP	Green Island Waste Water Treatment Plant – Dunedin City's primary waste water treatment facility and receives leachate for treatment from Green Island Landfill.
LFG	Landfill Gas
HDPE	High Density Polyethylene

1. Introduction

1.1 Background

As part of Dunedin's wider commitment to reducing carbon emissions and reducing waste going to landfill, the Dunedin City Council (Council) has embarked on the Waste Futures Programme to develop an improved comprehensive waste management and diverted material system for Ōtepoti Dunedin. The Waste Futures Programme includes the roll out of an enhanced kerbside recycling and waste collection service for the city from July 2024. The new service will include collection of food and green waste.

To support the implementation of the new kerbside collection service, the DCC are planning to make changes to the use of Green Island landfill site (Figure 1) in coming years.

Figure 1 Green Island Landfill Site

The proposed changes include:

- planning for the closure of the Green Island landfill, which is coming to the end of its operational life
- developing an improved Resource Recovery Park (RRPP) to process recycling, and food and green waste
- providing new waste transfer facilities to service a new Class 1 landfill currently planned for a site south of Dunedin, at Smooth Hill.

The resource consents for the new Smooth Hill landfill are subject to appeal. Depending on the outcome of this appeal process, and the time needed to undertake baseline monitoring, preparation of management plans, landfill and supporting infrastructure design and construction, DCC anticipate that the new Class I landfill facility, won't be able to accept waste until 2027/2028 at the earliest.

In the interim, DCC therefore plans to continue to use Green Island landfill for waste disposal. Based on Dunedin's current waste disposal rates, it is likely that that the Green Island landfill can keep accepting waste for another six years (until about 2029). Between now and then, and as it continues to fill up, the landfill will be closed and capped in stages. When the landfill closes completely, there will be opportunities for environmental enhancements and public recreational use around the edge of the site. Examples could be planting restoration projects and new walking and biking tracks beside the Kaikorai Estuary. Long term use and public access to the landfill site post closure will be determined in consultation with Te Rūnanga o Ōtākou, the local community and key stakeholders.

As current Otago Regional Council resource consents needed to operate a landfill at Green Island expire in October 2023, the DCC are now applying to ORC for replacement resource consents to continue to use the landfill until it closes completely, and waste disposal can be transferred to a new landfill facility. The replacement consents relate to ground disturbance, flood defence and discharges to land, water, and air. The site is subject to an operative designation (D658) in the Proposed Second-Generation Dunedin City District Plan (2GP) for the purpose of Landfilling and Associated Refuse Processing Operations and Activities.

The development of the new RRPP and waste transfer facilities at Green Island does not form part of the replacement consent applications. Resource consents for the development and operation of the RRPP will be applied for following the completion of design work and technical assessments later in 2023.

1.2 Purpose of this report

The purpose of this report is to support the replacement resource consent application. The report:

- Provides background information regarding the history of Green Island landfill and the current operation of the site, including leachate, surface water management, landfill gas, geotechnical stability and seismic hazards and other relevant management issues.
- Outlines the intended approach to the continued operation, closure and aftercare of the landfill, including changes to both the landfill operation methodology and infrastructure

This report is supported by a range of other technical reports. Of particular relevance to this report are the Groundwater and Surface Water Technical Reports for Green Island (GHD 2023A and GHD 2023B).

1.3 Current landfill operation and management

1.3.1 Current Consents

The operation of the Green Island Landfill including associated waste processing operations and facilities is currently subject to 14 existing resource consents granted by Otago Regional Council (ORC). The consents cover landfill operation activities relating to discharges to land, water, and air, taking and/or diverting water, and disturbance of a contaminated site. All consents expire on 1 October 2023.

The current consents limit the extent of landfilling through the combination of a maximum 38 ha landfill footprint, conditions limiting the deposit of waste to 270 m^3/day and 100,000 m^3/year[1], and the 2023 term of the consents. The consent conditions do not impose any specific limit on the overall finished height, shape, or contour of the landfill. However, the plans included in the 1994 resource consent applications show a finished landfill surface rising to a maximum height of 25 m above mean sea level (amsl).

The consent conditions also require the consents are exercised in accordance with a Landfill Work Programme (LWP) prepared by the consent holder, which is to be reviewed annually or at such lesser frequency as the consent authority may approve. Among other matters, the LWP is required to describe present projections and intentions for landfill operations, and the sequencing of works[2]. A Landfill Development and Management Plan (LDMP) was developed following the issuing of the consents to serve the purpose of the LWP.

1.3.2 Landfill Development and Management Plan

The LDMP is to document site-specific procedures, including monitoring and contingency actions to be implemented to ensure the landfill achieves the conditions set out in the resource consents. The LDMP is organised into the sections set out below.

1. **Introduction –** the existing resource consents, designation, and status and review of the LDMP.
2. **Site Management –** management structure, responsibilities, requirements for staff training, and community liaison.

[1] Resource consents 3839A V1, 3839C V1, 3839D V1, 94524 V1, 94693 V1, 94262 V1.
[2] Resource consents 3839A V1, 3839B V1, 3839C V1, 3839D V1, 3840A V1, 3840C V1, 4139 V1

3. **Landfill Development** – including design principles, landfill capacity, and the filling programme and sequence.
4. **Site Operations** – including controls and procedures for access control, stormwater management, leachate management, LFG management, greenwaste mulching and composting, salvage and management of diverted materials, roading and traffic management, waste acceptance and placement, waste cover, and control of nuisances.
5. **Environmental Monitoring** – including monitoring, recording, and reporting for surface water, groundwater, LFG, leachate, odour, and weather.
6. **Emergency Management** – including procedures for management of fires, hazardous waste/materials, leachate and LFG escape, extreme weather/flooding, machinery failure, accidents, and earthquakes.
7. **Closure, Reinstatement, and Aftercare** – including final capping, continued operation and maintenance of landfill infrastructure, and ongoing monitoring.

The LDMP was first provided to ORC in 1994 following the issuing of the consents and was subsequently updated in 2004, and 2007. The most recent LDMP, which reflects the current approach to landfill operation and management, was provided to ORC in February 2023.

1.3.3 Landfill Operations Plan

The landfill is currently operated by Waste Management NZ Ltd. under contract to the Council. Waste Management Ltd. are required to maintain a Landfill Operations Plan (LOP) which reflects the LDMP and more specifically addresses day-to-day management landfill operational matters.

The LDMP (February 2023) and LOP (October 2018) will be updated after the granting of any replacement resource consents to ensure that they align with the final approved consent documentation, and any resource consent conditions.

2. Site description

2.1 Site location and environs

The Green Island Landfill site is located approximately 8.8 km by road from Central Dunedin in the suburb of Green Island. The landfill site comprises a total area of 75.6 Ha, which is designated in the Proposed Dunedin City District Plan (2GP) for landfilling related activities as shown outlined in Figure 2 below. Primary access to the site is via Brighton Road.

Figure 2 Green Island Landfill – site location and context

The site is generally bound by State Highway 1 to the north, the Kaikorai Stream and Estuary to the west, the Green Island Wastewater Treatment Plant (GIWWTP) to the southwest, Brighton Road to the south, and the Clariton Ave residential area and Brighton Road industrial area to the east.

The Council is also proposing to rezone a block of land between Weir Street and Brighton Road, south of Clariton Avenue, to a General Residential Zone enabling low-medium density residential living.[3]

Other residential properties are located to the southeast at Elwyn Crescent, and to the north and west within Sunnyvale and Fairfield. Those residential properties are located at greater distances and separated from the landfill site by a combination of the State Highway 1 corridor, the Kaikorai Stream and Estuary, and rural and open space

[3] Variation 2 to the Proposed Dunedin City District Plan.

land. An area of undeveloped land zoned General Residential exists within Fairfield and has been identified for future sub-division to be accessed from Walton Park Avenue.

The margins of the Kaikorai Stream and Estuary bordering the landfill to the north and west are identified as a Regionally Significant Wetland in the Otago Regional Plan: Water; and an Area of Significant Biodiversity Value, and a Wāhi Tupuna of cultural significance to mana whenua in the 2GP. Low lying areas around the stream and estuary are also identified as being within a Hazard 2 Flood overlay at moderate risk of flooding in the 2GP.

2.2 Site ownership

The entire Green Island Landfill designation site in Figure 2 above is owned by Council.

2.3 Landfill Development History and Site Setting

The historical placement of waste and its distribution across the site is described in detail in Appendix D of the *Groundwater Technical Report* (GHD 2023A). The following provides a summary of the waste filling history that is relevant to the future engineering design and closure management presented herein.

The landform which existed before waste was placed can be characterised as a tidal estuary associated with the upper reaches of the Kaikorai Estuary. Abbotts Creek flows into the estuary immediately to the north of the site. Waste disposal first occurred at the Green Island site in 1954 with the disposal of industrial waste and the site has been used for waste disposal since that time.

Waste was originally end dumped directly onto the estuarine muds and up against the southern estuary edge where the pre-existing landform rises gently to a hillslope to south. A soil bund was constructed in the 1990s around the north and western sides of the landfill to confine the waste from the adjacent Kaikorai Stream and estuary (shown in Drawing 12547621-01-C101). Landfilling has continued north and west over the decades. The eastern portion of the landfill has a relatively shallow depth of waste of around 3 m to 6 m thickness, and is currently used for facilities and waste transfer station operations. This area is proposed to be developed in the near future to establish the Resource Recovery Park Precinct (RRPP) (see Figure 2). No further waste disposal is proposed to occur in this area.

The main landfill area is located immediately to the west of the facilities area. Waste placement in this area has been confined over recent decades within the constructed soil bund that encircles the landfill on the eastern, northern and western sides adjacent to the estuary (shown on Drawing 12547621-01-G101). However, prior to berm construction waste had been placed across much of the landfill operational area shown on Figure 2.

In recent years waste disposal has progressed north to south. In the northern and eastern areas waste has been placed up to the 2001 design contours (see Drawing 12547621-01-G102) and final capping was completed in December 2022. The southwestern half of the landfill has up to 6 m-8 m depth of waste placed during the 1990's, with a further 10 m to 15 m of waste able to be placed in this area to fill up to the design contours shown on Drawing 12547621-01-G101. This is the area where future waste placement is proposed to occur through to closure of the landfill.

Waste was originally end dumped directly onto the estuarine muds and up against the southern estuary edge where the pre-existing landform rises gently to a hillslope to south. The landfill has an access road on the outside of the bund, with the leachate collection trench located below the centre of this road, with perimeter groundwater monitoring wells installed at select locations each side of the leachate collection trench (see Drawing 12547621-01-G101). The leachate colection trench was installed on the outside of the soil bund in the mid-1990's. This included diversions of both the Kaikorai Stream and Brighton Road Stream to enable these works. This perimeter control is not present along the southern side of the landfill, with a shallow surface drain collecting leachate impacted runoff and groundwater The leachate collection system is described in further detail in Section 3.3 of this report. The main wastewater trunk sewer follows the existing southern edge of the existing landfill, flowing to the Green Island Wastewater Treatment plant (GIWWTP), which is located 200 m southwest of the landfill site. Section 3.0 of this report describes the development history of the landfill. The leachate collection trench was not installed along the southern side of the landfill as the 1994 consent design (Figure 11) included the possibility of placing waste over this sewer line. This option was retained through subsequent design iterations (although not advanced as the preferred option, as shown on Figures 12 and 13). However, since 2019 this has been abandoned as an option by Council – recognising the difficulties and risk in placing 20-25m of waste over the existing sewer.

A number of other sites have been used over the decades across the Dunedin region including the “Maxwell” landfill on the opposite side of the estuary to Green Island landfill. The Maxwell landfill, last operated and owned by Waste Management, was formally closed to waste disposal in mid-2017. Green Island landfill has continued as the sole municipal solid waste disposal facility in the Dunedin region after that time.

2.4 Site Setting and Climate

2.4.1 Site setting

The landfill is primarily constructed on the upper parts of the low lying Kaikorai Estuary and while the landfill extends up to a height of 25 m amsl the land on which it has been constructed is low lying (the western perimeter access road between the landfill and Kaikorai Stream is between 1.5 m and 2.0 m amsl, having been built directly over the estuary sediments.

A review of the ORC Natural Hazard maps indicates that the land in and around the landfill is subject to inundation risk associated with flooding from the Kaikorai Steam and from storm surge. This is reflected in in the Council 2GP which identifies the low-lying areas around the stream and estuary as being within a Hazard 2 Flood overlay at moderate risk of flooding. Surface water and stormwater management is discussed in detail in the *Surface Water Technical Report (GHD 2023).*

2.4.2 Climate Summary

Musselburgh climate station is a NIWA station (ref No. 1572) located 7.5 km to the east of Green Island Landfill and climate information from the station will be indicative of conditions at the landfill site. A summary of conditions is set out below.]

The climate is mild, receiving around 1600 hrs of sunshine annually, with average daily maximum temperatures varying between 19 degrees in summer down to 10 degrees in winter.

Average annual rainfall is relatively low at 750 mm per year. The rainfall is generally consistent throughout the year with monthly averages varying between 49 mm in September to 74 mm in December with between 12-17 raindays/month.

Predominant winds for the area are westerly with easterly winds being the other main wind direction.

An on-site climate station at Green Island Landfill has been established in the past few years. Preliminary findings from the station are presented in the *Air Quality Report* (GHD 2023C)

2.4.3 Climate change

Global temperature changes associated with human activities are resulting in climate change. Current IPCC reporting shows that this will result in a rise in sea level. In addition, while annual rainfall is likely to remain similar to existing or increase slightly (<5%), there will be an increase in the frequency and intensity of extreme rainfall events. As noted above, the areas adjacent to Green Island landfill are low lying and identified as areas subject to sea level flooding (storm surge) and fluvial flooding associated with the Kaikorai Stream. The climate change impacts noted will further amplify these two hazards as discussed below.

2.4.4 Fluvial Flooding

The ORC hazard maps for flood risk associated with river-based flooding is shown in Figure 3 below.

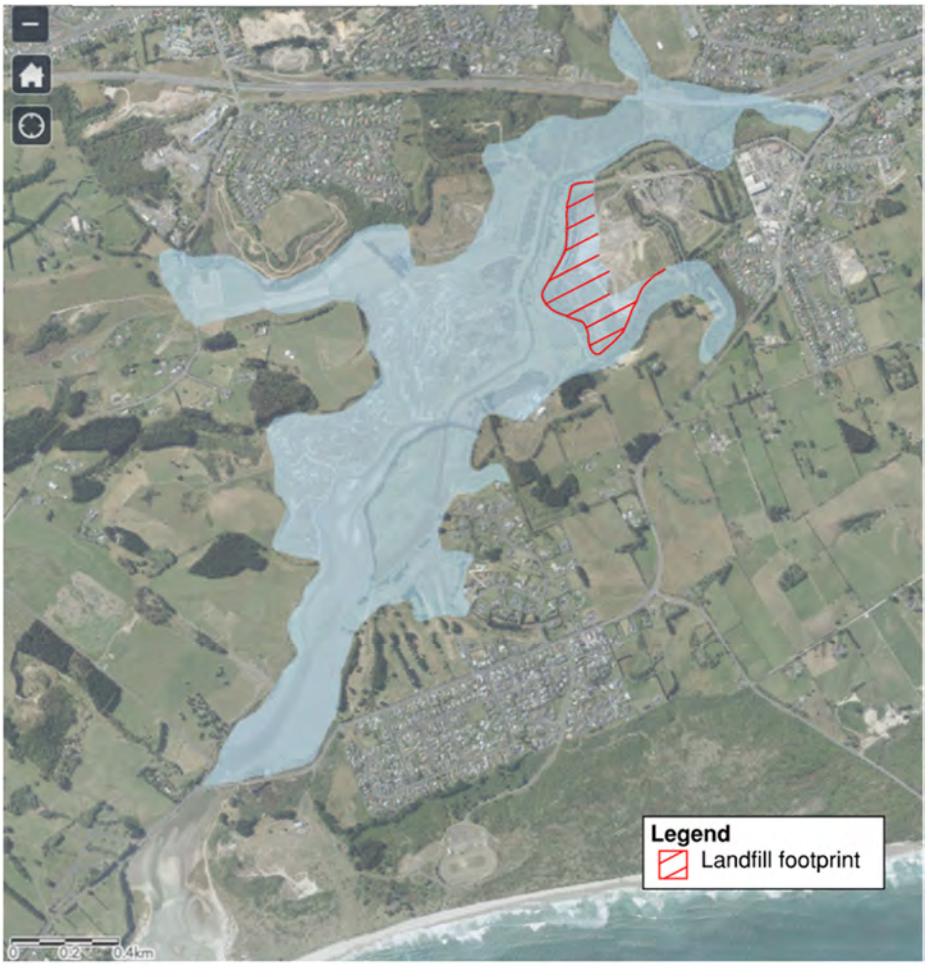

Figure 3 Fluvial flood risk area

The risk area, shown in light blue in Figure 3, is taken from the ORC Natural Hazards Portal flood map, which was based on the mapped extent of the 19 March 1994 flood with a level of 103.3 mRL [4] . The hatched area shows the location of the existing landfill footprint which is land that has subsequently been built up and hence this area would no longer be flooded. Therefore, while acknowledging the map is historical and approximate, it indicates that low lying areas around the perimeter of the landfill are prone to flooding due to high flows in the Kaikorai Stream. The majority of these areas are outside the footprint of the main landfill but infrastructure such as site access roads, perimeter drainage channels and the leachate collection system are within the flood zone.

Current climate change projections, using the upper range scenario (RCP 8.5), indicate that flood flows will increase by approximately 9% by 2050. This would be expected to increase flood levels by between 60 -100 mm and will not significantly impact the flooding extent in the area of the landfill or day-to-day operations. As the stream channel in the vicinity of the landfill and the estuary are low energy environments, the risk of channel scour and erosion that may impact the landfill is very low. However, there will be an increased frequency of inundation of the perimeter areas which could impact the leachate collection located within this area. As discussed in the above paragraph, this may require modification to elements of the leachate collection system that are susceptible to flooding (i.e. manholes, chambers, electrical cabinets and manholes) to allow continued operation. This issue is discussed further in the *Surface Water Technical Report (GHD 2023B)*.

[4] Note throughout this report two datums are used. On older figures/drawings a DCC Design Datum of AMSL +100m is used (hence a 1994 flood level of 103.3m). More recent data and the design drawings for this study use NZVD2016 as the datum and are referred to through this report as “amsl”..

Fluvial flood risk to the landfill area is also impacted by coastal and sea level changes. ORC hazard reporting notes that Kaikorai Stream flood levels can be affected by outlet conditions from the estuary with coastal wave action forming sand or gravel banks which block the outlet resulting in an increased levels that extend upstream to the area of the landfill. The impacts of such events will be similar to those described above.

2.4.5 Sea level Rise

The ORC hazard map for storm surge risk is shown in Figure 4 below. While not specific to sea level rise, this is indicative of areas that would be expected to be impacted on a long-term basis if sea level rise of 0.5 m was to occur. Current upper range scenarios indicate a sea level rise of approximately 0.25 m by 2050. It is noted that storm surge, associated with low pressure systems and astronomical situations would be on top of the sea level rise, increasing levels and extents of the area affected.

Figure 4 ***ORC hazard map for storm surge risk***

The increase in sea level rise may result in a general increase in water levels within the estuary and the Kaikorai Stream adjacent to the landfill and this would result in an increase in ingress of water into the leachate collection system. This is discussed further in the *Groundwater Technical Report* (GHD 2023A).

The increase in sea level would also be expected to result in a change in beach formation which may increase the frequency of the closure/blockage of the estuary outlet. Blockage of the estuary currently occurs periodically requiring the use of an excavator to re-establish the outlet. This may be required on a more frequent basis in future.

With respect to the continued operation of the landfill until closure, the landfill is expected to continue generating leachate for several decades after ceasing of filling and the leachate collection system will need to remain in operation for this period. The proposed closure date for the landfill accepting waste of late 2029(see subsequent sections in this report) is not expected to have a significant impact on the leachate collection system as a consequence of climate change induced hazards when compared to a October 2023 closure scenario.

2.5 Topography and geomorphology

The landfill and associated operations are located in the upper (northeast) part of the Kaikorai Estuary, immediately to the east of the Kaikorai Stream. Kaikorai Stream flows into the estuary approximately 400 m southwest of the site (see Figure 2). Prior to landfill development the site would have been characterised by low lying (1 -2 m above sea level) estuary flats and wetlands. Immediately to the east of the landfill the land rises gently to a series of low hills.

2.6 Geology

The geology setting of the site is described in detail in the *Green Island Landfill Liquefaction and Stability Assessment Report* (GHD 2023D). The following section provides an overview of that report.

The geology underlying the landfill area comprises sediments of estuarine origin underlain by Abbotsford Formation mudstone. The estuarine sediments, described as Kaikorai Estuary Formation (KEF) (BDGC, 2002), are approximately 11 m thick in the landfill area. The KEF was divided into an upper and lower layer (member), with the upper member being further divided into two subgroups - see Figure 5 below.

The elevated land to the south of the site is comprised of Abbotsford mudstone.

