Otago Regional Council

Reference: RM23.185

29 January 2024

Via email to: Rebecca.kindiak@al.nz;
cc. rachael.eaton@boffamiskell.co.nz; nick.elred@ghd.com; Maurice.dale@boffamiskell.co.nz; chris.henderson@dcc.govt.nz; and Michael.garbett@al.nz

Dear Rebecca,

Request for further information under section 92(1) of the Resource Management Act 1991 (the Act) – Consent Application Number RM23.185

Thank you for supplying further information in relation to RM23.185 – continued operation and expansion of Green Island Landfill. The information supplied has been reviewed by ORC, SLR Consulting and Jacobs Consulting who are providing a technical audit of the application. The information provided in the further information responses has led to additional (follow-up) questions by some technical auditors. To be able to make a full assessment of the application, I request the following information under section 92(1) of the Resource Management Act (the Act).

The technical audit memorandums are attached to this letter and provide further context for the questions below.

Landfill Design and Management

The relevant memorandum, which provides context for the below questions, has been prepared by James Elliott of SLR Consulting and is attached as Appendix 1 to this letter.

Leachate and Stormwater

(1) Please explain why remedial works to repair the leaking eastern culvert will only be undertaken *"within 12 months of consent being granted for ongoing operation, and if follow-up or additional works are required, then within three years"* when this is a known discharge of leachate into the environment?

(2) Please confirm the classification and fate of surface water runoff from intermediate cover areas.

(3) Please confirm whether the northern leachate pond is currently lined, and if not, whether lining of this pond is proposed as part of this application. Please provide justification for your answer.

(4) It is noted that in section 4.1.3 of the Surface Water Report that leachate may overflow from the northern leachate pond to perimeter swales and discharge to Kaikorai Stream. Please provide an assessment of the effects of the discharge of this untreated leachate to

the environment. In your answer, please specify what is meant by "prolonged high rainfall" in the context of the site.

(5) With respect to the combining of water categories on site, the Surface Water Report (Section 4.1) states that *"it is acceptable for … clean and sediment laden waters to be directed to the leachate system. The high proportion of catchments currently being directed to the leachate system without causing issues is proof of this".* It is unclear what "*without causing issues*" is referring to. Please define what an "issue" is in this context and provide the relevant evidence that an "issue" hasn't occurred.

(6) In light of the recommendations of this audit, please confirm whether any active extraction of leachate is proposed at the site. Please provide an explanation for your answer and, if active extraction is proposed, please describe the circumstances in which it will be undertaken and propose a condition(s) of consent reflecting this.

Landfill Gas

(7) Please specify the timing of the installation of new LFG extraction wells. Your answer should explain why you consider that this timing is appropriate.

(8) Please undertake a landfill gas risk assessment (LFGRA) for the site. This should address the points raised in Questions 2 and 6 of Mr Elliott's memorandum.

Capping and liner

(9) Please confirm whether or not a piggyback liner will be adopted at this site.

(10) Please provide the assessment (referenced in the Design Report) that indicates that a piggyback liner does not provide any additional benefits (compared with the existing leachate trench).

(11) Please provide additional information on the "physical and landscape constraints" that have resulted in the proposed 2% grade of the landfill cap.

(12) Was the impact of a composite lined cap modelled to assess if this would be more effective in reducing leachate head? In relation to the statement (response to s92 question 8 – see summary spreadsheet) *"the capping profile was subject to infiltration modelling which was deemed suitable"* please advise how and who deemed it to be suitable.

Landfill fire

(13) Please provide a Fire Risk Assessment either as a standalone document or as a revision of the existing Fire Management Plan. The Fire Risk Assessment should address the matters raised in Question 8 of Mr Elliott's memorandum.

Groundwater Quantity and Quality

The relevant memorandums, which provide context for the below questions, have been prepared by Tim Baker (groundwater quantity) and Anna Lukey (groundwater quality) of SLR Consulting and are attached as Appendices 2 and 3 to this letter. The questions raised in these memos are presented together because of their overlapping nature.

(14) Please explain whether the recently installed wells (RM22.511.01) will form any part of future groundwater quality monitoring programme. Please explain your answer.

(15) To provide a more accurate representation of groundwater direction/elevation at the site, please provide an updated analysis by surveying in all historic monitoring wells on site. If this analysis leads to any new information or conclusions, please also update any assessment that relies on the description of groundwater direction/elevation, including the Groundwater Conceptual Site Model.

(16) Please provide a revised description of the use of groundwater, including the sensitivity of the groundwater resource, in the area surrounding the landfill by taking into account the 49 bores identified through this s92 process. Please also provide an assessment of the potential adverse effects on these groundwater users.

(17) It is the recommendation of both Mr Baker and Ms Lukey that additional downgradient groundwater monitoring wells, including deeper wells, are required to determine the potential adverse effects on groundwater. These wells would enable additional information to be collected to support the nature of the groundwater beneath the site (elevation and direction of groundwater flows, presence or absence of an upward hydraulic gradient) and to support the subsequent conclusions drawn in the application as to the effectiveness of the leachate interception trench and the likelihood, and impacts of, any offsite migration of leachate. It is also the recommendation of Mr Elliott (Landfill Design) that further assessment be made as to the impacts of leachate on the surrounding environment in order to assess the adequacy of several landfill design elements. Taking into account your updated assessment of the sensitivity of the groundwater resource, and effects on any groundwater users, please provide a discussion that considers and evaluates the benefits of installing these additional monitoring wells now at the locations suggested in these memos, versus after consent is granted. Your answer should include a risk assessment, should address all of the concerns raised in Mr Baker and Ms Lukey's memos, should discuss how the proposed monitoring network meets the WasteMINZ guidelines,[1] and should include an outline of an adaptive groundwater management plan, if your analysis concludes that installation of the wells should be after granting of consent.

(18) Please provide an assessment of the impact that groundwater quality will have on the expected recreational land use and potential future receptors.

(19) Please confirm whether or not you agree to a consent condition requiring provision of a Groundwater Monitoring and Contingency Plan, which includes at least the below four items (listed in Mr Baker's memo):

- Details of all monitoring well construction (depth, elevation, material, logs)
- A sampling and analysis plan, including the sampling methodology to be followed.
- A plan for the installation of additional boundary wells, and new deep transect wells, including the proposed depths, construction, and timing of installation.
- Other items as addressed in the Groundwater Quality memo.