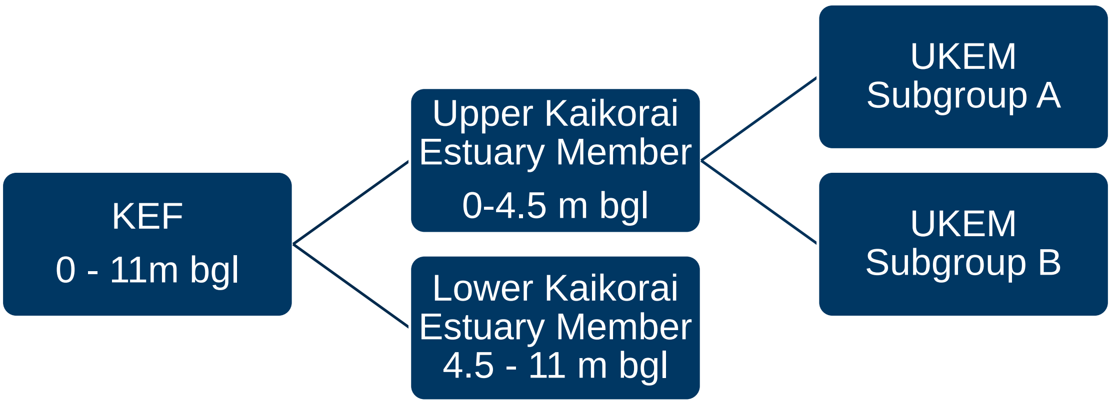

Figure 5 ***Lithological sequence mapping schematic***

Table 1 provides a summary of the lithological units as described in BDGC (2002).

Table 1 Description of lithological units

Member	Description	Subgroup	Thickness
Upper Kaikorai Estuary Member (UKEM)	Variable thin beds of sand, silty sand, sandy silt, silt, clayey silt and silty clay	Subgroup A -mostly homogeneous fine grained	4.5 m
		Subgroup B – heterogeneous, coarser grain size	
Lower Kaikorai Estuary Member (LKEM)	Massive homogeneous beds of clayey silt, silty clay and silt, and minor (possibly localised) beds of clay, very fine sandy silt and silty very fine sand.	-	6.5 m

2.7 Hydrogeology

The hydrogeology setting of the site including leachate distribution and seepage is described in detail in the Green Island *Groundwater Assessment Report* (GHD 2023A). The following section provides an overview of that report.

2.7.1 Site Setting

The KEF forms a shallow water bearing strata under the landfill and surrounding area with groundwater levels close to the ground surface. The UKEM and LKEM exhibit different hydraulic properties. Testing of three bore holes at various depths by Beca (1992) identified that the shallower deposits exhibited a higher permeability consistent with fine sand and silt (i.e. hydraulic conductivity in the order of 10^{-6} m/s) than the wells screened across the lower formation which is more representative of a marine silt deposit (i.e. a hydraulic conductivity in the order of 10^{-6} to 10^{-8} m/s).

BDGC (2002) characterised the saturated zone of the UKEM unit as exhibiting more varied lithology (and hence permeability), both laterally and vertically. The investigations undertaken during the installation of the interception trench in 1994 confirmed this variability, noting that hydraulic properties were characterised as being low to very low permeability representing the confining beds of silts and clay whilst there were also unconfined beds of moderate, to at times, high permeability associated with sand deposits.

The lower sub-member (LKEM) of the KEF was characterised by BDGC (2002) as being present approximately 3.5-4.5 m below the original ground surface and comprising clayey silt and silty clay. The hydraulic properties of this layer were characterised as having very low to low permeability. The underlying Abbotsford Formation is considered to be an aquitard with associated very low permeability characteristics. This material is found in the borrow pit which has been used to supply material for final capping.

2.7.2 Groundwater/Leachate Management

The current groundwater flow patterns are strongly influenced by both the landfill construction and the leachate collection system and associated pumping. Rainfall on the landfill that does not runoff to the stormwater collection system percolates through the landfill material to the base where it accumulates as leachate within the landfill resulting in mounding of leachate levels within the waste. Landfill Gas (LFG) wells within the existing landfill where they intercept the leachate mound have been used to confirm the leachate levels of between 16 m to 22 m amsl (see *Groundwater Technical Report* (GHD 2023A) for more details).

The low permeability of the lower layers of the KEF and the underlying Abbotsford formation along with the sub-artesian/artesian groundwater conditions inhibit downward migration of leachate into the underlying sediments. Mounding of leachate within the landfill and these underlying low permeability layers result in shallow leachate/groundwater flow outwards towards the perimeter of the landfill.

The leachate collection trench creates a hydraulic barrier which impedes groundwater and leachate migration offsite. This is achieved through the continuous dewatering of the trench via a series of pump stations, which pump groundwater impacted by the landfill via a rising main to the GIWWTP. In addition, within the cut-off trench is a High Density Polyethylene (HDPE) liner which was installed on the estuary/stream site of the trench. This liner acts as a further barrier whilst reducing the volume of water/groundwater entering the trench from the Kaikorai Stream. However, it does not completely prevent inflows from the estuary and stream.

Water levels in the trench are typically maintained at -0.8 m to +0.2 m amsl by the continuous dewatering of the trench (see Drawing 12547621-01-C204). These water levels are lower than the surface water levels, with typical stream and estuary water levels of 2.0 m to 2.5 m amsl. Figure 6 shows a schematic diagram of how the leachate trench and pump system operates. Historical and ongoing groundwater level monitoring within monitoring well arrays which run perpendicular to the trench demonstrates that the leachate trench system is effective at intercepting shallow groundwater flow and leachate. The groundwater depression at the base of the leachate trench is maintained to ensure that the trench acts as a hydraulic barrier, with leachate/groundwater effectively contained to prevent off-site migration of contaminants.

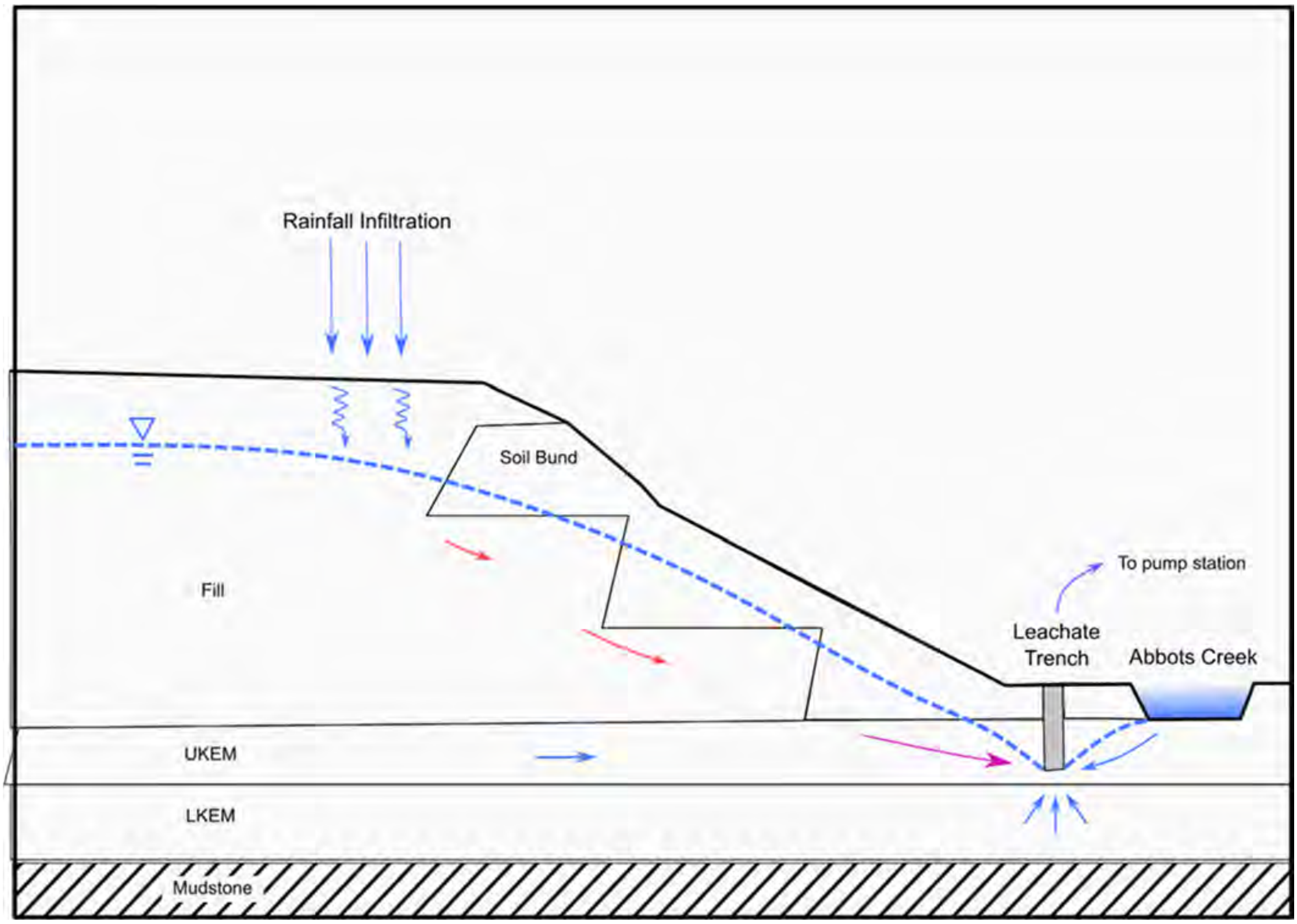

Figure 6 *Schematic Diagram of Leachate Collection System*

The collected leachate/groundwater is pumped via a series of pump stations (shown on Drawing 12547621-01-G101) to the GIWWTP, located 200 m to the south of the landfill (see Figure 2).

In the past five years the total pumping rates from the trench are typically between 1 and 2 litres per second (L/s), peaking up to 8-9 L/s after periods of rainfall. For nearly 20 years the GIWWTP has managed this range of leachate flow, with the system having been operational since its construction in 1995. The treatment plant treats the water along with Dunedin's wastewater. In total GIWWTP manages approximately 30 million litres per day (equivalent to approximately 350 L/s) of wastewater from the wider Dunedin area. Treated water from the GIWWTP is discharged to the ocean at Waldronville.

As noted by BDGC (2002), the interception trench is not embedded into the underlying Abbotsford Formation mudstone. Whilst the trench provides a hydraulic barrier for the migration of shallow leachate from the site, there is a potential for offsite migration of leachate if there is a pathway for leachate to migrate into the LKEM, being contained in a lens of more permeable sediment, and moving under the trench. However, as discussed earlier in this report, the underlying artesian groundwater conditions combined with the low permeability of the LKEM and Abbotsford Mudstone help impede any bypass of the trench. This scenario is supported by numerical modelling of the effectiveness of the leachate trench, which is described in detail in the *Groundwater Technical Report* (GHD 2023A).

2.7.3 Additional Leachate Control Matters

Two areas of the landfill leachate collection systems have been identified which require further attention, with proposed additional control measures recommended. The proposed control measures are described in Section 4.5.2 of this report.

Southern Valley leachate control

The leachate collection system was not constructed along the south-eastern margin of the landfill, where landfill waste was placed on the estuary sediments adjacent to the mudstone hills to the east. The main GIWWTP sewer, runs along this boundary (see Drawing 12547621-01-G101). The initial application for the landfill which was lodged in 1994 included an option for filling over the wastewater rising main, with waste abutting against the hillside (see Figure 11). Therefore, the leachate collection system was not constructed in this area in the 1990's. This option for placing waste across the sewer was retained until 2019 and has subsequently been excluded. As discussed in Section 2.3, the risk of placing waste over the sewer was determined to be unacceptable.

In the absence of a leachate collection system, the management of leachate in the southern valley has occurred via a shallow surface drain, which collects overland flow and shallow groundwater (including leachate) and conveys it towards pump station (PS1) located at the southern end of the landfill (Drawing 12547621-01-G101**)**. It is noted that the perimeter leachate trench extends from pump station 1 (PS1) toward the south-east hills and the Green Island Gravity Sewer main. Therefore, leachate impacted groundwater which flows from the valley which is not captured in the surface water drain is expected to be intercepted by the trench.

The geology of the hill to the southeast of the valley comprises silty clay and clayey silt materials associated with the Abbotsford Mudstone (and currently being used for capping materials). The low permeability of the silts and clay is expected to impede migration of contaminants to the south of the valley drain.

There is potential that the surface drain along the south-east valley does not capture all leachate seepage emanating from the valley. Leachate may find a pathway within the bedding material associated with the buried Green Island Gravity Sewer rising main, which runs adjacent to the surface water drain in this area. In addition, the surface drain is not as efficient at capturing and lowering leachate levels in the landfill when compared to a pumped interception trench. Therefore, it is recommended that the leachate collection system is extended through this area to address this potential pathway and to provide for improved leachate management within the eastern margins of the landfill (see section 4.5 of this report for details).

Eastern Constructed Wetlands

A culvert located on the eastern side of the landfill was recently identified as a potential pathway for leachate seepage being discharged to the environment. The culvert transfers surface water between the South-Eastern Constructed Wetlands and the Eastern Constructed Wetlands as shown on Figure 7**.** The majority of the culvert is located inside the leachate collection trench, crossing the leachate collection trench upstream of its discharge point into the Eastern Constructed Wetland.

Surface water sampling at the outlet of the culvert has identified elevated parameters indicative of leachate contamination, suggesting leachate is seeping into the culvert. In addition, the culvert has been observed to discharge a flow during periods where the water levels in the forebay in the South-Eastern Constructed Wetlands is below the invert of the culvert inlet structure. Further details of the water monitoring data and the proposed measures to remedy this issue are described in the S*urface Water Technical Report (GHD 2023B)*.

It is also noted that the leachate trench has a 90 m ‘gap' between pump stations Manhole MH8 and pump station PS9. Review of historical maps and aerial photographs taken prior to landfill construction indicate this gap aligns with a spur of land that extended into the estuary at this location from the adjacent Abbotsford Formation hillside. The leachate trench appears to have been constructed to butt into either side of the mudstone spur. Given the ridge of land will be composed of the same low permeability materials that underlie the adjacent hills this is not considered to be a pathway for leachate seepage.

Figure 8 and Figure 9 show the location of the ridge with respect to the landfill and leachate trench, as do further aerial photograph history in the Groundwater technical report. The implications of this gap to leachate and groundwater management are discussed in the *Groundwater Technical Report (GHD 2023A).*

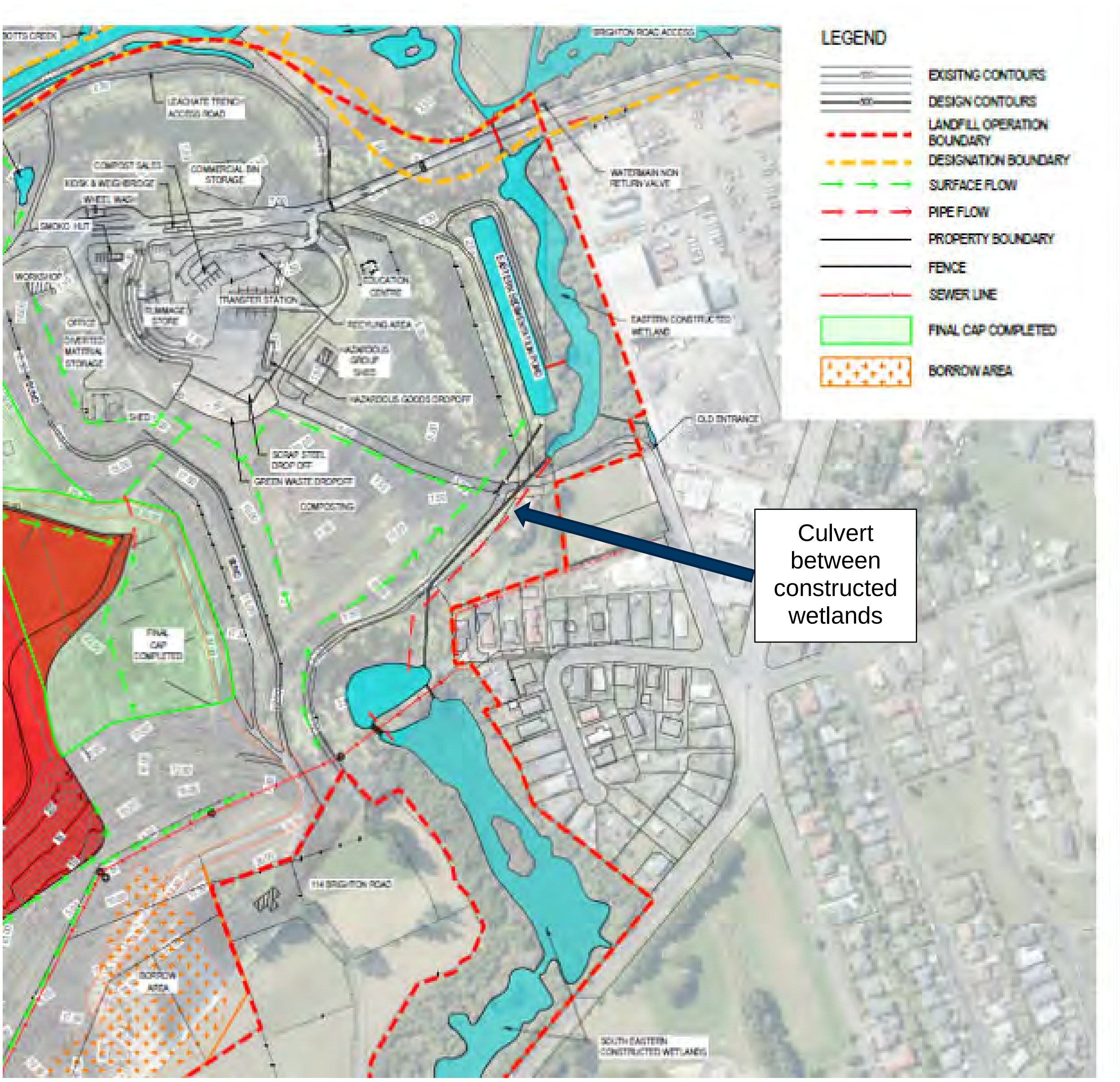

Figure 7 ***Culvert and Leachate Seepage Locations (extract from Drawing 12547621 – C402)***

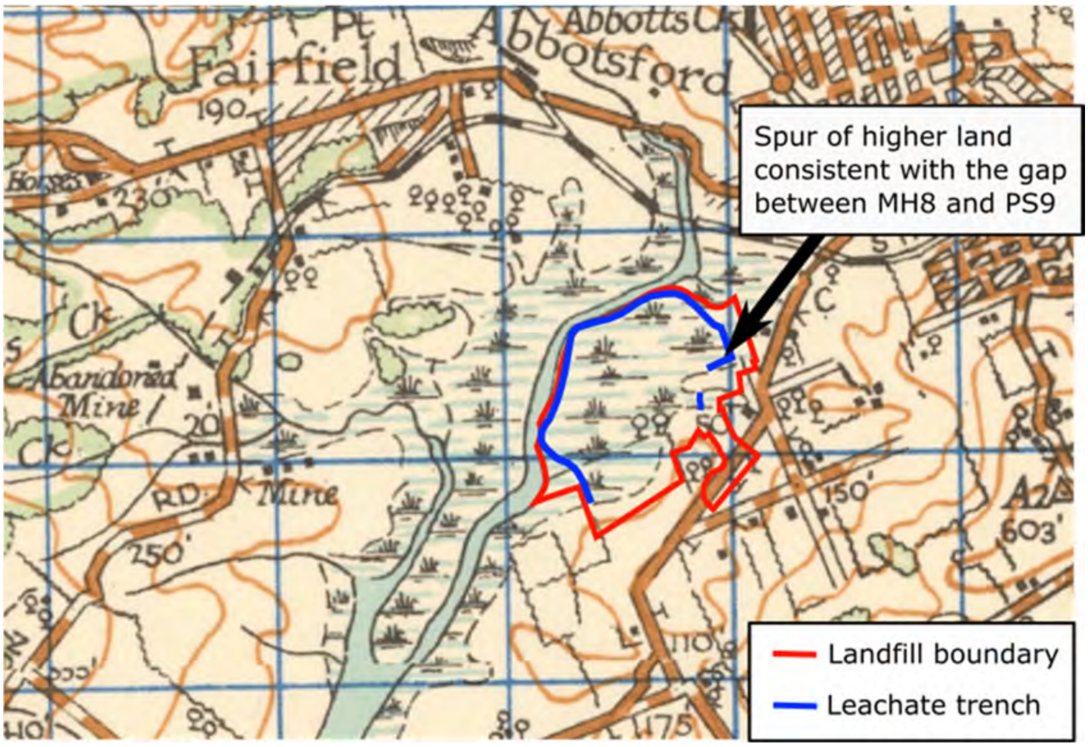

Figure 8 NZMS 1939 Historic Map Showing Spur of Land on eastern side of landfill

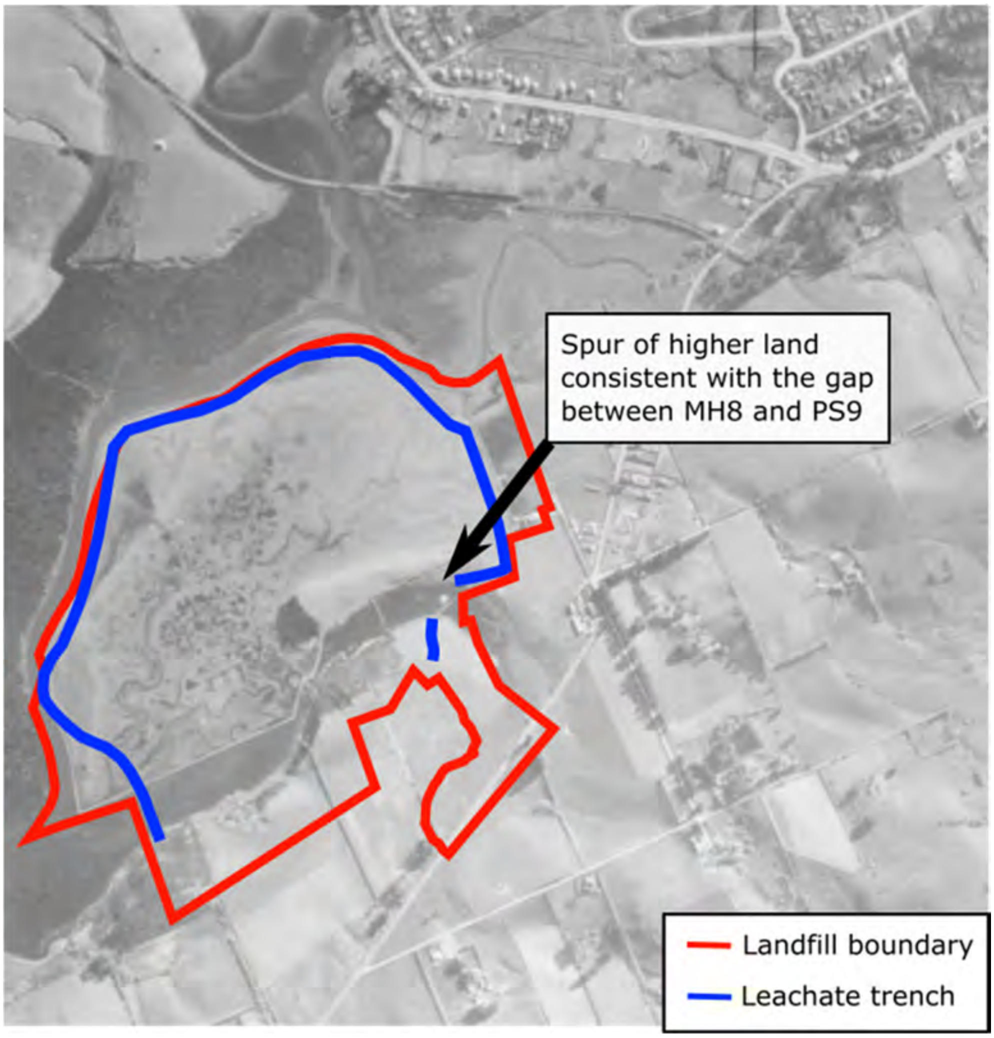

Figure 9 ***Aerial Photograph c. 1950***

3. Current landfill construction and operation

3.1 General Landfill Design

3.1.1 Consented Design

The final landform contours approved in the 1994 consented profile are shown on Figure 11. These are post settlement contours. The consented profile provides a central ridge at 25 m amsl along the spine of the landfill with the intent to create a refuse mound up to 15 m above the existing landfill at that time, or some 24 m above the general estuary levels. The created mound was to be shaped and contoured with slopes no steeper than 1 (V) in 5 (H) for the perimeter batters and generally flatter on the top. The landfill development since that time has been progressed by creating the initial bund approximately 3 m high and leachate collection trench around the landfill perimeter, excluding the southeast boundary where the landfill abuts the rising ground to the east (as described in section 2.7). The extent of the bund is shown on Drawing 12547621-01-G101. The initial bund was completed in the 1990s and is generally constructed from imported soils. It is understood that the bund was progressively extended above the landfill surface elevation to provide a visual buffer to operations for the nearby residents. The outside of the bund has been covered in topsoil and then been planted with trees and shrubs which have provided additional visual screening. Waste placement has progressed against the inside of the bund and then above the bund as a waste-to-face operation up to the design level. Figure 10 shows a schematic representation of how the bund has been developed.

The purpose of the bund is to provide:

- a buttress to place landfill against and provide a physical and hydraulic barrier from the adjacent Kaikorai Stream and estuary;
- Provide for the installation and maintenance of the leachate collection trench and associated conveyance systems on the outside of bund base;
- a visual and acoustic barrier for the surrounding areas, particularly during early stages of landfill development with trees and shrubs enhancing visual screening; and.
- a wind break to reduce wind-blown debris.

In regard to the wind break, debris catch fences have subsequently been installed on top of the bund to assist in controlling wind blown waste.

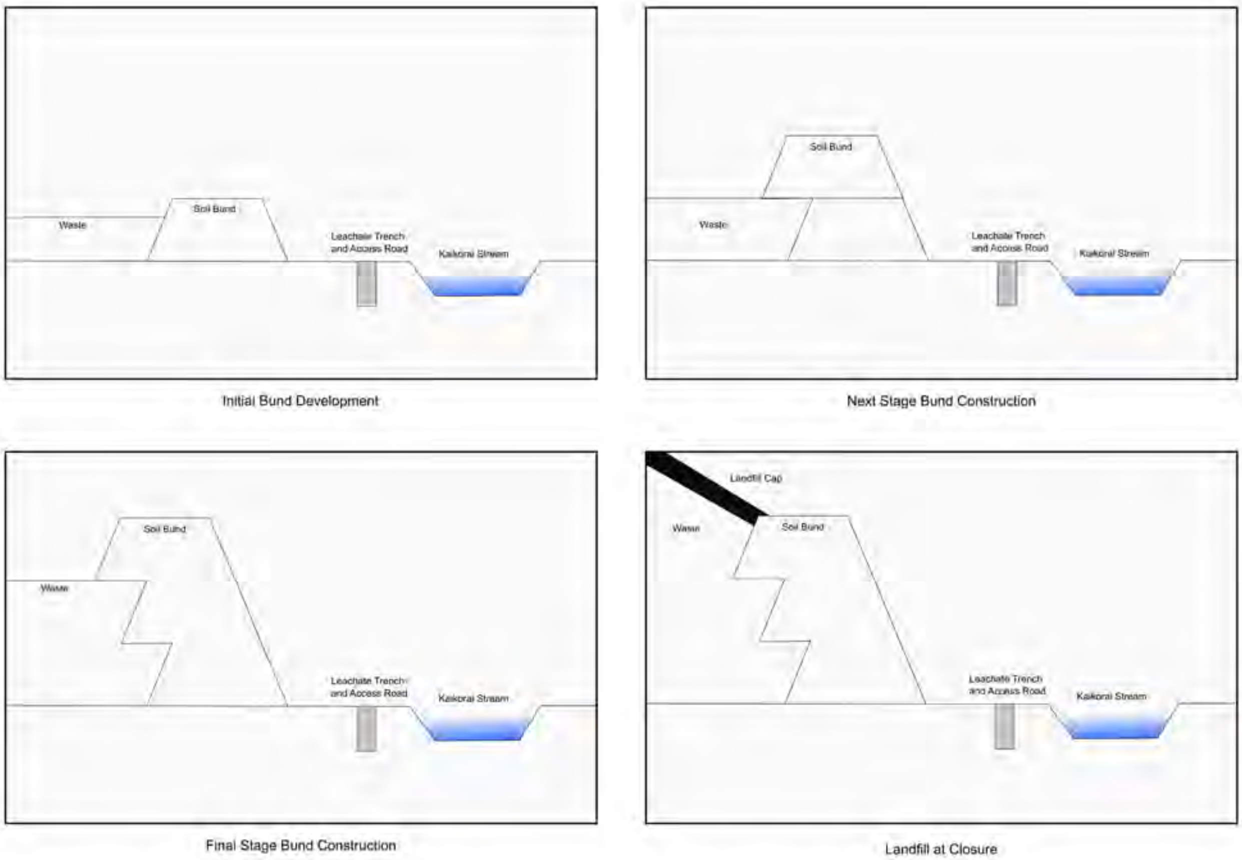

Figure 10 Schematic of Bund Development

3.1.2 History of Design Development

The 1994 consent profile is shown in Figure 11 (Royds Garden Ltd, May 1990. *Green Island Waste Management Centre: Conceptual Development)*, which provided the basis for the development of the landfill to the current design contours and included the concept of filling over the trunk sewer to the south-east of the current landfill. The trunk sewer is the main sewer connection between Dunedin City and the GIWWTP, located 200 m to the south of the landfill. Hence it is of critical importance to the city wastewater operations. The location of the sewer in relation to the landfill site is shown on Drawing 12547621-01-G101.

Figure 11   ***Royds Garden May 1990 Design***

Given the importance of the sewer to the Council and the potential complications with filling over the pipe alignment, the Council decided to develop options for future development. The preferred option in 1999 was to limit the landfill development to the north-west of the trunk sewer and not create the land bridge of waste to the south of the landfill shown on Figure 11. The levels of the landfill central area were retained as consented in 1994. This revision was formalised to the consent authority in a letter from Council to the ORC (14 April 1999) *Green Island Landfill – Future Filling Programme*. That same communication confirmed the plans to fill above the final contours by 2.25 m at the central ridge to allow for long term settlement to ultimately achieve the consented profile. The approval of the revised contours and approach to settlement was recorded in the ORC letter to Council dated 21 April 1999. Figure 12 shows the landfill final (post settlement) contour plan approved by ORC. The 1999 approved final contour design included an area of filling that extended towards the Eastern Sedimentation Pond, in the vicinity of the present-day composting windrows. The Council landfill engineers determined that this area of filling was not efficient from a landfill operations perspective, and in 2001 updated the filling plan to remove this area from the future waste placement plan (shown in Figure 13). No formal acceptance from ORC has been received for this change. However, the LDMP 2007 shows that this area had been removed from the filling contour plan. Up until 2019 the Council had retained the option for filling across the sewer along the south-east boundary - as shown on Figure 11. However, as discussed in Section 2.3 and 2.7.3, since that time they have discounted this option given the concerns with placing waste across the main sewer.

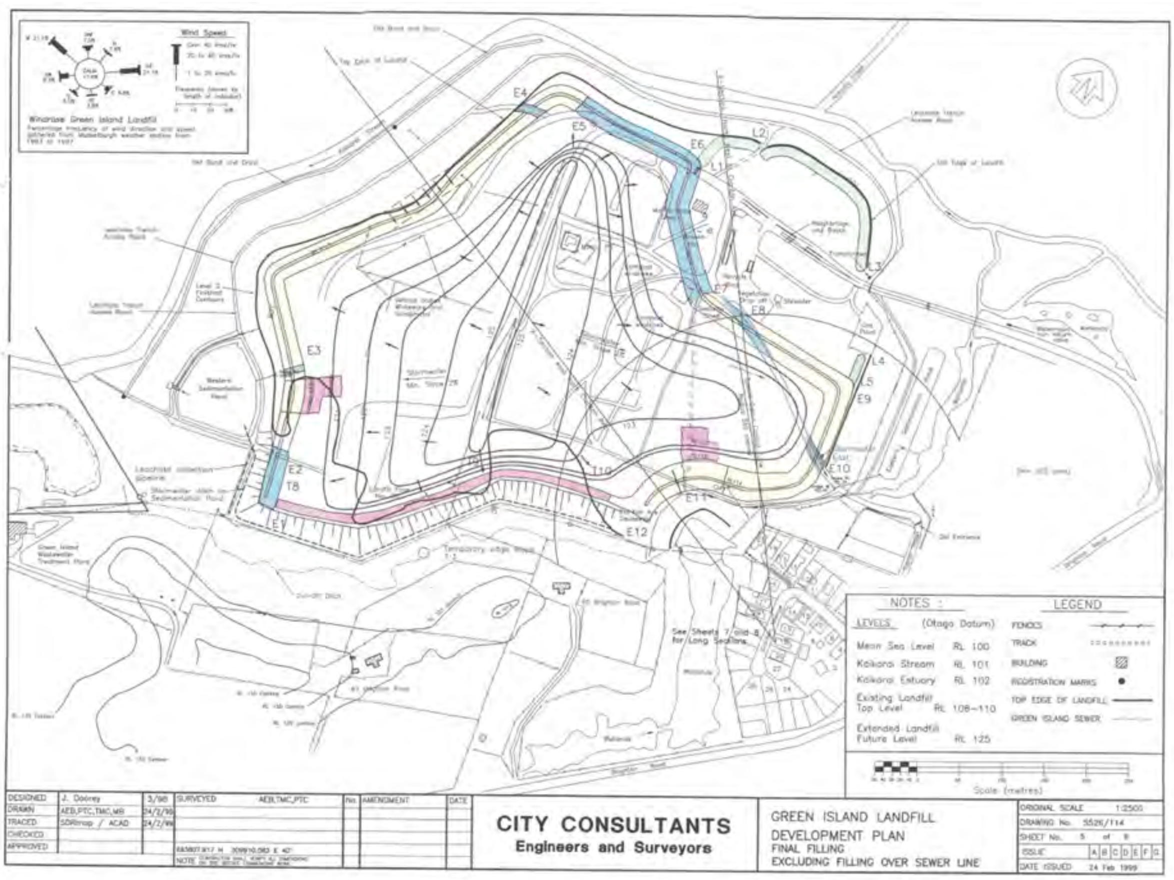

Figure 12 1999 Design

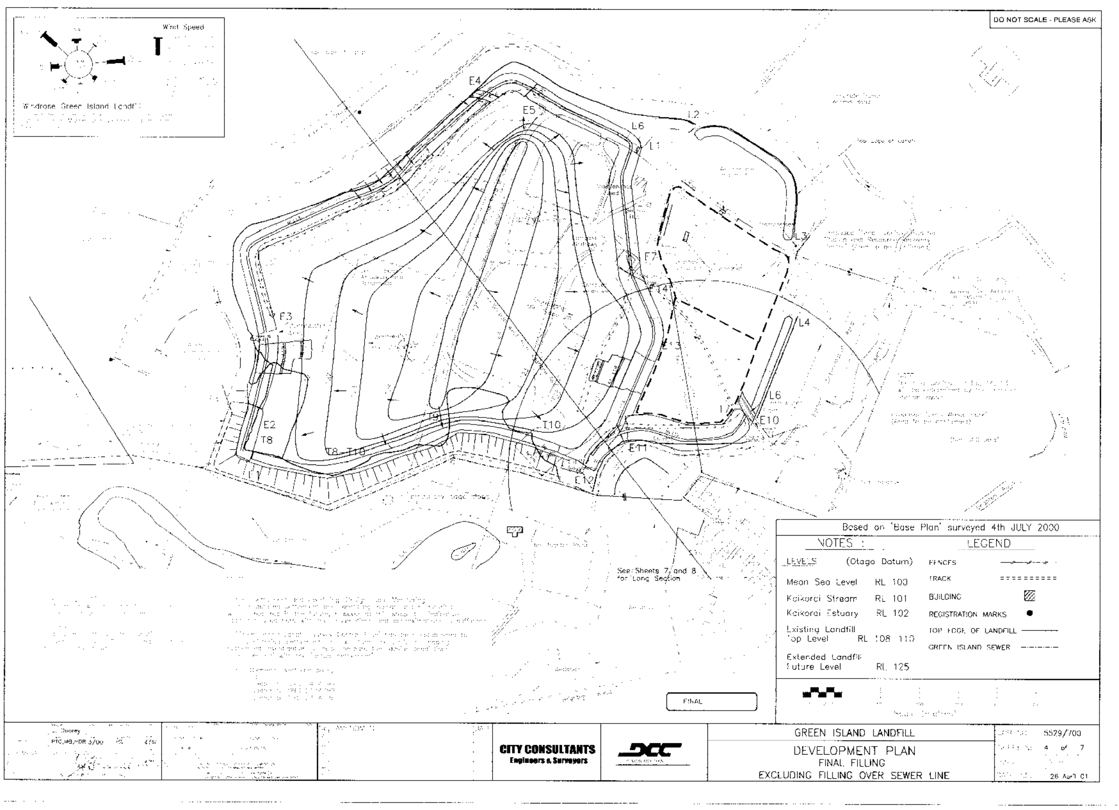

Figure 13 2001 Design

The current contours of the landfill (surveyed June 2022) are as shown in the general arrangement Drawing 12547621-01-C201. The drawing also shows the extent where final cap has been placed and where void exists for further waste placement. Waste has been placed over all the landfill footprint and including the area yet to be filled. The latter has around 10 m depth of waste and a further 10 m to 15 m of waste to be placed.

3.2 Waste Placement

Historically waste was placed directly onto the estuarine silts and sand that underlie the landfill. No landfill liner system has been used during development. Historical waste placement across the site is described in the *Groundwater Technical Report* (GHD 2023A)

Around 60,000 tonnes of waste and a further 60,000 tonnes of clean and contaminated soils are currently imported to the landfill each year. The total amount of waste and contaminated soils disposed each year has remained below the 100,000 tonne limit imposed by the 1994 consent conditions. The balance of material is clean soils which have been used for landfill cover. Due to the densities of the waste and the soils, the resulting landfill void filled annually is around 90,000 cubic metres. Contaminated soils are used for daily cover, mixing with wastewater treatment plant sludges, or are placed as general waste fill, whereas the clean imported soils are stockpiled and used for both daily cover and progressive intermediate capping.

All waste is transported to the landfill via the sealed access roads off Brighton Road to the site entry kiosk within the landfill compound for assessment of the waste delivery and direction of the loads to the landfill tip face or the waste transfer station. Only pre-approved trucking contractors can take waste to the tip face on the landfill. Domestic waste deliveries by cars, trailers and small trucks are offloaded into the waste transfer station located in the eastern part of the site. Site trucks are loaded with waste from this transfer station as well as two rural transfer stations in Dunedin and taken to off load the waste at the tip face.

Waste off-loaded at the tip face is spread in layers and compacted by multiple passes of the specialist waste compactor. At the end of each day's operation the waste that has been placed and compacted that day is covered with daily cover soils that are stockpiled close to the tip face. The tip face is generally kept to a small area, with waste placement occurring over a limited operational area such that portions of the landfill are progressively completed to reach the finished design level. This allows final cover to be placed progressively over completed stages and reduces rainfall infiltration through the waste and ultimately into the leachate collection system.

The current LDMP requires the active tip face to be kept as small as practical and no larger than 900 m^2 unless specific circumstances prevail that necessitate its expansion to a maximum of 1,200 m^2. The width of the active tip face is typically 30 m although this is more convention than an operational requirements. The future operation of the landfill intends to continue with these operating requirements. In addition, the Fire Report (Appendix D) recommends that the active tip face size is reduced to 300 m^2 during very high or extreme fire days (as reported by FERNZ).

The Green Island landfill current operations encourage the recovery of materials that can be reasonably recovered, recycled or composted. These materials are diverted at the site entry kiosk to the recycling facilities in the compound area.

Materials that are diverted from the waste stream include the following:

- Steel and whiteware;
- Garden waste drop off (for composting);
- Preowned items, donated by the public;
- Glass, steel and aluminium cans, paper and cardboard;
- Plaster board and polystyrene; and
- Household chemicals, E-waste and batteries.

Sludge and biosolids from DCC's three WWTP have been disposed of to date in specific areas at lower levels of the landfill, with waste placed over the top. The most recent sludge area is located in the south west corner – see Drawing 12547621-01-G102. In the future disposal of the sludge will be integrated within layers of the normal landfill waste (i.e. co-mingled), and no (or very limited) further development and use of sludge areas are anticipated. The sludge and biosolid materials will be lime stabilised, and mixed with the general waste. Based on existing tonnages of waste and sludge this will likely result in a 10% sludge to 90% general waste mix ratio. Treatment of sludge and biosolids is discussed further in Section 6.2 of this report.

3.3 Cap Design

The final cap placed to date is in accordance with the GHD (Sept 2021) *Green Island Landfill Capping – Design Report.*

The final cap is:

- 350 mm topsoil and sub-soil;
- 600 mm low permeability clay (with a permeability of <1 x 10^{-7} m/s); and
- 300 mm intermediate cap.

This provides an overall 1,250 mm capping thickness across the top of the waste. Noting that the 300 mm intermediate layer that is placed over the waste by the operator once filling is the same 300mm layer forming the lower 300mm of the 1,250mm final cap. This profile meets the recommendation of the WasteMINZ *Technical Guidelines for Disposal to Land* (2018).

Drawing 12547621-01-G102 shows the current area of capping and the proposed areas of future waste placement that will also be capped upon completion. Capping will not be placed on the existing soil bunds that surround most of the landfill. These were constructed from imported soils and do not require a capping layer. Furthermore, they have been extensively planted and the mature vegetation has an important role in screening the site. As of October 2022, 3 Ha of the 13 Ha portion of the current landfill operation has final cap placed (see Drawing 12547621-01-G202). All other areas have intermediate cap or are the open face for waste placement.

Surface water from the final cap is directed to the stormwater system before discharge to the estuary. Flows from nearly all intermediate cap areas and open waste is collected in open swale drains or perforated horizontal leachate collection pipes to drain to the perimeter leachate collection system and pumped to the GIWWTP for treatment and discharge. In a limited number of cases surface water from intermediate cap may also be directed to the surface water system where water is not at risk of also coming into contact with waste. Stormwater management is discussed in more detail in Section 4.6 of this report.

Material for the final cap is obtained from the borrow area to the south of both the existing landfill and the trunk sewer to the wastewater treatment plant. The haul road between the borrow area and the landfill is already formed and in operation, as soils from this borrow area have been used to construct the final cap completed to date. The proposed final extent of the borrow area is shown on Drawing 12547621-01-G102 and associated stormwater management is shown on Drawing 12547621-01-G402 and described in Section 4.5.