Surface Water Quality

The relevant memorandum, which provides context for the below questions, has been prepared by Claire Conwell of SLR Consulting and is attached as Appendix 4 to this letter. The primary issues outlined in this memo relate to the potential for migration of leachate beyond the leachate trench. Effects on surface water quality that are already occurring (and likely to continue occurring, based

[1] WasteMINZ Technical Guidelines for Disposal to Land (2022), revision 3, Appendix K

on the activities described in the application) are measurable. The uncertainty is the degree to which these effects can be attributed to the landfill versus other contaminant inputs into the catchment. It is considered that insufficient information has been provided to make this distinction.

Leachate

(20) The surface water report assumes that all the leachate generated on site is collected via the leachate trench and that no leachate is migrating into the surrounding surface water, on the basis that there is no evidence of leachate contaminants being present in surface water in exceedance of relevant guideline levels. As such, the application does not contain any assessment of the impacts of leachate on the surface water receiving environment. It is the opinion of Dr Conwell, as well as Mr Elliott, Mr Baker, and Ms Lukey, that a more comprehensive assessment is required into the overall weight of evidence approach to this assessment of effects. Therefore, please provide an assessment of the potential adverse effects of leachate on surface water in the receiving environment. This assessment should:

- Link to the answers provided in response to the questions in the landfill design (leachate) section and the groundwater section.
- Address all of the concerns raised in Dr Conwell's memo, and in particular should include a thorough assessment of cumulative effects on surface water, which takes into account contamination attributable to the landfill, any measurable or known contribution of contaminants from the upstream catchment, and discussion on the way in which contribution of contaminants from the landfill may be distinguished from other inputs including any uncertainty in this assessment.
- Take into account the results of the ecotoxicological monitoring that is currently being undertaken and include copies of analytical results and interpretation of results.

Stormwater

(21) Please provide the results for any surface water quality sampling in which samples were tested for dissolved zinc.

(22) Please undertake further statistical analysis, as described in question 8 of Dr Conwell's memo, of the available water quality data for the purpose of providing further evidence to support the conclusions as to adverse effects made in section 5.1 of the Surface Water Report.

Conditions

(23) Please confirm whether or not you agree to a consent condition requiring provision of an adaptive management plan for the surface water monitoring programme that includes at a minimum all of the elements listed in Question 3 of Dr Conwell's memo.

Ecology

The relevant memorandum, which provides context for the below questions, has been prepared by Elizabeth Morrison of SLR Consulting and is attached as Appendix 5 to this letter.

(24) Taking into account your answers to the questions in the landfill design, groundwater, and surface water sections, and the results from the additional ecotoxicological investigations currently being undertaken, please provide an updated assessment of effects on aquatic ecology. Your answer should include a thorough assessment of the

potential cumulative effects and should link to your responses to similar questions asked in other sections above.

(25) In light of Cawthron's recommendations for ecotoxicology investigations, Ms Morrison has recommended that further ecotoxicology investigations are implemented as part of an adaptive management plan, in the event that results from other monitoring, such as groundwater, surface water or ecological monitoring, indicate that more detailed investigations are required. As such, please propose conditions of consent that set out the circumstances in which ecotoxicological investigations would be undertaken, how this relates to/aligns with any proposed monitoring for groundwater or surface water and how this information would be used to inform other monitoring or adaptive management processes.

Landscape and Visual Assessment

The relevant memorandum, which provides context for the below questions, has been prepared by Rachael Annan of SLR Consulting and is attached as Appendix 6 to this letter.

(26) Please confirm whether or not you agree to adopt the recommendation in Ms Annan's memo (end of page 5) for an independent technical review of the following aspects of the (final) Vegetation Management and Restoration Plan:

- The effectiveness of the management plan in relation to ecological restoration and habitat health;
- Alignment with mana whenua outcomes sought derived from partnership discussions and the CIA.
- An effective approach to landscape character and visual amenity outcomes for surrounding residents (which draws on community consultation), including review of planting plans and schedules; and
- Planting implementation shall be signed off by a landscape architect, or other suitably qualified expert, with subsequent monitoring of vegetation health (and any replacement required). It is anticipated that an arborist report will be provided (and inform the Vegetation Management and Restoration Plan) regarding the health of existing vegetation.

Air Quality

The relevant memorandum, which provides context for the below questions, has been prepared by Tracy Freeman of Jacobs New Zealand Ltd and is attached as Appendix 7 to this letter.

(27) Please confirm whether or not you agree to adopt the consent conditions as proposed in Ms Freeman's memo.

(28) Please provide an updated assessment of odour effects which specifically takes into account expected odour emissions from the Organics Receivals Building (ORB, application RM23.571) on the site.

- Note that the ORB application was processed on the basis that organics processing was an activity captured by the existing landfill consents and their replacements (being this application RM23.185). Therefore, I consider that the odour effects of the ORB must be addressed here.

(29) Please explain whether the flare at the GIWWTP can be regarded as a principal flare for the purpose of the NES-AQ Regulation 27, and whether the proposed new flare complies with the design requirements in Regulation 27.

(30) Please provide a tracked changes version of the Air Quality Report.

Geotechnical

The relevant memorandum has been prepared by Matthew Adamson of SLR Consulting and is attached as Appendix 8 to this letter. There are no additional questions.

Flood Hazards

The relevant memorandum has been prepared by Tim Baker of SLR Consulting and is attached as Appendix 2 to this letter. There are no additional questions.

Your application remains on hold under section 88C of the Act until the requested information has been received. Unless I hear otherwise from you, I will continue to do some minor work on your application so that we can progress it once the application comes 'off hold'.

Please respond within 15 working days from the date of this letter (**20 February 2024**) with one of the following:

1. The information requested above; or
2. Written advice that you agree to provide the information, and the date by which you intend to provide it; or
3. Written advice that you refuse to provide the requested information.

If the information you provide raises more questions, your application will remain on hold until sufficient information has been provided to enable processing to continue.

If you have any further queries, please contact me on 027 278 7523 or shay.mcdonald@orc.govt.nz.

Information on the current processing costs for your application is included in the email relating to this letter.