The required volume of material from the borrow area for capping is in the order of 73,000 m^3., some of which was used in the2022 capping works. The B Adams (May 2018) report *Green Island Landfill – Clay Capping Borrow Options* demonstrates that sufficient material is available in the borrow area to meet this requirement. The final profile for the borrow area at closure is shown in the Boffa Miskell (2023) *Green Island Landfill Closure – Landscape, Natural Character and Visual Effects Assessment*. Once capping is completed, the borrow area will be grassed.

The borrow area soils have been tested to confirm the soils meet the permeability requirement of less than 10^{-7} m/s. Permeability for the low permeability soil layer is reported by B Adams (June 2019) *Green Island Landfill Clay Cover System.* QA from the construction monitoring has also confirmed the adequacy of this material for the purposes of capping. It is noted that while the specification for the low permeability clay layer requires a maximum permeability of 1 x 10^{-7} m/s, the actual permeabilities achieved during cap construction to date are significantly lower than this and can be in the order of 1 x 10^{-9} m/s. The cap permeability is discussed in more detail in the *Groundwater Technical Report (GHD 2023A).*

The final cap surface will have maintained grass or shallow rooted shrubs applied where the roots will not extend deeper than the 350 mm topsoil/subsoil layer.

3.4 Leachate management

3.4.1 Leachate collection and management

The Green Island landfill has been progressively developed since 1950s and does not include a base liner. In the early years of operation the landfill did not have an engineered approach to managing leachate. However, in the mid-1990s a leachate collection system was designed and installed. Drawings 12547621-01-G101 and C204 include details of the installed leachate trench which are contained in the Council (2007) Green Island – LDMP (Drawing G08, dated 2004). Figure 14 is a drawing from City Consultants (drawing 5526/234, Landfill Leachate Monitoring, 5 September 1997), which was part of a 1997 drawing set, which shows the typical design of the leachate collection system and includes the following components:

- A gravel filled leachate collection trench with a perforated 150 mm uPVC collector pipe that extends around the Green Island landfill site (excluding the SE valley), including the northern administration and facilities area.
- A 1.5 mm HDPE sheet placed on the "outer" face of the trench to restrict the influx of seepage from the adjacent stream. As noted in the *Groundwater Technical Report* (2023), some seepage from the estuary/stream into the trench occurs and contributes to the collected leachate volumes.
- Eight pump stations (PS1 through PS8) are installed at approximately 200 m spacings along the drain with manholes (MH0 through MH8) at approximately the mid-way point between pump stations to allow access for inspection and for the uPVC pipe to be cleared, if necessary.
- Each pump station and associated pump is set to maintain the leachate level to between -0.8 m amsl and -0.2 m amsl. Therefore, while the system is connected by a continuous pipe and trench, leachate is normally managed via pumping from the eight pump stations and their nominal 200 m length of associated trench. However, in the event a pump should fail leachate in the associated section can flow through to the adjacent pump stations and the hydraulic barrier can be maintained.
- At each pump station leachate is pumped to a buried 125 mm rising main that discharges to the Green Island Gravity Sewer main at either end of the leachate trench system.
- PS9 is separated from the main leachate system by the now buried spur of land comprising of mudstone shown on Figure 10 and Figure 11. PS9 has a 55 m length of associated trench and also discharges to the main sewer line.
- As discussed previously in this report, the leachate collection trench does not currently extend to the southern valley section of the landfill, between MW0 and PS9. Leachate and surface water is currently collected in this section by a surface drain and the leachate trench that extends to the Green Island Gravity Sewer rising main and is discharged to the sewer via PS1 (note: the leachate trench extends for 83.7 m from PS1 to the south, which takes the trench to be very close to the Green Island Gravity Sewer, as shown in Figure 15 and Drawing 12547621-01- G102.
    - Invert levels of the GI Gravity Sewer at MHA is 101.83 mRL (or 1.83 m amsl) with the top of casing of MW0 of 102.55 mRL (or 2.55 m amsl). Groundwater levels recorded in MW0 are approximately 1.7 m to 0.45 m below top of casing, which indicates that groundwater in the vicinity of sewer can be encountered at levels above the invert level.
    - BDGC (2002) includes logs of the leachate trench during its installation. Trench Profile 1, which records the lithology of the trench 72.5 m south of PS1 (i.e. in the vicinity of the GI Gravity Sewer), indicates that base of the trench and collector pipe intercepts silty clay, clayey silt and silt at depths between 2.4 m bgl and 3 m bgl.

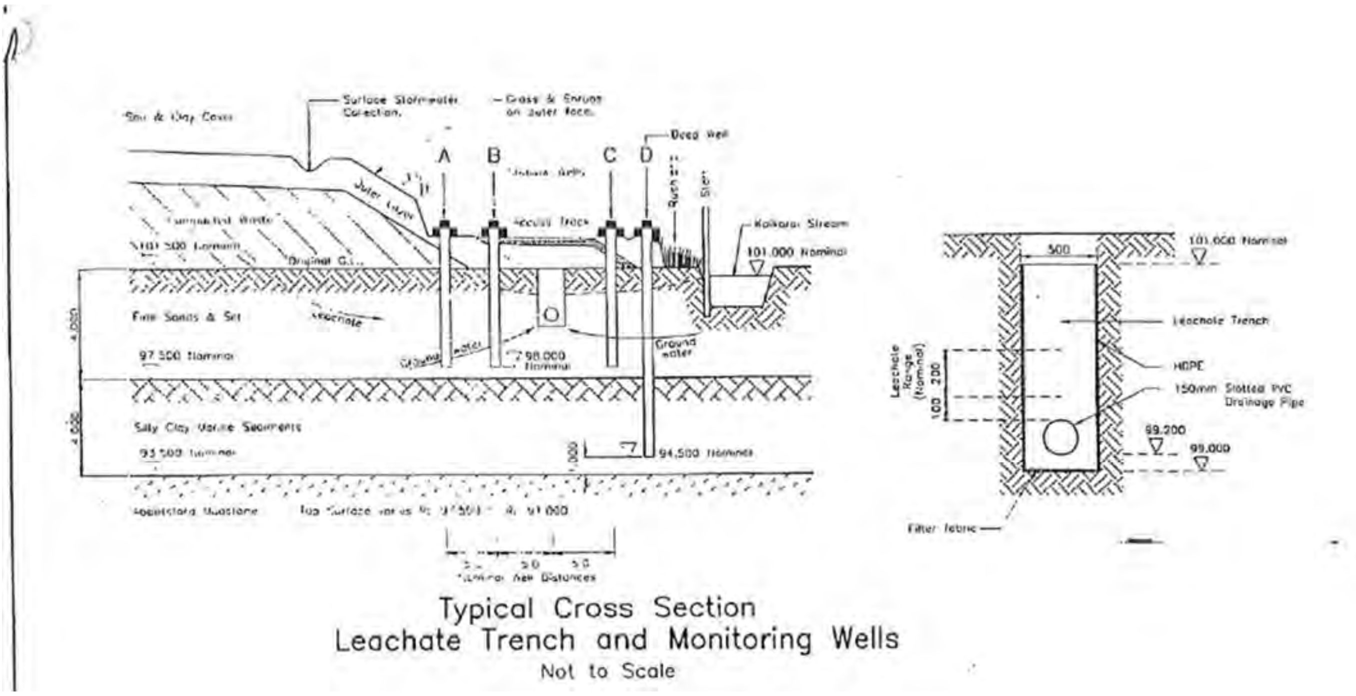

Figure 14 Typical design for installed Leachate Collection System (source: DCC City Consultants. Drawing 5526/234 date, 1997)

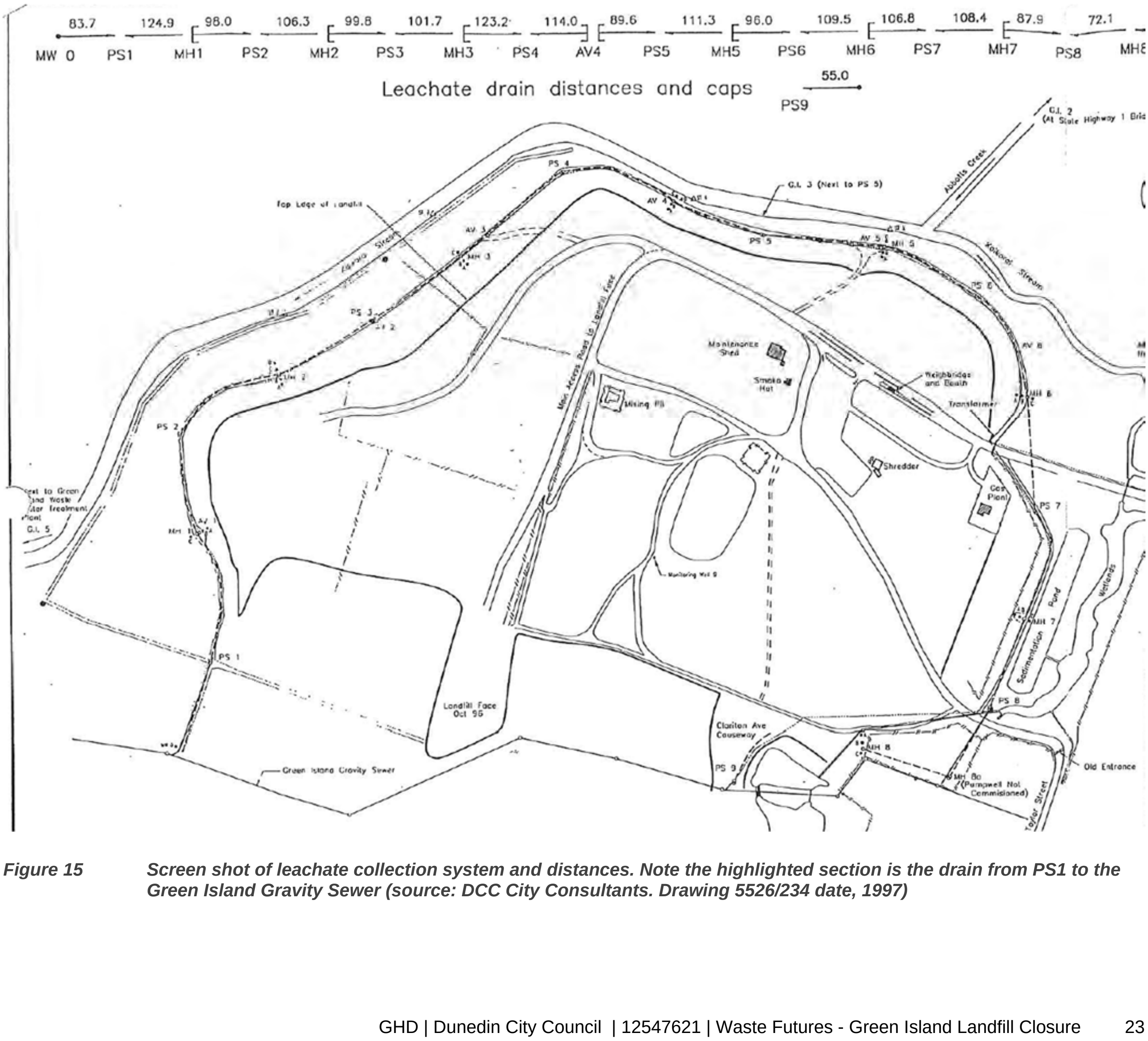

Figure 15 Screen shot of leachate collection system and distances. Note the highlighted section is the drain from PS1 to the Green Island Gravity Sewer (source: DCC City Consultants. Drawing 5526/234 date, 1997)

In the 1994 consent application it was contemplated that the extensive presence of low permeability soils within the landfill could result in perched or elevated levels of leachate developing within the waste, and this could result in seep breakouts on the sides or cap of the landfill. This has occurred on occasion since 1994 and has been managed by construction of open swales/drains on the face of the bund to direct the leachate to the perimeter leachate collection system. In recent years further steps have been taken to manage this issue via installation of internal horizontal leachate drains within waste to assist in managing perched leachate. These drains consist of perforated polyethylene pipework laid in a gravel drainage trench and discharge to the perimeter leachate collection system, as shown on Drawing 12547621-01-C204.

Leachate is currently mounding within the landfill waste throughout the older, deeper portions of the landfill. Leachate levels in the older and deeper portion of the landfill are discussed in the Groundwater Report (GHD 2023). It is noted in Section 4.1 that a soil makes up a large proportion of the volume of the waste stream to the landfill. This is likely resulting in perched leachate mounding within the landfill as the soils have lower vertical permeabilities than typical waste. The construction of the internal drains commencing in 2019 has been used to help control this , and, in conjunction with the progressive installation of the final cap, will allow for progressive lowering of the leachate mounding. Further proposed mitigation measures are discussed in Section 4.5.

3.4.2 Leachate Quantities and Quality

The current landfill leachate collection system extracts leachate from the landfill via the perimeter leachate collection trench and the southern surface drain. The leachate flow rate and composition are recorded and reported annually to the ORC. A copy of the latest version of the report is attached as 0.

The report includes monitoring data on both leachate quantity and quality. The following section provides a summary of the monitoring data findings.

Flow rates and pump hours are continuously recorded at the pump stations on the site. The recorded flow rates include pumped flow contributions from the surface water drains as well as leachate/groundwater systems. The report provides flow rate data collected over the 2021 - 2022 monitoring year for each of the pump stations, noting that these records have been reported for all years the leachate system has been operational. Graphs presenting cumulative net flow and another showing the average flow rate at each pump station along with a pie chart of the net contribution from each pump station are included in 0. As noted earlier in this report, in the past five years the total pumping rates from the trench are typically between 1 and 2 L/s, peaking up to 8-9 L/s after periods of rainfall.

The charts and pie diagram indicate that:

- Three pump stations are responsible for over 50% of the leachate volume flow at the landfill. PS5 contributed the largest volume of leachate over the monitoring year with 19% of the overall leachate volume, followed by PS2 at 17% and PS7 with 15% of the flow.
- The flow volume contributed by the remaining pump stations varies between 0.04% at PS9 and 14% at PS6.
- Flow rates and volumes are relatively consistent over the monitored year. However, this was a period of below average rainfall. In other years rates can vary significantly in response to rainfall events. Operational changes can also impact flows such as which catchments are reporting to the leachate system or are being directed to sedimentation ponds. Nonetheless, total flow discharges to the main sewer and GIWWTP generally sit within the range of 1 to 9 L/s.
- The volume of pumped leachate over the 2021 – 2022 monitoring year was 50,633 m^3. This is equivalent to 5,780 L/hour or 1.6 L/s,
- The trend over the past three reported years has been a reduction in pumped leachate from 77,908 m^3 in 2019-2020 to 50,633 m^3 in the 2021-2022 monitoring year. This is a 35% reduction in annual pumped volumes.
- The decrease in volume pumped compared to the previous monitoring year is considered be a result of there being less rainfall during the 2021 – 2022 monitoring year than the previous year, and an increase in the area of the landfill which has a permanent cap, which has likely reduced the amount of rainwater infiltration.

Samples of leachate are collected from PS3 and analysed for a range of parameters to represent the discharge to the GIWWTP. Analytical results are presented in 0 and compared to the Council guidelines for Trade Waste Bylaw 2008 (Trade Waste Guideline). In the 2021-2022 year only one exceedance of the Trade Waste Guideline was reported with the concentration of ammoniacal nitrogen reported at a value of 208 mg/l compared to the Trade Waste Guideline value of 50 mg/l. Other trends and observations in the leachate chemistry are described in pages 21 and 22 of 0 and in the *Groundwater Technical Report (GHD 2023)*.

3.5 Landfill Gas Management

3.5.1 Landfill gas collection and management

The Green Island landfill has been progressively developed since the 1950s. In the early years of operation, the landfill did not have an engineered approach to managing landfill gas (LFG). In the early to late 1990s, an engineered LFG collection and treatment system (system) began to be progressively installed across the landfill. However, this system was abandoned in 1998.

In 2009, LFG collection and treatment re-commenced at the landfill using an engineered system. This system continues to be expanded across the landfill as filling progresses.

Tonkin and Taylor have prepared a Landfill Gas Masterplan for Green Island Landfill and a Concept Design Report. The latest version of both of these documents (Tonkin & Taylor, 2023) are included in Appendix C and have been prepared to reflect both the current status of the system and an updated LFG design based on the revised closure plan for the landfill presented in this Design Closure Report (Section 4). At the time of the T+T report preparation (September 2023) the LFG system consisted of the following:

- Approximately 36 vertical LFG collection wells installed into the landfilled waste and connected to the system;
- Approximately 6 condensate drainage points;
- A series of 110 mm and 225 mm lateral connector pipes that connect to a 335 mm header pipe to convey the LFG to the destruction systems installed at the adjacent GIWWTP;
- The northern subheader (160 mm OD) and western ringmain (250 mm OD) have been installed and connected to convey the LFG to the destruction systems installed at GIWWTP.
- A LFG engine that uses LFG as a fuel in conjunction with gas produced from the GIWWTP with associated blower, power, and alarm systems to generate electricity which is fed back into the power grid. The LFG engine has a 600kW capacity and operates at an LFG flowrate of approximately 350 m^3/hr;
- A 450 m^3/hr candlestick flare, with its associated blower, power, and alarm system to treat the LFG collected that cannot be used by the LFG engine;
- The LFG engine and flare are co-located at the GIWWTP located 200 m to the south of the landfill; and
- Drawing 12547621-01- 501 shows the LFG system installed through to late 2022 and the proposed layout for the future sections of the landfill.

In addition to the above, a small mobile solar powered flare is used on the landfill to control LFG emissions from LFG wells that are not connected to the reticulated system. This typically occurs where wells are located close to the active tip face and reticulation pipework cannot be installed due to vehicle movements. A picture of the device is show in Figure 16.

Figure 16 On-site Solar Flare

3.5.2 Landfill gas quantities

The modelled LFG generation rates presented in Tonkin and Taylor (2023) are reproduced in Figure 17 and indicates landfill gas peaking around 2030 following the closure and final capping of the site. These predictions are based on the revised contours of the landfill presented in this Design Closure Report (Section 4).

In 2030 the peak LFG generation rate is estimated to be 903 m^3/hour. For the purposes of pipe sizing it has been estimated that the LFG extraction system will capture 80% of this peak LFG flow rate. Therefore, the expected maximum collected LFG that will be routed through the LFG extraction system pipework is 722 m^3/hour in 2030.

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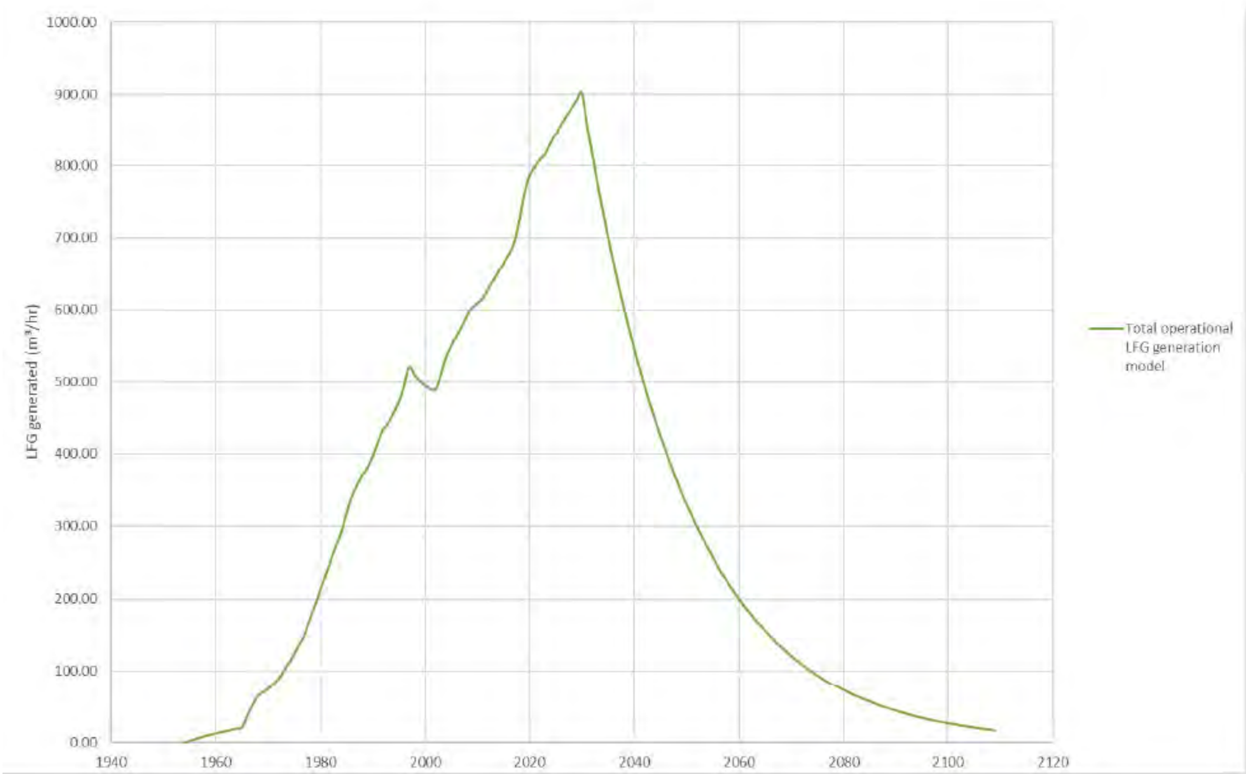

Figure 17 ***Estimated gas generation rates at the landfill***

The onsite gas collection system is monitored on a daily basis by the current landfill operator (Waste Management Ltd) for flow rate, methane content, temperature and pressure, with full weekly rounds of the whole field completed..

Total annual LFG flow rates have been measured by two flow meters immediately upstream of the engine and the flare. LFG flow to the engine and flare for the 2022 calendar year is presented in Figure 19. The average collected LFG flow since 2019 is plotted on Figure 18 in comparison to the modelled LFG collection curves. The maximum measured instantaneous flow recorded is 493 m^3/hr in January 2021. The collected landfill gas volumes are lower than the modelled landfill gas generation rate. T+T note that this is expected for an operational site. This is due to the site not being fully capped while it is operating, the interactions between the engine and the flare, and changes at individual extraction wells as a result of operational activities. T+T expect the collection efficiency will fluctuate over time throughout the operation of the site, however it is expected to improve overall as more waste is placed, areas are completed to final profile and permanent LFG extraction pipework is installed and capping is installed.

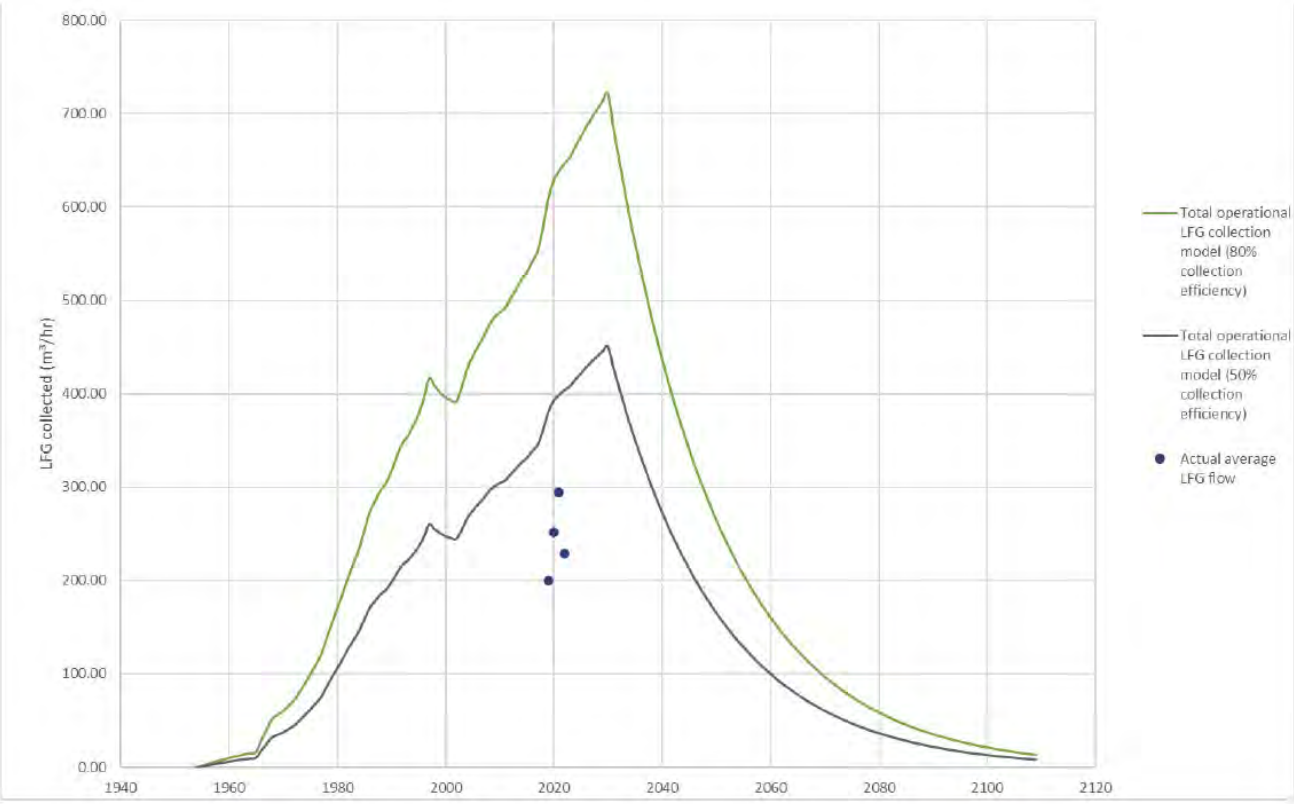

Figure 18 ***LFG modelled data compared to actual average LFG flows***

Methane concentrations shown on Figure 19 generally stayed just above 60% for calendar year 2022. This is an improvement on previous years and reflects the management of suction on the gas field. The target percentage for optimal performance of the GIWWTP generator is between 55-60% hence this year operated around the top of the range.

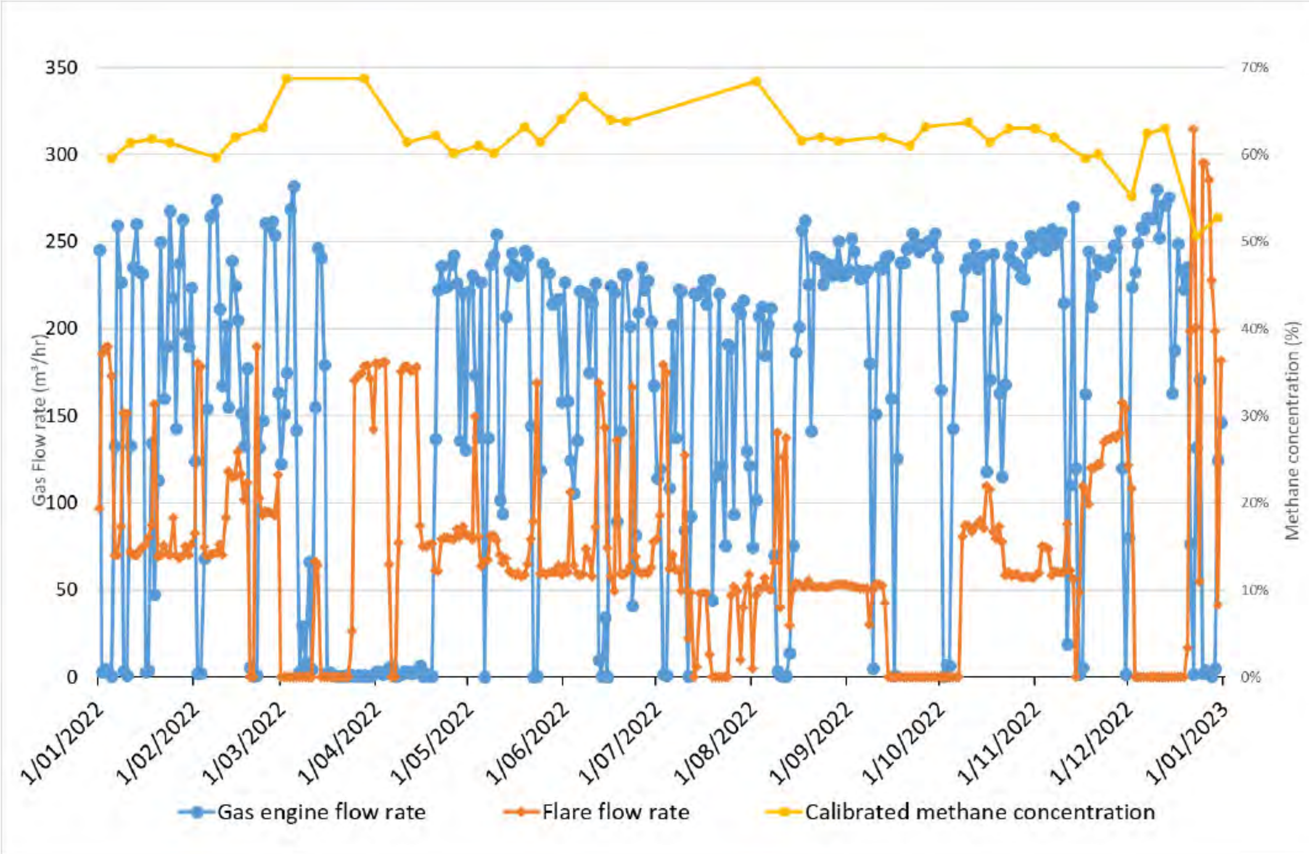

Figure 19 ***Methane Concentrations, gas engine and flare flow rate 2022 calendar year.***

3.5.3 Landfill gas environmental monitoring

Regular environmental monitoring of landfill gas is undertaken at the site. As identified in 0, this consisted of:

- Quarterly visual inspections of the surface of the landfill by monitoring staff;
- Monthly visual inspections by the landfill operator; and
- Monthly monitoring of LFG in four perimeter landfill gas monitoring wells. (G1 to G4 shown on Drawing 12547621-01-C504.

During the 2021-2022 monitoring period visual inspections identified some locations where bubbles were observed rising through puddle water in northern parts of the landfill, where intermediate cap is placed. It is noted that visual inspections are currently challenging due to vegetation cover and ongoing activities such as cap placement.

Landfill Gas Monitoring Wells G1 to G4 were installed I the 1990s to monitor for the potential of LFG emanating from the ground surface at the northeast boundary of the landfill (i.e. adjacent to private residences) – see Drawing C504. These wells are monitored on a monthly basis using a portable gas detector for methane (CH4), carbon dioxide (CO2) and oxygen (O2) percent compositions along with carbon monoxide (CO) and hydrogen sulfide (H_2S) concentrations. The LFG measurements are collected using a GA5000 or GEM5000 LFG measurement instrument, and are provided in Table 7 in 0. No methane or hydrogen sulphide were detected present in the gas wells in the 2021-2022 period or for the years prior to this. However, CO_2 was recorded present in the wells on several occasions with values ranging from 0.1% to 10.9%. A review of the logs and installation details for these wells indicate that the well screens are located in natural soil material and not waste (which could act as a source). The New South Wales Environmental Protection Authority (NSW EPA), *Assessment and Management of hazardous ground gases: Contaminated land guidelines* 2020 state that soil has background concentrations of CO_2 in the 0-10% range and wetlands and waterlogged soils can have CO_2 concentrations in the 0-5% range. No background concentration for CO_2 has been established for the site and so it is difficult to determine what percentage of this gas can be attributed to natural sources and what percentage is from another source(s). These wells are located to the north of a constructed wetland area and also to the east of the landfill. The leachate collection trench passes immediately adjacent to the landfill gas well locations and the pipe from the south eastern constructed wetland to the eastern constructed wetland passes approximately 20 m to the west of the well locations. It is possible that gases are present in these pipes including CO_2 and are migrating into the wells. There is no guidance contained in the WasteMINZ Disposal to land guidelines for trigger values for CO_2 concentrations. In enclosed spaces, corrective actions are required above 1.5% CO_2 (above natural background levels). From the data collected, it is not considered likely that the concentrations of CO_2 present in the gas wells pose a risk.

4. Landfill Closure Concept Design

4.1 Proposed waste characteristics, volumes, and projections

Council records all waste placed at the Green Island landfill and landfill gas emissions, and reports this annually in accordance with the Unique Emissions Factor (UEF) Regulations 2009. The waste volumes and composition are recorded in the following table extracted from the 2021 UEF report.

Green Island Landfill - 2007 to 2021 tonnage breakdown

Waste material classifications

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
C & D	-	-	2472.5	4656.1	4162.8	4045.0	5276.9	1715.3	2737.9	3354.8	4062.1	3485.9	1606.1	865.2	1,008.5
Commercial	3540.6	4349.2													
ComTS	-	103.9	86.4	83.6	76.7	74.3	151.2	226.6	207.5	217.8	244.0	257.6	213.4	211.8	268.1
Gen SW	10989.2	10965.5	11350.2	12161.0	22989.3	24445.8	23616.5	25613.6	27491.2	28948.3	48786.7	63688.3	50647.6	39,143.3	34,189.8
Other	81.6	113.9	89.0	81.4	79.6	84.6	191.7	86.9	51.8	44.5	76.9	110.2	48.8	83.3	125.9
Ref/Lit Co															
*Illegal Dumping				1.1	9.5	6.2	1.5	34.5	82.5	28.7	0.7	3.1	3.7	0.3	0.4
*Litter Col DCC Contract	973.9	835.3	724.4	634.5	646.7	598.3	601.9	594.3	508.5	580.5	547.2	460.2	505.5	353.1	433.9
*Refuse Col DCC Contract -Envirowaste	9253.9	9154.3	5380.9												
*Refuse Coll DCC Contract TPI			2211.2	6841.1	969.7										
Sp/Haz/1	5160.8	4816.8	4303.0	3611.5	4074.2	5374.8	7299.4	7358.5	6752.2	6864.1	4312.4	4873.3	5738.2	4,899.7	6,600.6
Sp/Haz/2															0.0
Animal Remains -charge	0.5	0.3	1.0	4.0	4.8	3.5	21.9	64.2	6.8	40.3	9.0	33.4	97.0	659.0	546.8
*Liquid	75.0	26.7	309.7	152.5	449.3	193.5	108.1	273.7	97.1	277.1	290.5	334.6	283.8	145.7	148.8
*Special/Hazardous NOT DCC	421.1	777.0	130.7	134.8	26.0	683.1	75.5	12.2	96.6	135.4	110.8	150.9	100.0	102.8	45.9
Chemicals -special disposal	3.3	0.2	0.2	0.6	2.1		0.2	0.5	0.5	2.8	0.3				
Dental School - Special Waste										189.7					
Fish Waste	-	-	3.5	42.5	13.2	14.4	12.8	31.4	1.9	2.2	14.7	1.6	27.3		
Grease Trap -heavy grease	5.7	9.8	-		2.8	9.8	29.3								
Meat Process -fat, bones, animal parts -not cooked	60.8	178.5	66.8	30.5	100.3	72.0	76.4	187.7	37.8	246.8	100.1	255.7	464.2	80.1	165.3
Septic Tank -emergency work	1.2	-	-		6.5			2.1							
Sumps -mud tank, road sump, gully trap, intercept	849.7	456.7	1371.4	1205.3	1357.7	788.7	698.9	848.1	850.4	2162.4	2916.1	1350.3	1657.5	2,087.5	2,035.3
Water Treatment Sludge (20-)														4.5	
WOOLSCOUR/TANNERY/FELLMONERY (20+)	-	534.1	1808.3	187.8	132.1	446.5	298.3	296.6	76.0	86.6	88.8	143.6	195.7	518.7	279.8
Woolscour/Tannery/Fellmongery	3542.6	2953.9	-												
Woolscour/Tannery/Fellmongery (20-)			600.9	150.4	303.2	147.1	120.6	215.0	271.0	202.0	182.7	21.2	16.6	145.7	125.2
Sp/Haz/xDn	631.9	0.0			6.4	19.2	19.7			0.1	58.4	0.6			
Sp/Haz/Dry	1090.0	165.6	474.4	435.6	296.8	715.6	152.5	261.0	4740.3	1160.7	2368.6	701.2	686.9	499.0	533.2
Tipface	11294.4	9138.2	8277.9	9548.3	11444.8	9816.2	9695.8	8511.1	7846.3	7585.8	7223.8	6728.3	6400.6	7172.4	7304.2
Total (tonnes)	**47976.0**	**44580.0**	**39662.3**	**39962.2**	**47154.7**	**47538.4**	**48449.1**	**46333.4**	**51856.1**	**52130.5**	**71393.7**	**82600.0**	**68692.7**	**56972.3**	**53811.7**

Inert construction material classifications

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Aggregate	1191.3	109.3	10.3												
Inert	88701.2	41745.3	52634.4	39190.4	66742.0	111515.2	118703.0	43073.3	25023.4	20625.5	34473.4	76354.9	50925.4	62095.6	35940.8
Dly Cover			27.9	116.2	779.1	2872.5	3055.3	2838.2	4891.0	5082.0	8999.7	3316.4	1407.4	1171.9	1536.2
Ref/Lit Co															
*Cover-free (From Hall Brothers)	8316.3	4116.7	5393.2		1625.9										
Total (tonnes)	**98208.8**	**45971.3**	**58065.8**	**39306.6**	**69147.1**	**114387.7**	**121758.3**	**45911.5**	**29914.4**	**25707.5**	**43473.1**	**79671.3**	**52332.8**	**63267.5**	**37477.0**

Diverted material classifications

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Commercial			0.0	0.0	0.0	0.0	0.0		0.9				270.8		
Domestic	0.0	0.0	0.0	2.8	424.0	934.1	933.4	1143.7	1469.9	942.6	857.5	1103.3	1379.0	1619.8	4139.1
Gardn Prod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Monitor					0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Public	166.3	887.0	1370.2	1052.6	4511.2	252.9	4262.8	862.5	514.9	141.2	236.6	155.9	15.0	47.9	65.0
Re	999.8	660.7	3315.7	3590.4	1039.2	23.6	63.8	61.8	66.6	49.5	70.5	101.9	1.8	0.0	0.0
Re Out	514.9	498.5	613.4	569.5	698.3	598.6	693.6	691.8	583.2	1034.4	1295.9	1205.5	1638.4	1331.4	1368.0
Tankered W					3864.7	3110.2	3434.0	3144.0	3422.1	3930.0	3391.8	3658.8	2683.1	2190.8	2495.3
Veg	1789.5	1863.0	2023.7	2090.0	2214.9	3143.8	2616.7	2127.3	522.8	403.3	501.7	841.6	588.0	681.4	1648.8
Total (tonnes)	**3470.4**	**3909.2**	**7323.0**	**7305.4**	**12752.3**	**8063.1**	**12004.4**	**8030.9**	**6580.3**	**6501.0**	**6353.9**	**7067.0**	**6576.0**	**5871.3**	**9716.2**
TOTAL ANNUAL TONNAGE	**149655.3**	**94460.4**	**105051.1**	**86574.2**	**129054.0**	**169989.2**	**182211.8**	**100275.8**	**88350.8**	**84338.9**	**121220.7**	**169338.3**	**127601.6**	**126111.1**	**101004.8**

Figure 20 Green Island Landfill 2007 – 2021 tonnage breakdown

The aggregated quantities of waste and soils disposed to the landfill are summarised in the following Table 2.

Table 2 Aggregated quantities of waste and soils disposed to the landfill (tonnage)

Year	Waste + Soil	Waste	Soil	% Waste
2017	121,220	71,400	49,820	59%
2018	169,340	82,600	86,740	49%
2019	127,600	68,700	58,900	54%
2020	126,111	57,000	69,111	45%
2021	101,000	53,800	47,200	53%

Green Island landfill currently accepts contaminated and uncontaminated soils, these are stockpiled separately. The more heavily contaminated soils are disposed to the active cell or mixed with GIWWTP biosolids and covered immediately. Lesser or non-contaminated soils are used as daily cover and intermediate cover.

Although there is annual deviation, the average waste and soil (including cover soils) placed to the landfill historically is around 120,000 tonnes per annum based on the last five years of data. Of which approximately 60,000 tonnes is waste, and 60,000 is soils (both contaminated and clean).

In terms of annual void consumption the following criteria have been assumed:

- Waste compacted to 0.8 t/m^3;
- Soils compacted to 1.6 t/m$^{3;}$
- 10% of soils lost to the voids in the waste;
- 10% settlement during the active waste placement with a further 10% post placement; and
- The long-term density of the combined waste post-settlement is around 1.3 t/m^3.

Based on the above criteria applied to the past three years weighbridge records (listed in Table 2), the void required per annum to accommodate the current waste volumes is 88,946 m^3 (rounded to 89,000 m^3) and exclusive of final cap volumes. Table 3 provides the analysis of how this value was derived.

Table 3 Average waste disposal over past 3 years (2019-2021)

Average waste disposal over past 3 years (2019-2021)							
Year	***Waste (t)***	***Soils and Diverted Waste (t)***	***Waste (m3 @ 0.8t/m^3)***	***Soils (m3 @ 1.6t/m^3)***	***Soil losses into waste (10%)***	***Settlement (in waste only (10% initial + 15% longterm)***	***Total void consumed per annum***
2019	68,700	58,900	85,875	36,813	-3,681	-21,469	97,538
2020	57,000	69,111	71,250	43,194	-4,319	-17,813	92,312
2021	53,800	47,200	67,250	29,500	-2,950	-16,813	76,988
Average	**59,833**	**58,404**	**74,792**	**36,502**	**-3,650**	**-18,698**	**88,946**

Looking to the future, this average waste volume to landfill is likely to represent an upper-limit (excluding any unusual one-off events such as significant natural disasters). Council's target is to reduce the amount of municipal solid waste disposed to landfill by 50% by 2030 compared to 2015 rates. The target is a reduction of 14,000 t/yr of waste – giving a target of 47,264 t/yr of waste for 2030 compared to the average disposal rate of 59,833 t/yr for waste over the past three year shown on Table 4. A reduction in the municipal waste tonnage to 47,264 t/y equates to an annual total void consumption of 76,000 m^3 (exclusive of final capping volumes) compared to the three-year average value of 89,000 m^3.

Council have signed a contract in 2022 with EnviroWaste for both kerbside collection of recycling/waste and the construction and operation of a Resource Recovery Park adjacent to Green Island Landfill (to be located in the current landfill facilities area to the north of the current active landfill operations). This change is anticipated to make a significant contribution to the targeted waste disposal reduction.

4.2 Landfill Closure – Remaining Void

4.2.1 Background

As discussed in Section 2 in this report, the 1994 resource consent application included a final landfill surface plan as part of the application (Figure 11). As described in Section 3 of this report, the proposed final landfill surface has been updated a number of times since 1994. The current configuration is shown on Figure 13 (2001 Design)**.** The current landfill surface (as of June 2022) is shown Drawing 12547621-01-C201**.** The remaining void available for landfilling can be calculated as the difference between these two surfaces with allowance for additional void as the waste settles. The value calculated as of June 2022 for the remaining void (exclusive of final cap) is 529,000 m^3.