Yours sincerely

Shay McDonald
Senior Consents Planner

Appendices:
Appendix 1. RM23.185 – Green Island Landfill Design and Management Technical Review
Appendix 2. RM23.185 – Green Island Landfill Groundwater Quantity & Flood Hazard Technical Review
Appendix 3. RM23.185 – Green Island Landfill Groundwater Quality Technical Review
Appendix 4. RM23.185 – Green Island Landfill Surface Water Quality Technical Review

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Appendix 5. RM23.185 – Green Island Landfill Ecology Technical Review
Appendix 6. RM23.185 – Green Island Landfill Landscape Assessment, Technical Review
Appendix 7. RM23.185 – Dunedin City Council – Technical Audit Responses; Air Discharges
Appendix 8. RM23.185 – Green Island Landfill Geotechnical Technical Review

Otago Regional Council

Appendix 1

RM23.185 – Green Island Landfill Design and Management Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	James Elliott
Company:	Otago Regional Council	**SLR Consulting NZ**	
cc:	Samantha Iles (SLR)	**Date:**	5 December 2023
		Project No.	13556

RE: RM23.185 - Green Island Landfill Design and Management Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including subsequent attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant, or DCC) for the operation, expansion and closure of the Green Island Landfill (referred to herein as the site).

The applicant is proposing to extend the life of the site allow acceptance of waste until sometime between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

SLR has prepared a number of Technical Memorandums in relation to the application. The Technical memorandum herein relates to Landfill Design and Management.

2.0 Scope of Review

2.1 Items Considered in this Review

The review considers landfill design and management only, as detailed in the documents listed later in this section, and as relevant to the questions posed by ORC (refer section 3.0). The design and management aspects considered as part of this review are summarised as;

- Proposed landfill cap.
- Leachate management.
- Landfill gas (LFG) management.
- Stormwater management.
- Landfill fires.

2.2 Key Documents Reviewed

The following key documents, which were submitted as part of the application, have been reviewed in the development of this technical review:

- Boffa Miskell Limited, *Green Island Landfill Closure, Assessment of Environmental Effects*, Dated March 2023. Referred to herein as the AEE.
- GHD Limited, *Waste Futures – Green Island Landfill Closure Design Report*, Dated 29 September 2023. Referred to herein as the Design Report.

- GHD Limited, *Waste Futures – Green Island Landfill Closure Surface Water Report*, Dated 7 March 2023. Referred to herein as the SW Report.
- Stantec New Zealand, *Green Island Landfill, Development and Management Plan*, Dated September 2023. Referred to herein as the LDMP.
- Tonkin and Taylor Limited, *Landfill Gas Masterplan, Green Island Landfill,* Dated September 2023. Referred to herein as the LFG Masterplan.
- Tonkin and Taylor Limited, *Green Island Landfill, LFG Management Letter Report*, Dated 21 September 2023. Referred to herein as the LFG Letter.
- GHD Limited, *Fire Management Plan, Green Island Landfill*, Dated 13 March 2023. Referred to herein as the FMP.

2.3 Scope

The scope of this review included;

- Review of the questions provided by ORC as detailed in Section 3.0 of this memorandum.
- Review of sections of the documents listed in Section 2.2 considered relevant to the questions posed by ORC (refer Section 3.0) for landfill design and landfill management.
- Considered the relevant landfill design and management aspects against the requirements of WasteMINZ 2018[1] (referred to herein as the WasteMinz Guidelines).
- Submitted a Section 92 request for Information to the applicant and reviewed associated responses.
- Prepared this technical memorandum.

2.4 Exclusions and Assumptions

The following assumptions and exclusions apply to the information provided herein.

- Discussion with respect to potential adverse human health and environmental effects associated with water and air discharges from the landfill are covered by other technical memorandums. Other technical memorandums should be read in conjunction with this technical memorandum.
- The entire contents of the documents listed in Section 2.2 were not necessarily reviewed. The review focussed on the areas described in Section 2.1.
- A detailed analysis of LFG modelling, LFG pipe sizing, HELP modelling etc. was not undertaken, and models were not rerun as part of this review.
- No site inspection was undertaken as part of this review. However, photos of the site were provided, and a SLR colleague inspected the site and provided verbal details of key site information.
- The design elements considered in this review are considered to be conceptual designs at this stage and are subject to detailed design at a later date.

[1] As of September 2023, the guideline document has been updated and reissued. However, given that the updates relate to waste acceptance criteria for landfills, and not landfill design matters, reference to the 2018 document is acceptable.

- The landfill has been operating for almost 30 years, and pre dates current landfill guidance including the WasteMINZ Guidelines. Some of the existing engineering controls do not conform to current guidance e.g. there is no engineered liner or leachate collection system on the landfill floor. This is a significant constraint for older landfills, including the site.

3.0 Response

3.1 General Matters

3.1.1 Question 1 - Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions?

The technical information provided in support of the application is generally robust, and clear about uncertainties and assumptions. However there are some items that require further clarification. A summary of these items is provided in the following, with a reference to other relevant sections of this technical memorandum where further information is provided.

- The classification and fate of runoff from the intermediate cap (referred to herein as intermediate cover). Refer response to Question 5 (Section 3.2.2.2, bullet point 1) for more details.
- The frequency and associated impacts to the environment of leachate overflowing from the northern leachate pond in prolonged rainfall events. Refer to response to Question 5 (Section 3.2.2.3, bullet point 6) for more details.
- The lining of the northern leachate pond. Refer to response to Question 5 (Section 3.2.2.3, bullet point 3) for more details.
- The exact timing of LFG well installation for the LFG capture system. Refer to response to Question 6 (Section 3.2.3, bullet point 6) for more details.
- The potential use of a piggyback liner. Refer to response to Question 7 (Section 3.2.4.1) for more details.
- Potential impacts from subsurface landfill migration. Refer response to Question 2 (Section 3.1.2).

3.1.2 Question 2 - Are there any other matters that appear relevant to you that have not been included? Or is additional information needed?

3.1.2.1 Landfill Gas Assessment

There is limited information provided in relation to the assessment of potential environmental impacts from landfill gas in the subsurface. There appears to be potential for LFG to migrate laterally from the waste mass through the surrounding geology and buried services, particularly given the low volumes of LFG being captured by the LFG collection system (refer response to Question 6), and the absence of a landfill base or sidewall liner.

There is some information provided in the AEE regarding LFG in the subsurface, including;

- Three LFG bores are located at or near the Site to enable monitoring of subsurface LFG.
- Periodic LFG monitoring of three LFG bores is undertaken.