As discussed in section 4.1, based on the past three years of data, the annual void consumption (exclusive of final cap) is around 89,000 m^3. This includes waste and soils (intermediate cover) and allows for settlement. It is important to note that the Green Island landfill has been operated to ensure that settlement is allowed for in the development of the final surface level to bring final contours to the levels shown on Figure 13 .

Table 4 provides the calculations for this estimate of annual void consumption based on landfill data from the past three years. As discussed in Section 4.1, the intention is for the municipal waste component to reduce from the current average of 58,404 t/yr to 47,264 t/yr by 2030. For the purpose of this report, it has been assumed that these two values represent the upper and lower bounds of what could be reasonably expected to be landfilled each year through to landfill closure. Therefore, it has been assumed the annual void consumption will be between 76,000 m^3 and 89,000 m^3.

Based on this assumption the 2001 final landfill surface (Figure 13) has capacity to continue to accept waste as set out below:

For a likely maximum annual void consumption of 89,000 m^3 :

- Until April 2028 – approximately 4 years and 7 months after the expiration of the current consents on 1 October 2023.

For a likely minimum annual void consumption of 76,000 m^3:

- Until July 2029 – approximately 5 years and 10 months after the expiration of the current consents on 1 October 2023.

The actual annual void consumption rate is likely to fall somewhere between these upper and lower bound values. It is noted that kerb side collection and separation of food and garden waste, recyclable materials and general waste is scheduled to commence in mid-2024 and the impact of this activity on waste minimisation will not occur until after that time.

4.2.2 Updated Closure Design

The Council has lodged applications for consents for a new landfill at Smooth Hill (20km south of Dunedin CBD) to serve the Dunedin region. These consents have been granted by both ORC and Council but are under appeal to the Environment Court at the time of report preparation (January 2023). Therefore, the commencement of operations at Smooth Hill is contingent on resolving the outstanding appeals. If these are resolved the Smooth Hill landfill would need to be designed, peer reviewed and approved before construction can commence and this process could take two to three years. This would be followed by a period of construction before the site could accept waste. Allowing for the Environment Court Appeals it is possible that Smooth Hill may not be ready to accept waste until at least 2027 and this may be delayed further depending on the Environment Court outcome.

Council has considered a number of options for extending the life of Green Island.. The purpose of extending the life of the landfill is to address:

- The risk of further delays to Smooth Hill development; and
- Allows for some overlap between Green Island and Smooth Hill operations. This is beneficial for a number of reasons – allowing a transition period as Smooth Hill ramps up operations and Green Island ramps down

In addition, extending the life of the Green Island landfill is also beneficial as the existing operation allows for efficient waste disposal as the infrastructure is already in place to receive and manage waste.

The preferred option for extending the life of Green Island landfill is shown on Drawing 12547621-01-C202 and is referred to as the Preferred Option for closure. The Preferred Option increases the landfill capacity by increasing the landfill cap height to the west and raising it by approximately 8 m compared to the 2001 closure design shown on Figure 13. The capping grades generally increase which is an improvement compared to the relatively low grades for the cap shown on Figure 13. This allows for more efficient shedding of stormwater runoff from the cap and reduces the risk of ponding due to cap settlement. In all other respects the Preferred Option is similar to the

2001 closure design. They both maintain the same landfill footprint and utilise the same supporting infrastructure including leachate collection system and stormwater management system.

The Preferred Option design results in an available landfill void of approximately 670,000 m^3 compared to a void of 529,000 m^3 for the 2001 design (calculated as of June 2022 and exclusive of final cap).

For a likely maximum annual void consumption of 89,000 m^3

- The projected life of the Preferred Option design would be until December 2029 – approximately 6 years after the expiration of the current consents on 1 October 2023.

For a likely minimum annual void consumption of 76,000 m^3:

- The projected life of the Preferred Option design would be until March 2031 – approximately 8 years and 5 months after the expiration of the current consents on 1 October 2023

As discussed in Section 4.2.1. these two values likely represent the upper and lower bounds of what could be reasonably expected to be landfilled each year through to landfill closure. Based on these calculations Council have a revised target date for closure for acceptance of waste by the end of 2029. This allows for some overlap with the opening of Smooth Hill landfill while not extending the life of Green Island too long into the future. It is possible that annual waste disposal rates to the landfill will reduce between 2022 and late 2029. If this occurs the entire available void may not be utilized, or the closure date may be delayed for a short period.   Once waste disposal at the landfill is complete it is anticipated to take two years to:

- complete final capping of the site;
- complete installation of all LFG wells and associated pipework;
- complete landscaping and vegetation of the cap and surrounding areas; and
- alter the leachate and stormwater management system that are no longer required.

4.3 Landfill guidelines

The Green Island landfill in its current form was consented in 1995. At that time the CAE Landfill Guidelines (2000) were not issued. As earlier waste was placed over the estuarine muds without liner or an integrated leachate collection system the 1994 landfill consent application provided for collection of the leachate through the construction of an earth bund and leachate collection trench on the estuary side of the landfill. Waste has continued to be placed over the full extent of the landfill footprint consented in 1995 and the bund including the leachate collection trench completed for the full extent of the landfill, where abutting the estuary.

The current New Zealand standard for sanitary landfill development is the WasteMINZ T*echnical Guidelines for Disposal to Land* (2018) (WasteMINZ Guidelines). That guideline recommends the installation of a low permeability liner and leachate collection system for Class 1 landfills containing Municipal Solid Waste, such as the Green Island landfill.

While the current design does not include a low permeability synthetic liner, leachate containment and management is achieved through:

- As described in Section 2.8, the landfill is underlain by low permeability estuarine deposits and the existing underlying groundwater system provides an upward (artesian) groundwater gradient. This restricts the ability for leachate to move downwards into the underlying sediments.
- Leachate mounds within the waste up to around average of 14m above sea level with some isolated areas up to 20 m amsl at the centre of the landfill. The lateral gradient and direction of leachate flow is towards the perimeter where either the leachate collection trench (along the estuary boundary) or the surface drain along the southeast landward boundary intercept and collect leachate. A series of pump stations drain leachate from the trench and drain and direct leachate to the GIWWTP.

The environmental monitoring set out in the annual and environmental monitoring reports GHD (2021 - Appendix B)) and discussed in the *Groundwater Technical Report (GHD 2023A)* and *Surface Water Report (GHD 2023B)* indicate that the leachate collection system has been effective at controlling and capturing leachate from the landfill. Two potential exceptions to this are the absence of the leachate collection trench along the south-eastern margin of the landfill (leachate and surface water are currently collected in a surface drain and the leachate trench which extends from PS1 towards the Green Island Gravity Sewer) and apparent leachate seepage into a culvert in the north east part of the site. Proposed remedial measures to address both of these issues are described later in this report.

Within the landfill, infiltration of rainfall combined with the presence of large quantities of soils has resulted in relatively elevated levels of leachate. However, landfill capping is now being placed over the complete sections of the landfill (see Section 3.3) and it is expected that as the landfill progressively has final cap applied and infiltration to the landfill waste reduces, the levels of leachate in the landfill waste will drop until there is equilibrium on the leachate head and flow rates through soils to the perimeter leachate collection system. To assist in the process the installation of additional internal horizontal leachate drains is proposed along with ability to extract leachate from the installed LFG wells if necessary. Both issues are described in more detail later in this report.

With the exception of the leachate and landfill liner systems, all other construction works relating to the current landfill operation (and described Section 2.4) meet the recommendations of WasteMINZ Guidelines including landfill cap design and LFG management.

It is noted that the location of the landfill does not meet the siting criteria outlined in the WasteMINZ Guidelines. As with other aspects of the guidelines, the siting criteria were not in place during the 1994 consenting process. The primary issue with regard to siting is the location of the landfill with respect to the estuary and wetlands and the relatively nearby residential areas. The potential effects associated with these issues and how they can be mitigated are addressed in this and other technical reports.

4.4 Proposed Changes to Current Landfill Operations and Closure

4.4.1 Introduction

As discussed in Section 4.3, Council has decided to progress with a revised design for the closure of Green Island landfill. Regardless of the changes in the design a number of modifications to the design, operation and monitoring of Green Island landfill are recommended in this report and are described in the following sections. In summary, the proposed changes are:

- extension of the leachate collection trench along the south-east margin of the landfill and connection to the rising main sewer connection;
- continued installation of internal landfill drains as part of waste placement to manage leachate within the waste;
- provision to utilise LFG wells to extract leachate from closed sections of the landfill as required to manage leachate levels; and
- remedial measures to address leachate seepage from the eastern culvert.

4.4.2 Proposed Leachate Management

4.4.2.1 Leachate Collection System

The existing Green Island landfill has waste placed directly on the estuarine muds and has an earth bund and leachate collection trench encircling the majority of the landfilled waste (shown on Drawing 12547621-01-G101). The leachate interception was not extended along the extent parallel to the wastewater trunk sewer at the time the trench was constructed in the 1990s as waste may have been placed across this area. To manage potential leachate seepage in this area an open swale drain has been constructed to intercept leachate and runoff (shown on Drawing 12547621-01-G101), whilst the interception trench extends across to the Green Island Gravity Sewer from PS1 (Figure 15). A small gap also exists between PS9 and MH8 where the underlying low permeability mudstones extend towards the landfill. The existing system is described in detail in Section 3.4.

Surface water and potential leachate seepage that accumulates in the swale drain along the base of the southern extent of the landfill is collected and pumped to PS1 and then the GIWWTP via the main sewer.

The revised design proposed in this application is that a leachate collection trench with pump stations at approximate 170 m centres similar to the existing leachate collection trench, will be installed over nearly the full extent of the existing swale drain which currently collects leachate seepage from the landfill (shown on Drawing 12547621-01-G102). Once the trench is constructed, the swale drain can be retired and shifted slightly down gradient of the interception trench forming a clean water swale that receives non-contaminated runoff from the capped landfill to the north and rehabilitated borrow area batters and existing slopes to the south. The swale will then be drained to the south western sedimentation ponds prior to discharge to the estuary. The proposed surface water layout is shown on Drawings 12574621-01-C204

The proposed interception trench will be joined with the existing system at MH12 on the west side, and approximately 40 m west of PS9 on the east side, forming an almost continuous system around the perimeter of the landfill footprint. The exceptions are the small gap between PS9 and MH8 described in Section 3.4 and the 40m gap between MH9 and PS9 in the proposed new section of trench underneath the existing borrow pit haul road. At this location the existing haul road bund impedes construction however the geomorphology and geology of the area is expected to enable any subsurface flows towards the existing and proposed leachate collection trenches. This is to be confirmed during the detailed design stage.

The detailed design and construction methodology of the leachate collection trench will need to consider the several site-specific factors, including the local geological and seismic conditions. An initial assessment of the seismic hazard has been undertaken by GHD (refer section 4.4.5 for a summary). This included determination of the expected ground movements and soil liquefaction potential. To resist the anticipated seismic loads the concept design of the leachate collection trench has taken into consideration the configuration, materials, and long-tern structural integrity.

The trench configuration has incorporated manhole and pumpstation spacings of between 70m to 90m which is a tighter spacing than the existing trench. This will allow for suitable staging of construction and minimise the potential disturbed area should the landfill mass shift during a seismic event. The materials specified in the trench construction were chosen to minimise liquefaction and brittle failure (gravel and PE piping). It is recommended that the rising main connection to the proposed pump stations and power supply be above ground so as to provide for easy inspection/repair post a seismic event.

The trench will be offset at least 5 m from the existing sewer line, centre to centre towards the landfill side. The offset is for reducing risks of damaging the sewer line during installation of the trench well for construction of the clean water swale drain. It is assumed that benching at maximum 1.5 m depth or battering at minimum 1V:1H slope will be suitable for the construction. The leachate trench will be constructed in short sections to manage both potential odour issues and to ensure the stability of the slope is maintained. Additional geotechnical investigation will be needed prior to the detailed design of the trench to confirm both the spacing between the sewer and trench excavation and the appropriate length of trench that can be open at any time. The spacing may be adjusted during the detailed design based on the actual ground conditions for safe excavation and/or as required for construction of the swale drain. The *Air Quality Report* (GHD 2023C) provides a summary of measures that will need to be adopted during construction works to manage odour.

The installation of this proposed leachate collection trench may require replacement of the existing materials within the trench alignment (including waste and soft soil) with suitable soil material to facilitate the safe construction of the interception trench and minimise liquefaction. Any materials removed from the excavation will be disposed directly to the Green Island Landfill. Any groundwater/leachate extracted during construction will be directed to the leachate collection system for treatment via GIWWTP.

The new trench and replacement swale drain construction will be integrated with the required final landfill cap which will extend down to the leachate trench and swale drain along this boundary. A typical section of the proposed interception trench construction and other details are shown on Drawing 12547621-01-C304. Works will be completed within three years of consent being granted for the continued operation of Green Island landfill.

It is expected that the proposed extension to the leachate collection trench system will also assist in controlling leachate levels within the landfill as the trench will draw down leachate/groundwater levels below the existing surface drain by up to 2m. Along with other proposed measures this will assist in controlling leachate levels – although the impact of the extended trench is likely to be confined to a relatively small area of the landfill.

4.4.2.2 Leachate Drainage to Final Portion

To augment the leachate collection trench, the current landfill operation has progressively installed horizontal trenched leachate drains over the intermediate cover soils in the location of the southern progression of waste placement as well as in the northern sector of waste placed in 2019-2022. Any leachate collected within the trenched leachate collection pipes drains by gravity to the pump stations on the perimeter leachate collection trench. The trenched horizontal leachate drains installed to date are shown on Drawing 12547621-01-204. Prior to the trenched leachate drains being covered with waste they act to remove contaminated stormwater that collects on the intermediate cover soils, assisting with control of perched and mounded leachate level within the landfilled waste.

This system also includes small bunds on the perimeter of the proposed southern waste placement area which directs leachate that may flow towards the proposed landfill batter to the gravel leachate drains and on to the sewer connection via the leachate collection trench pump stations. This reduces the potential for leachate breakout at the perimeter bund, assists in the dewatering/management of sludge deposited at the site and addresses the recommendation in the Tonkin and Taylor Dec 2021 – *Green Island Landfill - Perimeter Bund Assessment.* See Drawing 12547621-01-C304 for details.

As part of the ongoing landfill development it is proposed to continue with the horizontal trenched leachate drains within the landfill approach with minor improvements. The existing intermediate cover soils surface in the area of future waste placement are between 9 m amsl to 13 m amsl (consisting of approximately 10 m of compacted waste and various stockpiled soils). The intermediate cover soils are relatively thick as a result of the residual soil deposits from the rotation of cover soil stockpiles in the area. This increased intermediate cover soil thickness will likely result in the future waste filled in this portion of the landfill from being somewhat hydraulically disconnected from the main body of waste which presents an opportunity to extend the trenched leachate drains with appropriate grading and waste placement.

It is proposed that the existing intermediate cover soils will be graded as part of operations to direct leachate away from the external landfill batters at no less than 5% toward the centre of the landfill towards the additional trenched leachate drains which are placed approximately 20 m from the landfill cap extent. This system will direct any leachate that may otherwise breakout at the edge batter to the horizontal leachate drain. Beyond these drains it is proposed that waste is strategically placed and capped to promote leachate drainage to the extended drainage network. The layout of the extended drainage (See Drawing 12547621-01-C204) has taken into consideration:

- the existing intermediate cap profile and minimising cut and fill as appropriate;
- avoiding the existing asbestos pit and asbestos soils placement area;
- abutting the existing sludge placement areas to allow for potential drainage from the placed sludge as it compresses and settles during ongoing operations;
- keying into the existing pump station infrastructure where appropriate and installation of new pumpstations as required; and
- maintaining drainage lengths of around 150 m to allow for jetting of the pipework if required.

All horizontal leachate drainage installed on this final portion of the landfill will be heavy walled HDPE pipe with gravity falls generally between 2% - 5% and rodding points to allow the system to be jetted as programmed maintenance. The pipe will be encased in TNZ F2[5] drainage media and fully encased with filter geotextile (see Drawing 12547621-01-C304). All collected leachate will be discharged to the perimeter leachate collection system and ultimately the GIWWTP.

Note typically all runoff from intermediate cover is treated as leachate as it is generally within sub catchments of the landfill where runoff has a risk of coming into contact with waste. However, in some cases intermediate cover may be associated with sub catchments with no risk of runoff encountering waste. In these cases runoff may be directed to the stormwater system.

4.4.2.3 Leachate Management in Completed Section of the Landfill

The landfill will have a full waste depth of up to 25 m with approximately around 12 m to 15 m of waste in the southern portion to be placed. Current leachate levels are shown on Figure 21 (at August 2022). Mounding of leachate is already occurring within the existing waste mass. Although removal of this mounding is a priority for Council, retrofitting a conventional leachate collection system to the base of the 10 m deep waste already placed and mostly capped is not feasible. As such, and in addition to the horizontal leachate drains described above, the landfill operator may use the series of LFG existing wells (especially in the deeper waste) to remove leachate utilising in-bore submersible, air powered pumps to manage leachate levels. Extracted leachate will be discharged to the perimeter leachate collection system and ultimately to the GIWWTP. The design of the system will allow those pumps to be deployed to any gas-well that is measured as having a high leachate level. Figure 21 The beneficial impact on the control of leachate levels is also discussed in the Section 4.4.5 and the *Groundwater Technical Report (GHD 2023A)*.

[5] A standard granular material defined by Waka Kotahi

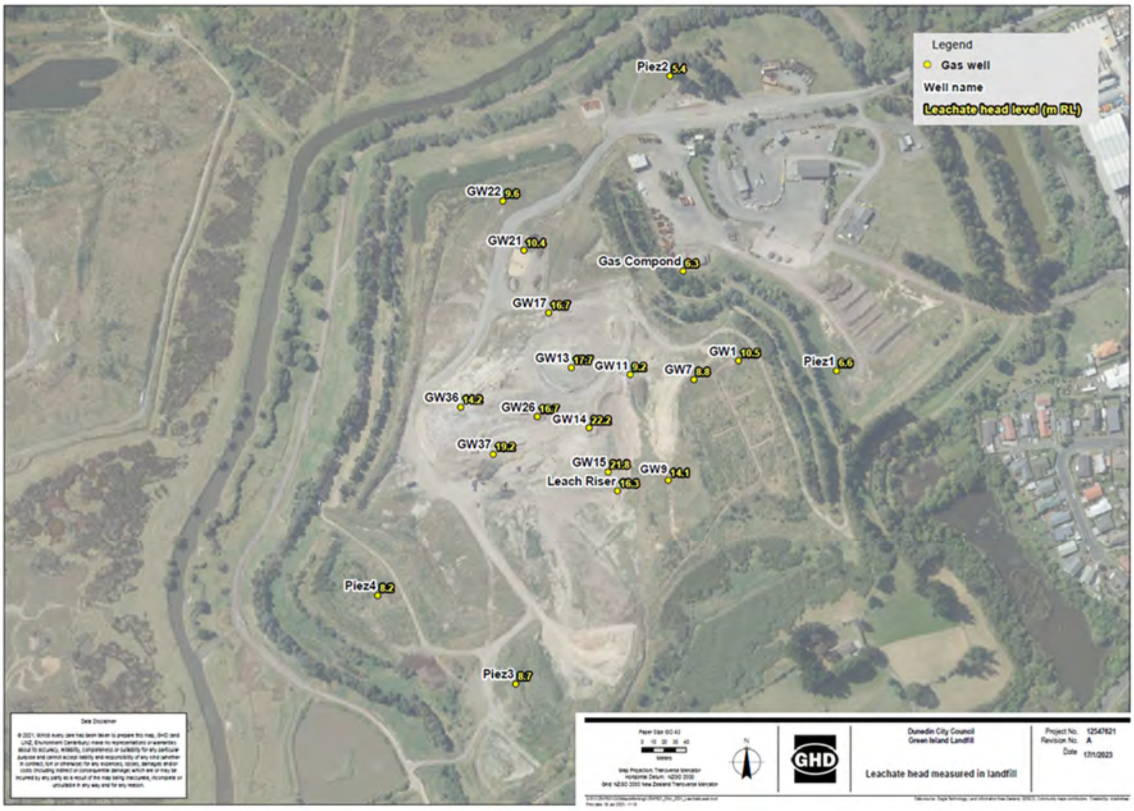

Figure 21 ***Leachate Levels within Existing Landfill (amsl, August 2022)***

4.4.2.4 Management of Leachate By-Pass of Drain

As discussed in Section 3,3 recent surface water testing has identified that the culvert between the south East Constructed Wetland and the Eastern Constructed Wetland is likely to be leaking leachate into the surface water system. A pipe inspection has been completed on the culvert and the inspection findings and the proposed remedial measures are described in the *Surface Water Technical Report (GHD 2023B).*

4.4.2.5 Existing and Anticipated Leachate Volumes

As discussed earlier in the report, all leachate collected from the perimeter interception trench and open swale drain, is currently pumped directly to the GIWWTP for treatment and disposal. The average pumping rate during the 2021-22 monitoring period was 1.6 L/s (0). Numerical modelling reported in the *Groundwater Technical Report (GHD 2023A)* indicates future volumes at closure are likely to be similar (in the order of 2 to 3 L/s). A number of factors will influence the future leachate volumes including:

- Capping of the landfill is expected to reduce leachate volumes as infiltration of rainfall into the landfill will reduce compared to the current site conditions;
- Construction of the extension of the leachate trench along the south-eastern margin of the landfill will increase volumes as the trench will be more effective at collecting both leachate and groundwater seepage from this part of the site than the existing surface drain; and
- Stormwater from some catchments which are currently conveyed to the leachate collection system will ultimately be redirected to convey to the stormwater systems on site.
- In all cases, significant rainfall events will influence leachate volumes, as described in Section 2.8 and the *Groundwater Report (GHD 2023A).*

4.4.2.6 Response to Climate Change/Sea Level Rise

As described in Section 2.5 a number of factors could influence long term water levels in the Kaikorai Stream adjacent to the landfill. The *Groundwater Report (GHD 2023A)* modelled a 0.5 m rise in water levels associated with the stream to reflect the possible impacts of climate change over the operational and foreseeable closure period of the landfill. The modelled impact on leachate volumes is in the order of an additional 0.5 L/s. The installed system is capable of managing an increase of this amount.

The modelling assumes that additional seepage will occur in response to an elevation in the Kaikorai Stream level and with seepage increasing through the sediments between the stream and leachate trench resulting from the increase in groundwater gradient. An additional risk is that flooding of the landfill perimeter will result in inundation of the leachate trench and manholes. The planned response to this risk is to raise the level of the perimeter road berm that runs around the landfill between the adjacent Kaikorai Stream and leachate trench by approximately 1.0m to minimise the risk of inundation by surface waters. In addition, any manholes, chambers and electrical controls or similar devices will need to be raised above a potential future flood level, and protected if necessary, from damage from flood debris.

4.4.3 Proposed Approach to Landfill Liner Absence

The Green Island landfill does not have a modern liner system installed. As the full extent of the landfill footprint has been landfilled it is not possible to retrofit a new liner over the underlying sediments without extensive excavation of existing waste materials. This is not considered warranted given the performance of the current leachate collection system and the proposed changes discussed in the above sections of this report and demonstrated through numerical modelling in the *Groundwater Technical Report (2023A), a*s well of long history of surface water quality testing outlined in the *Groundwater Technical Report (2023A)*.

A “piggyback” synthetic liner was considered for placement over the previously placed waste in the southern portion of the existing landfill. This is the area where future waste will be placed through to landfill closure. This approach would require complex construction and has three key risks detailed below.

- The first risk is that uneven/differential settlement has been observed and is anticipated in both the underlying waste and the estuarine sediments beneath the landfill as further waste is placed in the southern area. Therefore, significant deformation of a liner is expected under the additional loading of waste. Given the almost certain nature of the differential settlement the risk of stress on a liner system that could tear if the differential settlement exceeded the elongation limits of the liner is considered high. On the basis that the existing leachate collection trench meets the required environmental outcomes, the addition of a “piggyback” was assessed as not providing any additional benefits and has reliability risk.
- The second risk is performance during seismic events. As described in Section 4.4.5, during large seismic events the landfill and the underlying estuarine sediments will be subject to deformation, settlement and lateral spreading. This could compromise any installed liner system and any remediation would be challenging once waste has been placed on the liner.
- The third risk is construction of a liner would separate the existing and new landfill gas systems. This would complicate the installation and operation of the LFG recovery systems making it harder for efficient recovery of landfill gas.

4.4.4 Construction Sequence

The placement of waste over the graded waste surface will be constructed as “Waste to Face” with the outer face of the waste being final cap. It is not proposed to continue constructing perimeter bunds to higher elevations. Drawing 12547621-01-C203 and C304 shows the construction sequence for both the western side of the landfill where the bund has been constructed previously and the southern side of the landfill adjacent to the main sewer where historically a bund was not constructed. The drawings show the proposed waste and cap placement as well as the proposed leachate collection trench which will be constructed through this section.

The waste placement will be in strips extending to full design level plus an allowance for settlement of the waste to the design level – in the order of 10% additional height. This is necessary to both create a final landfill surface at the appropriate level following settlement and to prevent the deeper fills becoming depressions over time, leading to ponding and increased rainfall infiltration to the landfill.

The waste placement will extend north to south from the existing landfill access road. Three stages of landfill filling are envisaged, as shown on Drawing 12547621-01-C304. This is broadly consistent with the Stantec (February 2023) *Green Island Landfill Development and Management Plan*.

Table 4 provides a summary of the anticipated volumes in each stage and the likely completion dates based on a landfill closure of late 2029. Capping of each stage will occur periodically dependent on the rate of void filling and completion of the stages or sections.

Table 4 Staged volumes and completion dates

Stage	Total volume[6] (m^3)	Landfill capacity[7] (m^3)	Estimated completion date[8] (year)	Cap area (m^2)
1	45,000	41,000	2023/2024	26,750
2	288,000	252,000	Mid 2025	38,000
3	425,000	377,000	Late 2026	50,500
Total	758,000	670,000	End of 2029	115,250

4.4.5 Landfill foundation and internal stability

4.4.5.1 Overview of Completed Study

A study has been undertaken to provide an assessment of the landfill stability under static, elevated ground water and seismic loads. The findings from the study are documented in *Green Island Landfill Closure – Liquefaction and Stability Assessment (GHD 2023D).* The scope of the study included:

- seismic hazard assessment – engagement of Prof. Mark Stirling to provide site specific consideration of the seismic hazard at the Landfill site through development of a Probabilistic Seismic Hazard Assessment (PSHA)- documented in the above report;
- liquefaction susceptibility assessment of the underlying natural soils using both historic and study specific geotechnical investigation data;
- slope stability and lateral spreading assessment of the preferred closure design for a series of cross sections with varying landfill structure. Analysis included static, elevated groundwater, Serviceability Limit State (SLS) and Ultimate Limit State (ULS) seismic events and post-earthquake conditions;
- estimation of the size of likely displacements if slopes are unstable; and
- Sludge area assessment – assessing the influence of areas of sludge within the landfill on stability.

4.4.5.2 Seismic Hazard

The *Green Island Landfill Closure – Liquefaction and Stability Assessment (GHD 2023D)* includes a seismic hazard assessment. The assessment identified several geological faults within the vicinity of the Green Island Landfill. No geological faults are located beneath the landfill footprint. The design ground motion for both SLS and ULS were derived as described in the following paragraph.

[6] Total volume is the volume from the existing surface reshaped for leachate drainage, as described in Section 4.1 and as shown on Drawing C204, and the proposed final design contours (top of cap post-settlement, as shown on Drawing C202). The volume is based on interim batters filled at 1(v) to 2.5(h) to the final landform level. The volume does not account for additional volume that may be achieved when settlement is considered, or provision site access.
[7] Landfill capacity is the total volume minus the volume of capping for the stage (0.35m topsoil and 0.6m of clay).
[8] Based on closure date of end of 2029 and a filing rate of 89,000 m^3 /annum.

Method 1 of the EGEPM1 provides estimates of hazard parameters based on the generic probabilistic seismic hazard analysis (PSHA). It is stated that the values provided in the module are applicable only for routine geotechnical engineering projects until a compressive update of the National Seismic hazard Model (NSHM) is completed. Given that the revised NSHM was not available at the commencement of this project, and the potential environmental impact if the site fails, Method 2 of the EGEPM1 (site-specific PSHA) was adopted. The site specific PSHA prepared by Professor Mark Stirling considered the nearby identified faults in the derivation of the hazard parameters. The PSHA report is included in Appendix C of the Geotechnical Report (GHD 2023D) report and the results are summarised in Section 4.3.5 of this report.

Since the PSHA was finalised the new National Seismic Hazard Model (NSHM) was announced by GNS in October 2022 (GNS Science 2022)which provides higher values for both SLS and ULS design seismic parameters than those derived from the Method 2 PSHA. While the NSHM has been developed to inform design standards and actions, at the time of reporting (February 2023) it is not a design standard and the direction from GNS is that it should not be used as such until further industry advice is available. However, an appropriately conservative approach has been adopted for this study and the revised higher values for Peak Ground Accelerations (PGA) for both SLS and ULS seismic design cases have been adopted in this design. This approach is consistent with industry advice to account for hazard uncertainty (Ministry of Business, Innovation, and Employment & New Zealand Geotechnical Society, 2021).

A summary of the seismic design inputs and design criteria are presented in Table 5.

Table 5 Seismic criteria

Item	Description	Reference
Design life	100 years	Client's requirement
Importance level	IL3	NZS1170.0 Table 3.2 (Standards Australia and Standards New Zealand, 2002)
Return period	SLS – 1/25 ULS – 1/2500	NZS1170.0 Table 3.3 (Standards Australia and Standards New Zealand, 2002)
Site subsoil class	Class C	Derived based on the available geological information
Design PGA and Magnitude	NSHM (used for analysis) SLS – 0.06g; 6.0 (M_w) ULS – 0.51g; 7.3 (M_w) PSHA SLS – 0.01g; 6.0 (M_w) ULS – 0.47g; 7.3 (M_w)	(GNS Science, 2022) (Stirling & Niroula, 2022)

4.4.5.3 Landfill Stability - Summary of Findings

The following section provides a summary of the findings from the geotechnical study.

Non-seismic Stability

- Based on the slope stability assessment, all analysed cross sections (see Figure 22) met the factor of safety [9](FoS) stability criteria for all static load cases (see Table 6 for stability criteria). This has assumed that leachate levels within the landfill will be generally controlled near to, or below 12 m RL and will not exceed 16 mRL within 40 m of the top edge of the bund. The proposed methods for controlling leachate levels are described in Section 4.3.2. The elevated ground water stability case has been modelled assuming that the leachate control methods do not temporarily function. The outcome is that if the leachate levels are above 16 mRL, the landfill stability does not reach the target factors of safety of 1.2.

[9] Factor of Safety in geotechnical engineering is the ratio of shear resistance to driving force along a potential failure surface. A FoS greater than 1.0 implies the available shear strength to resist slope failure is greater than the driving force to initiate failure. A FoS below 1.0 suggest the slope is unstable and some form of failure/slope movement is possible.

Liquefaction:

- Results from the liquefaction assessment indicate that majority of natural soils underlying the Green Island landfill are not liquefiable under both SLS and ULS seismic events. The exception is some layers in the UKEM geological unit which exhibit sand-like behaviour. This material is likely to undergo liquefaction under a ULS seismic event.
- Liquefaction induced free field settlement was estimated for both SLS and ULS seismic design cases. No free field settlement is anticipated under SLS. Up to 35 mm of free field settlement is likely under ULS. Differential settlements of drains and other infrastructure within the site may occur, particularly where the liquefied layers are located within the foundation zone of influence. Given that the reported free field settlement is reasonably small, the liquefaction impact on the landfill and other infrastructure at the site is likely to be minimal.

Lateral spreading:

For the seismic SLS load case scenario, only some of the cross sections met the FoS requirement. None of the sections met the FoS requirement under the design ULS seismic event. When the analysed seismic FoS was less than 1.0, displacement criteria apply and analysis was carried out based on the methodology in the NZ Bridge Manual. (Waka Kotahi NZ Transport Agency 2022).

Table 6 Slope stability load cases and acceptance criteria

Load case	Description	Target FoS
Static – long term groundwater level – local	Static case with long term groundwater and leachate levels modelled. Slip zones to be limited within the landfill.	≥1.5
Static – long term groundwater level – global	Static case with long term groundwater and leachate levels modelled. Slip zones extend to the toe leachate drain or to the nearest free face.	≥1.5
Static – elevated groundwater level – local	Static case with elevated groundwater and leachate levels modelled. Drained soil parameters to be adopted. Slip zones to be limited within the landfill.	≥1.2
Static – elevated groundwater level – global	Static case with elevated groundwater and leachate levels modelled. Slip zones to be extended to the leachate drain or to the nearest free face.	≥1.2
Seismic – SLS – non liquefied	Seismic SLS (0.06g; 6.0 M_w) case with long term groundwater and leachate levels modelled.	≥1.0 or displacement based criteria (<0.3 m displacement).
Seismic – ULS – non liquefied	Seismic ULS (0.51g; 7.3 M_w) case with long term groundwater and leachate levels modelled. This load case is only valid when liquefaction is not anticipated.	≥1.0 or displacement based criteria (<1.0 m displacement).
Post-earthquake – flow failure	Immediately post-earthquake – static case with long term groundwater and leachate levels modelled. This load case is only valid when liquefaction is anticipated.	≥1.05

Load case	Description	Target FoS
Seismic – ULS – liquefied	Seismic ULS (0.51g; 7.3 M_w) case with long term groundwater and leachate levels modelled. This load case is only valid when liquefaction and lateral spreading are anticipated and when the FoS for post-earthquake – flow failure is greater than 1.05.	≥1.0 or displacement based criteria (<1.0 m displacement).

Displacement Calculations

- During a SLS seismic event, the landfill is expected to remain stable with negligible deformation (c. 5mm).
- During an ULS seismic event, the landfill is likely to deform around the landfill perimeter. The degree of deformation is likely to be variable. The magnitude of the slope deformation is dependent on various factors with the major factors being founding ground conditions/susceptibility to liquefaction and the presence of internal bunding within the landfill. The geology of the site is somewhat variable due to the nature of the estuary sediments beneath the site. (Tonkin & Taylor Limited, 2021) (GHD Limited, 2022b). Where there is no liquefiable layer present the total seismic induced slope displacement is likely to be in an order of 35 mm to 325 mm. This applies to southwest and western areas of the landfill.
- In areas where liquefaction is expected to occur, under an ULS seismic event, lateral spreading is anticipated. Based on the adopted displacement assessment method, the total seismic induced slope displacement is likely to be in an order of 270 mm to 930 mm when a liquefiable layer is present. Depending on the continuity of the liquefiable layer, up to 200 m from the free face (i.e., Kaikorai Stream, sedimentation ponds, etc.), could experience the ground distortion as a result of lateral spreading.
- During an ULS equivalent seismic event, the northern, western and southwestern perimeters of the landfill are likely to move towards the nearest free face (i.e., Kaikorai Stream or sedimentation pond) as a result of lateral spreading, in an order of 270 mm to 930 mm. The exception is section 5 (see Figure 22). Minimal displacement is anticipated in this part of the landfill – primarily as the underlying marine sediments are thinner is this zone with mudstone close to the original ground surface beneath the waste.
- Where displacement occurs it is likely that multiple cracks, with some vertical and lateral movement, will form nearest riverbanks, toe of landfill and within the landfill and landfill cap. The lateral movement and cracking is expected to be generally parallel to the Kaikorai Stream/ nearest free face. Due to the predicted deformations, damage to the existing leachate collection trench is likely in some places. Such deformation could include failure of the pipe joints and between the pipe connections to the pump stations. Around the southern section of the landfill (Section 6 on Figure 22) where the landfill is immediately adjacent to the southern hill slopes the largest deformation is predicted (930 mm). The reasons for the larger predicted deformation are:
  - o The absence of soil bunding in this area – bunding has a beneficial impact on both the FoS and anticipated deformation;
  - o The full thickness of estuary sediments – these thin to the north along the south/southeast boundary and in the vicinity of Section 5; and
  - o The presence of potentially liquefiable materials.
- The Geotechnical Report (GHD 2023D) has established acceptable slope displacement limits of <0.3 m for a SLS event and <1.0 m for a ULS event based on reference criteria. The calculated slope displacements do not exceed these established criteria.

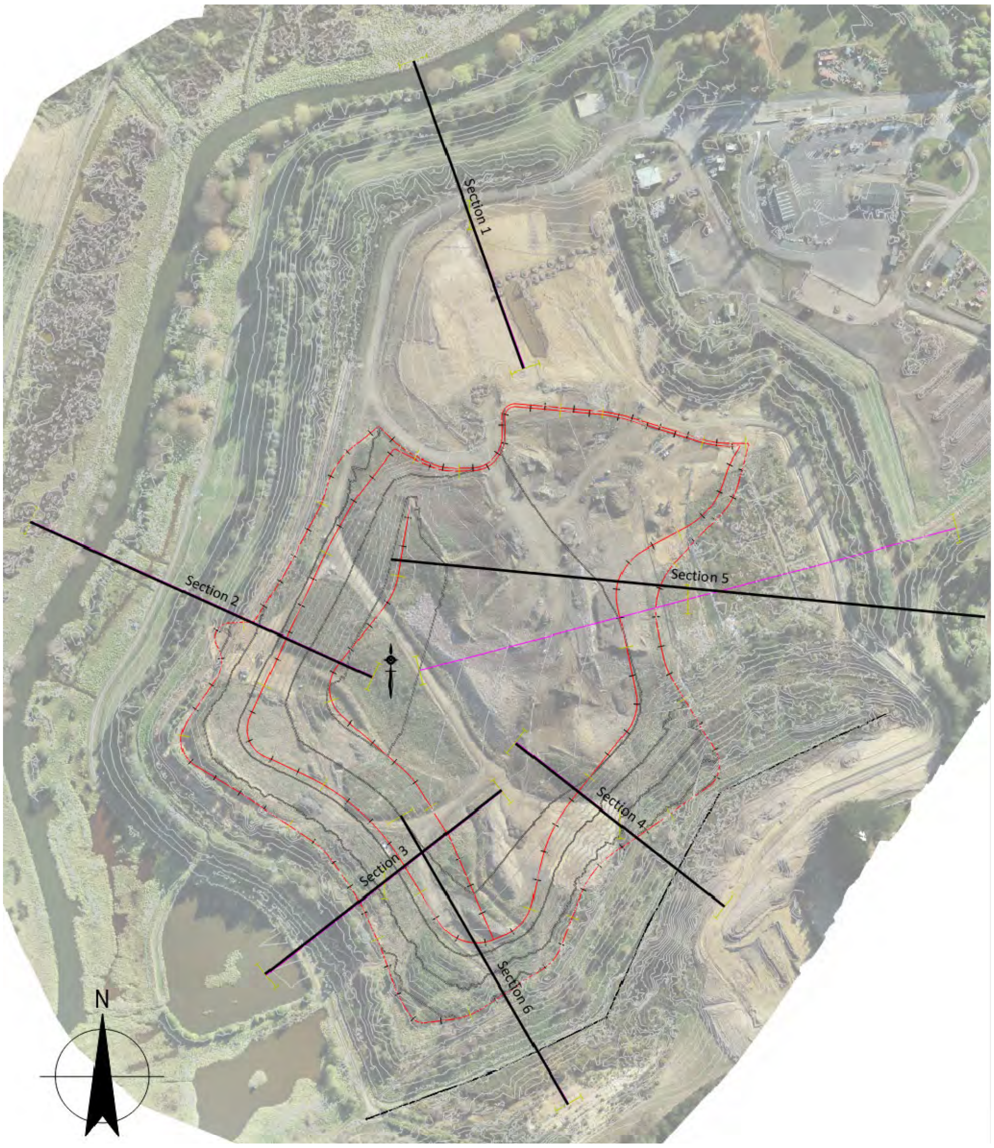

Figure 22 ***Slope Stability Analysis Cross Sections***

The assessment concluded that under the highest seismic loads contemplated (ULS – a 1 in 2,500 year event) some deformation of the landfill and associated infrastructure will occur. Under all other conditions (SLS and static loads) deformation is not anticipated or will be negligible (c.5mm). The level of predicted deformation (<1m) falls within the project's acceptance criteria. However local damage to infrastructure can be expected (e.g. pipe work and capping). The proposed approach to address this risk is to develop a response that ensures loss of waste and leachate to the environment is minimised as far as practicable given the size of a ULS type seismic event. The proposed response is set out in the following section of this report and focuses on:

- where practicable, strengthening the existing infrastructure to be more resilient to a seismic event; and
- planning a response to remediate the anticipated impacts in the post-seismic event period.

4.4.5.4 Planned Approach to Seismic Hazard

Two approaches to increasing the earthquake performance of the infrastructure in an ULS seismic event have been considered.

Approach 1 – Strengthen the Landfill to Resist Ground Movement

For conventional slope stability engineering a number of approaches are often adopted to increase the resistance of a slope to failure – effectively increasing the FoS above 1.0. These may include:

- Unloading the head of the slope;
- Reducing the slope angle;
- Strengthening the soils the slope is comprised of using products such as geotextiles;
- Loading the toe of the slope to increase the resistance to ground movement;
- Burying retaining/strengthening structures at the toe of the slope (i.e. stone columns);
- Improving the foundation soil strength; and/or
- A combination of the above.

For the Green Island landfill these approaches were not considered practicable as:

- They require significant disturbance of existing waste and or founding soils with associated environmental risks and impacts;
- The limited space at the toe of the embankment and the potential for disturbance/impacts on the existing estuary environment;
- Loss of existing mature screen planting that mitigates visual effects at present;
- Even with significant potential works the risk of slope instability during a ULS event remains along with associated deformation;
- The high associated costs; and
- They would result in loss of airspace for waste.

It is noted that the Preferred Closure Design for landfill closure includes raising the crest of the landfill by up to 8 m in the southern area. For most of the analysed sections this has minimal impact on the slope FoS and the anticipated displacement. For cross section 6 the impact is somewhat larger – as discussed in the above sections – with deformations of up to 930 mm anticipated. However, the anticipated displacement remains below the acceptance criteria for deformation. This section of the fill is assumed to be located on a full thickness of estuary sediments some of which are likely to liquefy. Whilst there is no stream free face in this part of the landfill, lateral spread is still likely to occur on the fill slopes that overlay the liquefiable soils. Furthermore, currently the leachate collection system has not been installed along this section. It is proposed to extend the leachate collection system through this section after consents are granted for continued operation of the landfill (see Section 4.4.2.2). Therefore, resilience to deformation can be factored into the design of the trench in this area. This will be considered during detail design of the leachate collection system extension

Approach 2 – Increase the resilience of key infrastructure and plan for post event remediation

If it is accepted that failure may occur during a ULS event along with some ground deformation then the key issue to address is the loss of contaminants to the environment. The leachate collection trench and associated infrastructure is at risk from disruption associated with any ground movement. The proposed response is two-fold: increase the resilience of the infrastructure now to the extent practicable; and plan for necessary remedial actions following an earthquake event.