A maximum carbon dioxide concentration of 10.9% has been recorded from LFG bore monitoring. There are no CO_2 trigger values included in the WasteMINZ Guidelines. The AEE states that the recorded "*concentrations* (of) *CO_2 are not considered to pose a risk*".

Based on the limited information provided on subsurface LFG, the following comments are made;

- A subsurface CO_2 concentration of 10.9% may not be insignificant, and could be an indicator of migration of LFG away from the waste mass through preferential pathways like the natural geology and buried services (e.g. leachate interception trench (LIT)).
- In the absence of trigger levels for CO_2 provided by the WasteMINZ Guidelines, values from other jurisdictions could be consulted to enable an assessment of CO_2. It is noted that other nearby jurisdictions overseas have action/trigger values of 1.5% CO_2.
- Statements about the risk from LFG should be based on a site specific LFG risk assessment (LFGRA), which should in turn be based on a robust conceptual site model, and associated data set.

Based on the above comments, it is recommended that a LFGRA is undertaken for the Site, or if a LFGRA has already been completed, this is provided for review. Refer also to the response to Question 6 which is related to LFG management at the site.

3.1.2.2 Assessment of Potential Leachate Impacts

A key input to the design elements of the application is that leachate is not impacting the surrounding environment. Whilst review of leachate impacts is outside the scope of this review, further assessment has been recommended in other technical memorandums (prepared by SLR) related to groundwater quality and surface water quality. The outcomes of further assessment could influence the comments provided herein.

3.1.3 Question 3 - If granted, are there any specific conditions that you recommend should be included in the consent?

Based on the information provided to date, and considering the comments provided herein, it is recommended that specific conditions are included. A summary of the key items that should be addressed by specific conditions are provided in the following. Note that the below are not intended to be the actual conditions. Further consideration, including review of any additional information that is provided after issue of this technical memorandum, would be required before the exact conditions are confirmed.

- The need for further assessment of potential impacts, particularly from leachate, to the surrounding environment from the landfill, to help inform the need for, if any, additional management measures such as active leachate extraction (refer Section 3.2.2.3 for more details) and enhancements to the landfill cap profile and grades (refer Section 3.2.4.2 for more details).
- Improvements to be made to leachate management, such as active leachate extraction from the existing LFG wells, in an effort to reduce leachate head within the waste mass (refer Section 3.2.2.3 for more details).
- A site specific LFGRA based on a robust conceptual site model and data set to assess potential impacts from LFG on nearby sensitive receptors (refer Section 3.1.2.1 for more details).

- Implementation and timing, and where required additional details/detailed design, of proposed remedial activities, which include construction of the final cap in specific areas, installation of additional LFG wells and potentially LFG flares/engines, extension of the LIT, and eastern culvert works where leachate seepage has previously occurred.
- Surface water management, including the need to reduce the mixing of different water types; and to be clear about the fate of all water types, including intermediate cover runoff (refer Section 3.2.2.2 for more details).
- Details regarding assessment of fire risk, and associated additional mitigation, monitoring and management requirements and reviews as detailed in section 3.2.5.

3.2 Landfill Design and Management

3.2.1 Question 4 - Is the landfill design and management fit for purpose with regards to the Technical Guidelines for Disposal to Land (WasteMINZ, 2018)?

The landfill has been operating for almost 30 years, and pre-dates current landfill guidance including the WasteMINZ Guidelines. Some of the existing engineering controls do not conform to current guidance e.g. there is no engineered liner or leachate collection system on the landfill floor. This is a significant constraint for older landfills, including the site.

In considering if the landfill design and management was fit for purpose in relation to the WasteMINZ Guidelines, the application documents were compared to the requirements, recommendations and objectives of the WasteMINZ Guidelines. Notwithstanding the legacy of no liner or leachate collection system on the landfill floor, the proposed landfill design and management is generally in line with requirements specified in the WasteMINZ Guidelines, with the following exceptions;

- Section 5.6 of the WasteMINZ Guidelines includes objectives of surface water and stormwater management. One of these objectives is to "*maintain separation of stormwater from waste/leachate*". Based on the application documents, leachate is combined with runoff from areas that aren't considered leachate, and also leachate will overflow from the northern leachate pond during prolonged rainfall events. Both of these scenarios result in leachate combining with stormwater, which does not align with the aforementioned objective. Refer response to Question 5 for more detail.
- The landfill does not include a base liner and leachate collection system. Due to the age of the landfill, and the guidance at the time, this is not considered to contravene the WasteMINZ Guidelines relevant to this review. However the leachate head in the landfill is over 10 m in some parts. This is a considerable head of leachate and is not in line with the WasteMINZ Guidelines objective to minimise leachate head. Refer response to Question 5 for more details.
- Further to the above, the WasteMINZ Guidelines states that leachate needs to be controlled to influence the biodegradation of the waste and consequently the generation of landfill gas. The elevated leachate head is expected to be inhibiting the performance of the LFG collection system and is therefore not considered to meet the requirements of the WasteMINZ Guidelines.
- The proposed grades and material thickness' of the landfill cap profile are not considered to meet the recommendations of the WasteMINZ Guidelines. Refer response to Question 7 for more detail.

The aforementioned items do not strictly mean that changes are required to landfill design and management. However further assessment is considered necessary to demonstrate the suitability of the proposed design and management elements that don't conform to the WasteMINZ Guidelines. This is detailed further in subsequent responses.

3.2.2 Question 5 - Is the leachate and stormwater management appropriate for the site, including the changes proposed by the Applicant as part of this application?

3.2.2.1 Background

The water management systems at the landfill are described in various reports, including the SW Report. Surface water runoff is split into three category types as follows;

- *Clean: Non-contaminated or potentially low concentrations of sediment. Can flow directly to the natural environment.* The AEE states that currently the "clean" runoff flows either to Kaikorai Stream, via one or more of either perimeter drains, open swales, culverts and existing sedimentation ponds.
- *Stormwater: Non-contaminated water, but potentially containing elevated sediment concentrations. Requires directing to a sedimentation pond for treatment prior to discharging to the natural environment*. Stormwater runoff goes to a sedimentation pond, prior to discharge to the natural environment.
- *Leachate: Contaminated stormwater or has the potential to be contaminated from contact with waste or leachate. This contaminated water must be directed to a leachate pond, or a leachate drain or channel/swale which then goes to a leachate pump station, hence is pumped to the Green Island Waste Water Treatment Plant (GIWTTP).* Leachate will be allowed to either infiltrate into the waste, or it will be collected and diverted to a leachate drain or channel which is served by a leachate pump station.

Further to the type of water described above, the landfill is divided into specific surface water catchment areas. Each catchment is intended to only include one of the three types of water defined for the site (i.e. clean, stormwater, leachate). However, some of the catchment areas are combined before being directed to the relevant location. This includes combining clean water with stormwater and or leachate.

The AEE also states that "*if necessary, it is acceptable for cleaner waters to either flow to, or be directed to a sedimentation pond, or clean and sediment laden water to be directed to the leachate collection system*".

The landfill contains two sedimentation ponds, one in the east, and one in the west.

There is one leachate pond (Northern Leachate Pond) used to store runoff that is considered Leachate. The landfill includes a leachate interception trench around much of the landfill boundary (which also accepts water from the Northern Leachate Pond), which directs leachate to the Green Island Wastewater Treatment Plant (GIWWTP).

Horizontal leachate collection drains are proposed to be installed in new areas of waste.

The three categories of water described in the AEE, and the proposed management measures for each category, in principal, are generally considered to be appropriate. However the following comments are made in relation to stormwater and leachate management.

3.2.2.2 Stormwater Management

In relation to stormwater management, the following comments are made;

- Runoff from intermediate cover areas is not clearly defined in the documentation. The SW Report indicates that areas of intermediate cover are treated as leachate. However, the LDMP indicates that intermediate cover runoff can be considered as sediment laden water (which is interpreted to mean “stormwater”) that can be discharged to the environment via a sedimentation pond. The Design Report indicates that runoff from some areas of intermediate cover will be treated as leachate, and from other areas will be treated as stormwater. The classification, and fate, of runoff from intermediate cover areas should be confirmed and be made consistent across all application documents.
- Some of the catchment areas include a combination of water categories. However, effort should be made to avoid mixing higher quality water with lower quality (as described in Section 5.6 of the WasteMINZ Guidelines). Mixing various water types increases the volume of water needing management via the sedimentation ponds and/or GIWWTP. This is particularly evident in the Catchments 2, 2a and 5a which are from areas of final capping but are directed to the northern leachate pond and treated as leachate. Similarly for catchment 4a, 6a, 7a, 7b and 10, where potentially sediment laden waters (i.e. stormwater) are treated as leachate. It is noted that there are constraints to keeping water types separated (e.g. where “Clean” water flows downwards onto a “Stormwater” area), which may limit the possibility of separating all water types.
- It is acknowledged that where water categories are combined, the water is considered to be the lower quality water of the two categories being combined (i.e. if clean and leachate are combined, the water will be treated as leachate), which is also considered appropriate if combining waters is unavoidable.
- Further to the above, it is noted that the SW Report (Section 4.1) states that “*it is acceptable for clean and sediment laden waters to be directed to the leachate system. The high proportion of catchments currently being directed to the leachate system without causing issues is proof of this*”. It is unclear what *“without causing issues”* is referring to. This statement should be supported with definition of what an *“issue”* is and provide the relevant evidence that an *“issue”* hasn’t occurred.
- There is reference to runoff being allowed to soak into waste mass. Whilst this is acceptable for rainfall in the active tipping area, it should not apply to runoff from areas up stream of the active tipping face. Care needs to be taken to ensure that water does not pool on the landfill, where it could generate odours or become a hindrance to landfill operations. Given the significant head in the landfill, where possible, water considered to be leachate should be directed to the GIWWTP via the quickest route, rather than be allowed to seep into the waste mass.
- It is noted in Section 4.1.3 of the SW Report, *“in prolonged high rainfall events water from this pond (northern leachate pond) will overflow to perimeter swales and discharge to Kaikorai Stream*”. It is not clear what a prolonged high rainfall event is, however, leachate should not be allowed to discharge to the environment without treatment. This needs further assessment in relation to the potential frequency of leachate overflow and associated potential impacts to the surrounding environment.

- The discharge of water from the final vegetated cap direct to the environment is considered acceptable, provided the cap is sufficiently vegetated to prevent both erosion of the cap, and sediment laden water from discharging directly to the environment.

3.2.2.3 Leachate Management

In relation to leachate management, the following comments are made;

- Some parts of the landfill have leachate head of 10 m or more. It is acknowledged that due to the age of the landfill, and the guidance at the time, a base liner and leachate collection system were not incorporated into the landfill design. Therefore it is difficult to manage leachate levels in the waste mass, and to address the WasteMINZ Guidelines objective to "*minimise head of leachate above the liner*". However, a 10 m leachate head is considered to be significant, and is not in line with WasteMINZ Guidelines. There is no active extraction of leachate at the site. The Design Report states that active extraction from the existing LFG wells is an option for leachate removal. It is recommended that leachate is actively pumped from the waste mass, on a trial basis as a minimum, to assess if extraction can reduce the leachate head in the cells, and in turn reduce the potential for leachate migration offsite to occur. A reduction in leachate head at the site would also be expected to improve the LFG collection rates (refer response to Question 6). Active extraction, even a trial, should be based on a thorough understanding of the landfill, and take into account any effects the extraction may have at the site, such as fate of removed leachate, potential for increased LFG generation, possible rebound of leachate after extraction etc.
- Further to the above, the Design Report refers to extracted leachate being transferred to the perimeter leachate collection system and ultimately the GIWWTP. It is recommended that any leachate actively extracted from the landfill is transported to the GIWWTP via enclosed drains that do not allow for potential loss of leachate to the environment such as in the LIT or surface drains.
- The lining of the northern leachate pond is not entirely clear. An unlined, or poorly lined pond has the potential to allow migration of leachate into the underlying geology. It is noted that the landfill itself is not lined, and that the northern leachate pond is within the LIT catchment area. Therefore if leachate did leak through the northern pond base it may not necessarily have any noticeable, or significant impact on the environment. However, the suitability of the liner should be considered in relation to potential for leachate to impact the environment.
- The proposed horizontal leachate collection drains in the waste mass, where waste will be placed atop the existing waste mass, are considered appropriate and should be used wherever possible to help improve leachate removal and therefore reduce leachate head within the waste mass.
- Remedial measures to address the leachate seepage from the eastern culvert should be implemented at the earliest opportunity to reduce potential for more leachate seepage from the waste mass.
- The LIT allows for mixing of leachate and groundwater within the trench. This increases the volume of leachate. Similar to the comments made about the stormwater management system, the mixing of leachate with other water types, including groundwater, should be avoided.