The proposed remedial actions to be completed in advance of any event are set out below.

- It is likely that any ULS level event would rupture sections of the leachate collection system. The leachate pumps all discharge to a buried header pipe that connects to the GIWWTP sewer. Disruption of the header pipe at any location could significantly impact the operation of the system. Therefore, it is proposed to replace the buried pipe with a surface pipe. Providing an additional HDPE header pipe to the ground surface means that will be more flexible and resistant to ground movement and any failure can be quickly identified and addressed. Inclusion of some curves in the pipe will also allow it to accommodate some ground displacement and movement of the pipe.

- In a similar manner to the header pipe, an additional power supply cable for the pump stations will also be provided on the ground surface.

- Resilience assessment of each individual pump station electrical control box and associated equipment. As discussed in section 4.4.2, resilience improvements may include raising the various pieces of infrastructure to avoid inundation during flood events and protecting them (if necessary) from damage from floating debris.

A ULS event may also cause disruption to the leachate collection system and associated pipe work. As described in Section 3 of this report, while the leachate trench nearly encircles the entire landfill site it effectively operates as a discrete dewatering system associated with each of the pump stations. As part of the mitigation for any potential significant event, the landfill will maintain on site the following back up equipment:

- A diesel powered back-up generator to run the leachate pumps in the event power is lost to the landfill site;
- Additional header pipe and power cable in the event sections of the existing pipe and cable are damaged and require replacement; and
- Two spare submersible pumps.

As discussed in section 4.4.2, the existing and future LFG wells will be used as a method for controlling leachate levels within the landfill. Maintaining leachate levels at near 12 amsl and not exceeding 16 amsl has been assumed in the stability analysis presented in the *Green Island Landfill Stability Assessment (GHD 2023)* and assists in reducing the ground rupture under a ULS event. Design and detailing of this system and equipment will include consideration of robustness and resilience to a seismic event.

The proposed remedial actions to be completed after an event occurs are as follows:

- In the event of a section of leachate collection system being disrupted or a pump station damaged the leachate in the associated section of trench will collect in the existing drainage gravel medium associated with the trench. After any event the immediate approach to ensure leachate does not enter the environment will be to:
  - Use earthmoving equipment located on site to create a new sump (if required) into which leachate and groundwater can collect;
  - Deploy a temporary pump and connect to the surface header pipe and electrical supply;
  - Once the temporary system is installed, remediation of the system can be undertaken; and
  - Stockpile relevant materials on site including gravel for trench drainage materials for remedial works.

As noted in Section 3 of this report, the total leachate flows from the site are relatively modest (typically 1 to 2 L/s) and the flows to any given section of the trench are typically less than 1 litre/second. Therefore, it is likely temporary remediation can be implemented before leachate overwhelms the associated section of gravel filled trench and is lost to the environment. In the event leachate fills the associated section of gravel trench and begins to pond at the ground surface, temporary soils bunds will be constructed to retain leachate prior to a pump being deployed. The containment of leachate will be assisted by the proposal to raise the perimeter road berm by approximately one meter (see Section 4.3.2).

Once temporary works are in place the damaged sections of leachate trench will need addressing. Techniques such as CCTV inspections of the associated slotted pipe can be undertaken to identify where any ruptures have occurred and target areas for remediation.

It is likely that the landfill surface will undergo disruption, including any areas of completed capping. This may also disrupt the LFG collection system. Long term remedial works will be required to remediate capping and/or LFG extraction system issues. However, a priority will be to minimise odour issues by placing intermediate cover on any areas of exposed waste or cracks that may be pathways for both odours/gas escaping the landfill and for the ingress of stormwater. The site will maintain stockpiles of both intermediate cover and capping materials on site with a minimum of 5,000 m^3.

An emergency management area will be created within the landfill footprint that enables temporary short term storage of excavated and contaminated soils and waste material. This will allow:

- Good access for construction machinery etc; ;
- Material stockpiles; and

- Contaminated materials pad with run-off directed to leachate / sewer.

In the event that the GIWWTP is also temporarily out of action, accessible offtakes from the header pipe will be installed to allow leachate to be pumped to tankers and transported to alternative disposal locations. The nearest facility is the Tahuna WWTP. The pumped system would be operated in a manual mode to allow tanker disposal.

4.4.6 Landfill Gas Management

No material changes are proposed to the approach to LFG management at the landfill as outlined in section 3.5. The system will continue to be operated, maintained and expanded as required to ensure adequate management of LFG at the landfill. It is noted that a second mobile solar powered flare is intended to be acquired and utilised at the site to ensure offline wells can be appropriately managed.

4.4.7 Stormwater Management

Stormwater management and recommendations regarding additional mitigation measures are addressed in the *Surface Water Technical Report* (GHD 2023B).

5. Ancillary works

5.1 Operating hours, deliveries and weighbridge and traffic

The landfill currently operates 7 days per week and is closed only on certain public holidays.

The hours during which waste is accepted on site are slightly less than the operating hours to allow landfill staff to prepare and close off the tip face.

Table 8 Site Operating Hours

All Year Round	Operating Hours	Gate hours
Monday to Saturday	08:00 – 17:30	08:00 – 17:30
Sunday	09:00 – 17:30	09:00 – 17:30
Christmas Day, Easter Friday - Closed, Anzac Day Closed until 1pm	Closed	

The layout of the support facilities for Green Island Landfill are shown on Drawing 12547621-01-G101.

All incoming waste is assessed at the weigh bridge and directed to either the waste transfer station or to the tip face. Only pre-approved waste delivery operators with large trucks are permitted at the tip face. All domestic loads, or loads not pre-approved for disposal at the tip face, are directed to the waste transfer station where the waste is sorted and loaded on to the landfill operator's trucks to transfer to the tip face.

All recyclable materials are directed to the waste diversion facilities where metals, paper, cardboard and glass are deposited into skips for off-site re-cycling.

Waste is delivered to the Green Island landfill or the on-site waste transfer station from local residential and commercial sources in the Dunedin city and environs, and further afield from two Council operated waste transfer stations in Waikouaiti and Middlemarch

All waste deliveries are by road and most will exit SH1 at the Green Island SH1 Interchange, to access the 50 km/hr Brighton Road, entering the site at 9 Brighton Road that leads directly to the landfill weighbridge and kiosk. The intersection of Brighton Road and the main landfill access has existing right and left turning bays to allow turning traffic to pull off and avoid impeding through traffic.

All public roads and internal access to the weighbridge, waste transfer station and wheel wash are sealed.

All roads on the landfill are constructed with aggregates over a formed subgrade. This includes roads that provide access to the tip face and from the capping soils borrow area to the south of the landfill.

Vehicles exiting the landfill tip face or any unsealed areas have access to a wheelwash adjacent to and immediately prior to the exit weighbridge and kiosk. General vehicles that are dirty can use this wheelwash and do so on occasions (more so in wet weather). Vehicles disposing of hazardous wastes are required to use the wheelwash on departure from site. Any waste spills are immediately picked up and sealed site roads are swept with a suction street sweeper on occasion.

Compositing of green waste is also undertaken within the facilities area. The location of the operation is shown on Drawing 12547621-01-G101. In 2022 a total of approximately 1,300 tonnes of green waste was accepted at the landfill. The following process is followed:

- Incoming green waste is assessed at the weigh bridge. Any rejected materials are directed to the landfill. Only green waste is accepted – no food waste is processed.
- Deliveries are typically by households or small commercial/landscape operators.
- Green waste is stockpiled and periodically shredded and placed in windrows. These are turned and screened every few months until composting is complete.

- In recent years most of the generated compost has been used on site. Historically some has been sold off site.

5.2 Existing site facilities

The Green Island landfill has been operating since 1970 and with the current format since 1995. The landfill operation has all facilities required for the operation of the landfill. This includes:

- Sealed access roads
- Kiosk and weigh bridge
- Wheel wash
- Waste transfer station
- Dangerous goods store
- Recycling station
- Whiteware storage and refrigerator de-gassing (arranged as programmed de-gas contractor visits)
- Green waste processing and composting
- Community goods repurposing workshop and outlet shop (rummage shop)
- Equipment storage and maintenance sheds
- Landfill operators' offices, ablutions and staff quarters
- Landfill waste compactors and earthmoving equipment
- Landfill gas wells, transmission pipes and flares and engine (at the GIWWTP)
- Leachate collection system (in the form of perimeter interception trench and surface drainage), pump stations and conveyance pipework to the GIWWTP
- Surface water drainage systems including sediment control ponds
- Groundwater monitoring wells, and surface water monitoring stations
- Final cap over completed portion of the landfill

5.3 Odour and Dust Management

Odour management and recommendations regarding additional mitigation measures are addressed in the *Air Quality Report* (GHD 2023).

5.4 Fire Risk Management

Fire management and recommendations regarding additional mitigation measures are addressed in the *Fire Risk Management Report* which is attached in Appendix D.

6. Landfill construction, operation and closure

6.1 Landfill construction activities

The landfill operation provides for the following activities:

- Installation of horizontal leachate drainage to the soil base layer for the remaining areas of the landfill to be filled;
- Installation of leachate collection system and associated trench to the southern boundary of the landfill that abuts the trunk sewer;
- Remediation of the culvert between the eastern ponds;
- Installation of infrastructure for air operated leachate pumps to be used in landfill gas wells;
- Extension of aggregate roads as the tip face is extended;
- Installation of long-term stormwater infrastructure;
- Progressive placement of intermediate and final cap; and
- Grassing and maintenance of the landfill cap when completed.

6.2 Operational activities

Council is working towards diverting organic waste (whether collected by Council or other private operators) away from landfill, but cannot guarantee all putrescible waste being diverted either before or during the operating life of the landfill. For this reason, Council is seeking consent for the Landfill to continue to be a Class 1 Landfill suitable to accept municipal solid waste, and hazardous materials using the following Ministry for the Environment (MfE) 2004 Module 2 guidelines:

- Class A total concentration (TC) limits for wastes that generate leachate. If the waste fails this screening criteria then;
- Class B leachability limits from Module 2 are used for acceptance criteria where the TC is exceeded. .

Section 4.9.11 of the LDMP (2023) provides a description of how waste has historically been categorised and tested when it arrives at the landfill. The LDMP (2023) states that the use of Class A TC limits has been used since 2016 with the approval of ORC, as it has been a more useful indicator of material that may require TCLP testing for Class B limits. Historically, when waste has not met the Class B TC limit, the material when tested using the TCLP testing method resulted in the material concentrations being comfortably met most of the time. This is noted as creating unnecessary cost and time to Council with no significant change in the risk to the landfill operations or the receiving environment.

Cleanfill and contaminated soils meeting the TCLP limits stipulated in the consents will be comingled with other waste or may from time to time be deposited in the landfill. As previously described, daily cover will generally be the soils accepted at the landfill. Final cover soils must not be contaminated and these soils will be won from the borrow area to the south of the landfill.

The waste composition for waste disposed to Green Island landfill will be co-mingled in the body of the landfill but is expected to include (by weight)

- General Waste 46%
- Special/Hazardous Waste 4%
- Contaminated or non-contaminated soils 50%

Waste minimisation (for both putrescible (organic) waste and other non-putrescible streams) is expected to occur both during the operating life of Green Island landfill. This will include Council-led initiatives such as enhanced kerbside collection services and waste segregation at transfer stations, as well as non-Council initiatives driven by a broader response to increasing waste disposal levies and emissions trading scheme costs.

These initiatives will change both the quantity and composition of waste disposed at Green Island landfill, preserving void space and reducing LFG generation. However, in the short term, using the current waste composition provides a realistic view of future waste characteristics until such time as these initiatives are fully implemented.

Special waste is likely to include biosolids from Council Wastewater Treatment Plants. A review of Council's long-term biosolids strategy is being undertaken in 2021/22 with a view to reduce biosolids to landfill long term. However, the timing of any landfill diversion initiatives will not be known ahead of landfill consenting. Lime stabilisation of the majority of Council's WWTP biosolids will commence in 2023 and have the effect of reducing pathogen hazard, reducing odour and allowing these biosolids to be co-mingled and disposed of with the general waste at the tip face. Lime-treated materials will be mixed with general waste in the landfill. Regardless of the future management option chosen, the option of landfill disposal will need to remain available alongside other biosolids management strategies to ensure the resilience of Council's management of biosolids.

Incoming waste will be weighed at the weighbridge and trucked to the landfill tip area through the main landfill access road. Access roads on the landfill will be amended as the waste level rises.

Daily cover will be 150 mm of imported soils and other appropriate materials. Acceptable imported soils may include contaminated soils that are non-odorous and meet the waste TCLP acceptance criteria for landfill waste, or construction and demolition waste. Daily cover will be placed at the end of each working day such that there are no uncovered areas of waste while the site is not operating.

The operating extent of waste placement will be limited to around to 900 m^2 and a maximum of 1,200 m^2 and a depth not less than 1.0 m compacted depth of waste to be placed to avoid excessive ratio of cover soils to waste. Intermediate cover will be placed where waste will not be overlaid with fresh waste for more than three months. Vegetation cover on intermediate cover is encouraged.

The final cover soils will be low permeability clays stripped from the borrow area to the south of the landfill and placed in compacted layers not less than 300 mm thick. The final cover shall be graded to the stormwater system where possible to allow runoff of uncontaminated water and reduction in leachate generation. Intermediate cover will be stripped before placement of fresh waste.

Machinery likely to be used during Operational Phase I (excluding waste delivery trucks) includes:

- Excavators x 2;
- Bulldozer x 1;
- Reuse compactor x 1
- Water cart x 1; and
- 6 wheeler truck x 1.

6.3 Closure and aftercare activities

Closure activities include placing the final capping layer on completion, establishing any final landscaping and removing any facilities and infrastructure that are not required during the aftercare period, or modifying such infrastructure for the aftercare period.

Aftercare activities include maintenance of the cap and stormwater systems, management and maintenance of the leachate and LFG systems and ongoing site and environmental monitoring.

Prior to the end of the life of the landfill a Landfill Closure Plan will be prepared to detail the activities required for closure of the landfill and the aftercare period. In general terms, the following paragraphs set out the issues to be addressed.

The final capping system will be constructed progressively after filling in any area as the final waste level is reached. Cap construction will generally comprise:

- Excavating soils from the soil stockpiles and placing in layers on the landfill cap in accordance with the design;

- Placing an upper topsoil and/or growth layer from materials stockpiled on site;
- Constructing surface contour drains to manage stormwater falling on the landfill cap, including connections to the perimeter drainage systems;
- Establishing vegetation; and
- Removal of all facilities not required during the landfill aftercare period such as catch fences for windblown refuse.

Aftercare activities comprise:

- Ongoing operation and maintenance of the LFG extraction and treatment system;
- Ongoing operation and maintenance of the leachate collection, treatment and disposal system;
- Maintenance of the site stormwater systems;
- Maintenance of the landfill cap, including filling any areas that may have been subject to differential settlement, repair of any surface erosion and maintenance of vegetation as required;
- Maintenance of any remaining site infrastructure, including fences;
- Ongoing environmental monitoring as required by consents;
- Ongoing pest and bird management;
- Any reporting required by consents; and
- Responding to contingent events as set out in the Landfill Closure Plan.

6.4 Landfill operation and post-closure management

The Green Island landfill is an existing operation that is managed in accordance with the LDMP last updated and submitted to the ORC in February 2023. The operation of the landfill will continue in accordance with this management plan.

A copy of the latest LDMP is included with the resource consent application. In addition, a memorandum has been prepared documenting proposed revisions to the LDMP reflecting recommendations made in this Design Report and other technical documents.

6.5 Post Closure Use and management

The final cap proposed for the Green Island Landfill provides for 350 mm of growing media above the low permeability clay layer. This depth of growing media provides for the planting of shallow rooted plant species and grasses only, to prevent roots developing into the low permeability soils that would allow landfill gas to escape and rain to infiltrate the waste. Trees and deep rooted species will not be accepted.

If tree species are proposed as part of the landscape design of the end use, additional soils will be placed to the thicknesses recommended in the landscape planting design. This additional soil to be placed such that there is no ponding water upslope of the landfill surface.

The closed landfill will not be accessible by the public for a period of time after closure while LFG is being generated. This may be several decades. However, the areas surrounding the landfill may be used for recreational and other purposes.

The grassed surfaces will be regularly mown to reduce the fire hazard. Mown surfaces also allow for ongoing inspections of the cap and landfill gas monitoring. Vegetated areas will have regular weed management and plant trimming as required to promote healthy plant development.

The landfill will have continued monitoring of the groundwater, surface water and landfill gas monitoring systems until these discharges are deemed minimal. This is expected to continue for at least two decades and likely through to the end of any granted resource consent for the continued operation and closure of Green Island landfill.

6.6 Hazard Management

Section 6 of the LDMP (Feb 2023) sets out the approach to emergency management at the site and provides links to the appropriate sections of Waste Managements LOP. Key issues addressed are discussed below:

Fire: Section 6.2 of the LDMP outlines the possible causes and response to fires. Appendix D of this Design Report provides a fire risk study with additional recommendations regarding fire risk management. A summary is provided in Section 5.3. Proposed amendments to the LDMP are documented in a list of proposed updated to the LDMP appended to the AEE.

Hazardous Waste: Section 6.3 of the LDMP states that if an unidentified hazardous substance arrives at the landfill, the landfill reception booth has the right to turn it away providing there is no danger to anyone. If it appears dangerous to turn the substance away a risk assessment will be undertaken to decide the best cause of action. Where discharge and dispersion of a hazardous material has occurred, site staff will immediately secure the area and take measures to contain the material. Should any emergency arise with hazardous materials the site supervisor and Council shall be contacted without delay and further assistance sought from the Emergency Services if appropriate.

Landfill Gas: Section 6.4 of the LDMP notes that gas migration and concentration can present a danger to public health and safety. Gas can migrate considerable distances and remain a hazard. In the event of a gas fire, the area shall be cordoned off from the public and, if necessary, the landfill closed. In the event of gas concentration being detected, the area shall be cordoned off. The gas source shall be isolated and stopped. If needs be, the Fire Service shall be called.

Leachate: As described in earlier sections of this report, leachate management at the site is primarily through the perimeter leachate collection system. If the pump system fails or there is a break or blockage in the piped system and there is a possibility of leachate seeping to the surrounding environment, then the landfill operator shall contact Council immediately. If leachate break out occurs on the landfill bunds, then the landfill operator shall contact Council and shall agree steps to be taken to remedy the situ.

Section 4.3 of this Design Report sets out additional measure to be implemented to address the possible risk of failure of the leachate collection system during a large seismic event. Proposed associated amendments to the LDMP are documented in a list of proposed updated to the LDMP appended to the AEE.

Stormwater and Access: Sections 6.6 and 6.7 of the LDMP outline the response to flooding and extreme weather events and note that access issues will most likely be related to flood events. Measures to increase the resilience of the site to flood events are described in section 4.3 of this Design Report and proposed associated amendments to the LDMP are documented in a list of proposed updated to the LDMP appended to the AEE.

The LDMP notes that the landfill has potential to receive refuse seven days a week all year round and an all-weather road access has been established to ensure that vehicles can enter and leave the landfill safely. Planned non-access to the landfill area can be dealt with by either holding the refuse at transfer stations or by the refuse being diverted to other landfills. This is not an Emergency. Equally unplanned non-access for a short period (half a day) may cause issues but is unlikely to be termed an Emergency.

The situation that will lead to an Emergency is when there is a non-planned failure that will take more than 48 hours to restore and limits the ability of Council and its contractors to access the landfill for both refuse disposal and the ability to respond to a fire, or any other emergency.

The most likely cause of failure will be wide-spread flooding because of very extreme and sustained rainfall. This could create roading problems usually over a wide area and therefore put an abnormal demand on DCC and their contractors.

The important issue is that the regaining of access to the landfill is recognised as one of the areas that deserves a high priority.

The following actions are to be taken:

• Determine whether the access has been blocked by a failure on the landfill site or on a DCC public road.

• If possible (4-wheel drive or foot), inspect the landfill for other damage such as erosion to the landfill and check the stormwater, leachate system and stormwater ponds for stability, flooding etc. and determine if any of the other emergency situations have occurred and respond according to those emergency procedures.

• In the first instance, the landfill operator should be contacted (who will have some heavy construction equipment on site) to assess the situation.

• If the situation is beyond the capability of the landfill operator, or, if the landfill operator is not available then Council's Landfill Engineer should be contacted who will arrange for Council's Roading Network Maintenance Contractor to assist with the assessment and reinstatement of the access.

Earthquake: Section 6.11 of the LDMP indicates that the design of the landfill has taken into account the risk issues associated with earthquakes and the landfill geometry has been designed to withstand the design earthquake situation. Studies completed associated with this application have used revised seismic models and identified that some landfill damage is possible during extreme seismic events (see Section 4.0). Proposed LDMP amendments are documented in a list of proposed updated to the LDMP appended to the AEE.

7. References

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8. Limitations

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