However, the LIT appears to provide a preferred flow path for leachate where it can be extracted and sent to the GIWWTP. This is expected to reduce the volume of leachate entering the water table, which would be expected to reduce the impact of leachate on the surrounding environment. Therefore, whilst the mixing of leachate and groundwater should be avoided, the use of the LIT to reduce potential impact of leachate on the surrounding environment is considered to be acceptable. This is of particular importance given the absence of a liner and leachate collection system at the base of the landfill.

Furthermore, the extension of the LIT as proposed in the application is considered appropriate to further reduce the potential for leachate migration offsite. The extension of the LIT should be subject to detailed design, in particular noting that the drawings provided in the application show;

a. A direct connection between leachate and groundwater.
b. The materials to be placed on either side of the trench following excavation are not defined.
c. The horizontal component of the trench extends into existing waste.
d. The trench is founded in the natural underlying geology.
e. The existing trench is understood to include a High-density Polyethylene (HDPE) layer, and its unclear if this will be incorporated into the LIT extension.

- Regardless of the above, further assessment of the potential for leachate to impact groundwater and surface water should be undertaken to assess the effectiveness of the LIT in preventing impacts to the environment, and to inform if additional measures to manage leachate are required.

3.2.3 Question 6 - Is the landfill gas management appropriate for the site, including the changes proposed by the Applicant as part of this application?

The LFG Masterplan provides details of expected LFG generation and collection at the landfill based on site specific modelling. The forecast LFG production rate peaks at 903 m^3/hr , and the forecast LFG collection rate is 80% of the generation rate, which equates to 722 m^3/hr.

The existing landfill gas management system, as summarised in the LFG Masterplan is as follows;

- A total of 38 vertical LFG extraction wells, with approximate spacing of 40 m.
- LFG collection and header pipework and ring main for transmission of LFG
- One LFG engine with 350 m^3/hr capacity, and one candlestick LFG flare with 450 m^3/hr capacity

The LFG Masterplan details proposed improvements to the LFG management system which are summarised as follows;

- Extension of existing LFG management system (including wells, lines, and ring main) across the proposed future filling area.
- "*Discussion of replacing the existing backup flare with a new enclosed flare*", and "*other …options could be considered for the site* (which)*..could include installation of additional electricity generators*".

In principle the proposed LFG management system, once installed and on the assumption it performs as per the design expectations, would appear to be appropriate for the longer term management of LFG at the landfill. However, I have some reservations about the LFG management system, particularly in the period before the entire system is installed, which are summarised in the following.

- The leachate level in the waste mass is more than 10 m above the base of the landfill in some areas. Leachate build up within the waste mass would be inhibiting the generation of LFG, and would also be expected to be reducing the effectiveness of LFG wells where leachate is present at a level above the base of the LFG well. A reduction of leachate levels (refer response to Question 5) would be expected to increase LFG generation rates, and may improve LFG collection efficiency also.
- The modelled LFG generation rates and associated modelled LFG capture rates presented in the LFG Masterplan are much higher than recent LFG capture rates. For example, in 2022, a total of 2M m^3 LFG was captured, which equates to about 228 m^3/hr. This is compared to modelled 80% and 50% capture rates of 646 m^3/hr and 404 m^3/hr respectively. This indicates the system is performing poorly. It is noted that the modelled rates are based on a lower leachate level, than what is present at the site. This may result in LFG generation estimates being overestimated. Improvements to leachate level management (refer response to Question 5) may improve LFG collection rates. The LFG Masterplan offers some reasoning for the discrepancy between captured and modelled LFG rates, however leachate level is not mentioned, which is curious.
- It is also noted that the LFG utilisation and treatment systems (engine and flare) have significant downtime. This results in the landfill having extended periods of lower capacity for LFG utilisation/treatment. The maximum recorded LFG flow was 493 m^3/hr in January 2021, which exceeds the capacity of the flare and the engine if one was operating without the other. Furthermore, the maximum future predicted LFG collection rate is over 800 m^3/hr, which exceeds the capacity of the flare and engine operating together. It is therefore surmised that;
    f. Even with the relatively low LFG collection rates, the system could potentially have extensive periods where treatment capacity is less than the LFG capture rate due to regular downtime of the flare/engine.
    g. If the capture rates improve (as predicted in the LFG Masterplan), the above issue will be exacerbated further.
    h. If LFG collection rates improve to predicted rates (i.e. 80% capture), the treatment capacity, even if both the engine and flare are operating at full capacity, will still not be sufficient.
- The above is expected to become more critical if the LFG generation rates increase over time, which the LFG Masterplan predicts will occur. It is noted that the installation of a replacement flare has been “discussed”. It is recommended that treatment capacity is improved to ensure that all captured LFG can be treated, even during periods of downtime of the flare/engine, and that treatment capacity is sufficient for the expected increased capture rates in the future.
- It is understood that existing wells in areas where waste is to be placed will be extended over time to the top of final waste height. This is supported, although noting that wells that are located in operating areas are at risk of damage from landfill operations (e.g. waste placement and compaction), as well as from settlement. The detailed design of such wells will need to account for this hazards.

- The exact timing of installation of new LFG extraction wells is not clear. Typically this would be done at the time that waste reaches final height. The period in which areas of waste are without LFG extraction capability should be minimised. It is recommended that more detailed timing of LFG well installation compared to waste placement in each area is provided, to provide an understanding of waste volumes that may be left untreated.
- The LFG Masterplan considers the use of horizontal LFG wells for LFG collection. However, the LFG Masterplan recommends that horizontal LFG wells are not installed due to the "sporadic nature of filling and the varied waste depth". Whilst it is agreed that horizontal wells may not be as effective in this type of landfill, they may still provide some collection capacity in areas where LFG may remain uncollected for a significant period of time whilst the waste mass reaches full height.

3.2.4 Question 7 - Is the landfill closure concept design appropriate as described in section 4 of the Design Report (Appendix 3)?

The landfill closure concept design is generally considered appropriate. However, some specific comments on the landfill closure are provided in the following;

3.2.4.1 Piggyback Liner

Section 4.4.3 of the Design Report is titled *"Proposed Approach to Landfill Liner Absence".* This section identifies that a piggyback synthetic liner (piggyback liner) is an option for the landfill development. This section seems to indicate that a piggyback liner will not be adopted, although it is not explicitly stated. Three key risks in relation to a piggyback liner are identified. Whilst a piggyback liner may not necessarily be warranted for this site, the following comments are made;

- A piggyback liner could include a number of layers and materials and shouldn't necessarily be limited to synthetic materials only.
- Two key risks highlighted by the Design Report in the application of a piggyback liner include differential settlement and performance during seismic events. These two factors apply to a number of engineering controls at the landfill (base liner, cap, leachate and LFG management systems), and the design of the piggyback liner needs to take account of such factors. The fact that these risks exist doesn't necessarily mean that the option shouldn't be considered further.
- A third risk highlighted by the Design Report in the application of a piggyback liner relates to complications in the installation and operation of the LFG system. It is agreed that it may complicate things, but similar to the above, the design would need to account for this, and the fact that things may become complicated shouldn't necessarily be the reason not to proceed.
- The Design Report states that the existing leachate collection trench (this is assumed to mean the LIT) meets the required environmental outcomes, and the addition of a piggyback liner was assessed as not providing any additional benefits. The assessment referred to above should be provided. Additionally, confirmation that the current LIT is meeting environment outcomes should also be provided, noting recommendations relating to further assessment in Section 3.2.2.3 and in other SLR Tech Memos.

3.2.4.2 Landfill Cap Profile

The existing landfill cap profile is not described in Section 4, however it is described in Section 3.3 of the Design Report, which from top to bottom consists of;

- 350 mm topsoil.
- 600 mm compacted low permeability (<1x10^{-7}) clay.
- 300 mm compacted intermediate cover soils.

Section 4.3 of AEE states that final capping profile across the remainder of the site will meet these same requirements as the existing cap. Assessment of the cap profile layers against the requirements of WasteMINZ Guidelines (Table 5-8) is summarised below;

- The cap profile includes a topsoil layer of 350 mm, which is greater than the 150 mm thickness recommended in the WasteMINZ Guidelines. The increased thickness is considered acceptable.
- The cap profile includes a 300 mm intermediate cover layer above the waste. This is less than the 500 mm combination of soil cover and gas dispersion layers recommended in the WasteMINZ Guidelines .
- It is also noted that WasteMINZ Guidelines includes a 500 mm “subsoil layer”. There is no subsoil layer included in the cap profile.
- The WasteMINZ Guidelines state that “where the final cover is designed to minimise infiltration of water into waste, a combination of flexible membrane liner….or geosynthetic clay liner with compacted soil…is typically used". The proposed cap profile does not include a membrane or geosynthetic clay liner (GCL).

It appears that the cap profile does not strictly meet the minimum recommended final cover requirements detailed in the WasteMINZ Guidelines. However, the reduced thickness of the intermediate cover layer, and the absence of a subsoil layer and a membrane/GCL, may still be appropriate, subject to further assessment of potential for leachate to impact the surrounding environment. If leachate is found to be impacting the surrounding environment such that additional mitigation/remedial measures are required, then the cap profile may need enhancement to further reduce the potential leachate generation rates, and reduce potential impacts of leachate on the surrounding environment.

3.2.4.3 Landfill Cap Grade

The proposed landfill cap includes grades as low as 2%. This is well below the minimum grade recommended by the WasteMINZ Guidelines of 5%. It is understood this grade is proposed due to existing landscape and physical site constraints

The intent of the minimum grade of 5% specified in the WasteMINZ Guidelines is to promote rainfall runoff, and to allow for some changes in the final grade due to differential settlement. The flatter grade increases the potential for flat spots to occur due to differential settlement, which creates the potential for increased seepage through the final landfill cap.

The grade is therefore not considered appropriate at this time, but may be reconsidered based on further information, such as details of the physical and landscape constraints, further assessment related to potential impacts of leachate on the surrounding environment (which the landfill cap is primarily intended to reduce/prevent), and any other measures taken to manage leachate (e.g. active extraction from the waste mass).

It is noted that Section 1.3.1 of the Design Report states that the consent conditions do not impose any specific limit on height of the landfill, and therefore it may be possible to increase the cap grade without reducing the volume of airspace available for waste placement.

3.2.5 Question - 8 Has the risk of landfill fire been adequately assessed? Please explain.

To provide an answer to this question, The Fire Management Plan (FMP) was reviewed. It is noted that in section 1.2 of the FMP, it is referred to as a "*fire management assessment report*", with one report objective being to "*assess the potential and associated risks of a fire occurring on site*..". Whilst there is discussion about potential sources of fires, there does not appear to be an assessment of risk in relation to the identified hazards. Rather, the report details the expected fire hazards, and then provides details of mitigation, monitoring and management requirements for the potential fire hazards. It is recommended that a fire risk assessment is prepared, or if it has been completed already, it is provided for review, and is detailed in the FMP to assist in assessment of the suitability of the mitigation, monitoring and management requirements.

Regardless of the above, the mitigation, monitoring and management requirements detailed in the FMP generally appear acceptable, noting the following;

- Battery fires are becoming an ever increasing issue for waste collection and disposal. Vigilance at the tipping face and weighbridge are needed to detect these in incoming loads in particular. A plan for managing these is critical, including provision for such a fire to be extinguished typically by dumping in a dedicated fire safe area away from the waste mass and other infrastructure.
- Further to the above, as the occurrence of such fires increases, so too does the need to enhance mitigation, monitoring and management requirements. Therefore regular reviews, and potentially updates, to the FMP are warranted.
- Table 4 states that "monitoring of oxygen…and carbon monoxide…in the collected gas" will be undertaken. The details of the monitoring (i.e. frequency, location, method etc..) should be documented in a LFG monitoring program, and results reviewed after each event and reported periodically to help assess the potential for a landfill fire to occur or have occurred.
- Table 5 states that a "*thermal imagery camera will be purchased*" and a "*review will be undertaken by 1st January 2024 with the aim to setup a fixed mount thermal imaging camera which is capable of scanning the active landfill area and vegetated surface of the landfill*". I agree with this measure, and support its implementation. Full details should be provided, including the results of the proposed review by Council.
- Section 5.6 of the report details fire risk mitigation and readiness. There is reference to water sources, in section 5.6.3, including fire extinguishers. Other types of fire fighting methods apart from water may be needed, dependant on the type of fire. For example a chemical fire maybe inadvertently provoked by the addition of water.
- A key environmental impact from a subsurface landfill fire is odour. Odour should be a key part of monitoring for a landfill fire, along with other items that are proposed for monitoring including presence of smoke, increased carbon monoxide in the LFG system etc..

4.0 Closure

SLR trusts that this technical memorandum is adequate for its purpose. We are happy to discuss any aspects of our assessment and work collaboratively with you to undertake additional revisions if required.

Regards,

SLR Consulting Limited

pp

James Elliott,
Technical Director – Land Quality and Remediation

Emma Trembath
Technical Director – Environmental Services

Otago Regional Council

Appendix 2

RM23.185 – Green Island Landfill Groundwater Quantity & Flood Hazard Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	Tim Baker
Company:	Otago Regional Council	**SLR Consulting NZ**	
cc:	Samantha Iles	**Date:**	10 November 2023
		Project No.	13556

RE: RM23.185 - Green Island Landfill
Groundwater Quantity & Flood Hazard Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including multiple attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant) for the operation, expansion, and closure of the Green Island Landfill.

Dunedin City Council is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

2.0 Scope of Review

This review covers Groundwater Quantity and some Flood Risk aspects of the application. A separate memo addresses Groundwater Quality (Lukey, 2023), although as they are interrelated, there is some cross over.

The Groundwater Quantity aspects of the application considered as part of this review this review include:

- Review of the hydrogeological conceptual model to check that it has been developed and is understood adequately and that subsequent effects assessments appropriately address all groundwater related effects.
- Review of the assessment of effects arising from any diversion or take of groundwater resulting from the landfill.
- Review of groundwater / surface water interaction and effects of the any groundwater diversion/take on surface water quantity and wetlands.

Following a review of the Application, a Section 92 Request for Further Information was submitted to the Applicant. This review considers the information presented in the RFI response.

The key documents reviewed were:

- AEE Appendix 3: Waste Futures - Green Island Landfill Closure Design Report
- AEE Appendix 5: Waste Futures - Green Island Landfill Closure Groundwater Technical Assessment
- AEE Appendix 10: Waste Futures - Green Island Landfill Closure Geotechnical Investigation Factual Report

3.0 Response

ORC posed the following questions (in bold) which we respond to in turn below.

Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?

In reviewing the geological and hydrogeological conceptual model prepared by the Applicant, I found several areas where there are limitations in the information provided regarding groundwater flow direction and groundwater levels – this propagates to uncertainty in the adequacy of existing monitoring locations. These issues have been discussed with Anna Lukey, author of the Groundwater Quality assessment, and are presented in her report, however for completeness, I summarise them below:

- A fundamental assumption of the hydrogeological model is that the leachate collection trench intercepts all groundwater and prevents offsite migration. While the trench intercepts the more permeable estuarine silts and sands, I disagree that it would prevent offsite migration because trench does not extend to the depth of the Abbotsford Mudstone (basement) and therefore there remains potential for groundwater flow beneath the trench, above the low permeability mudstone.

  The applicant states that upward hydraulic gradients are a form of control on downward and offsite migration (Both Appendix 3 and 5 refer to artesian conditions preventing downward migration of contaminants). However, as I discuss below, there is very limited evidence of upward hydraulic gradients.

- The historical stream diversion, and historical evidence of channels on the estuarine mudflats (beneath the footprint of the landfill) increases the potential for preferential flow paths beneath the landfill (noting it is unlined). It is my view that the monitoring network around the boundary is currently insufficient to adequately represent off-site groundwater discharges.
    - Recommendation: Additional monitoring locations, particularly of deeper groundwater should be added to the network. Locations should include consideration of former estuarine and stream channels. Please refer to Technical Memo of Anna Lukey for more information on the proposed locations of these.

- There is very limited information on groundwater levels and flows beyond the landfill footprint, and because of this no piezometric contour maps of flow direction outside of the landfill has been able to be generated. The Applicant notes that this is due to the lack of private wells around the landfill, which is understandable, but not a reason to limit further investigation or information gathering.
    - Recommendation: All historical monitoring wells on the site should be surveyed in, allowing accurate representation of groundwater flow direction/elevation at the site.
    - Recommendation: the applicant should consider adding to the network of monitoring wells with additional wells at the property boundary around the landfill.

- While the ‘typical monitoring cross-section’ shown on Figure 2.4 (Appendix 5) shows a deep well (labelled D), the D wells actually only exist on Lines 2, 4 and 7 and there a no borelogs available for these wells. This means monitoring of the groundwater in

the Lower Kaikorai Estuary Member (LKEM) is limited to those three transects. It is my opinion, that a Deep well should exist on every transect and that they be screen immediately above (they need to tag) the Abbotsford Mudstone layer.

- Recommendation: Addition of a D well to each transect

- There is limited information on hydraulic gradients between the different geological units at the site, or demonstration of the 'artesian' gradient referred to in Appendix 3 and 5.

  The Applicant, in the s92 Response (Question 69) states that the levels recorded in monitoring wells C & D at Transect 2 & 4 indicate an upward hydraulic gradient between from the lower to upper Kaikorai Estuary Member. I remain uncertain whether this is an upward hydraulic gradient, or just a reflection of the drawdown caused by the leachate interception trench. Furthermore, without wells in the Abbotsford Mudstone, there is no knowledge of what, if any, gradient exists between the mudstone and the estuarine deposit.

  - Recommendation: further demonstration of hydraulic gradient between all geological units is required. This assessment needs to ensure that the effects of groundwater drawdown from the trench are considered when making any conclusions. I would be comfortable seeing this work done as part of an adaptive groundwater monitoring plan, should ORC decide to issue consent.
  - Recommendation: Include one or two new wells in the Abbotsford Mudstone to prove hydraulic gradients

Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]

Addressed above.

If granted, are there any specific conditions that you recommend should be included in the consent?

With regards to groundwater levels and flow direction, I would request that a Groundwater Monitoring and Contingency Plan is developed and is subject to ORC approval. The plan should include:

- Details of all monitoring well construction (depth, elevation, material, logs)
- A sampling and analysis plan, including the sampling methodology to be followed.
- A plan for the installation of additional boundary wells, and new deep transect wells, including the proposed depths, construction, and timing of installation.
- Other items as addressed in the Groundwater Quality memo.

Has the applicant appropriately assessed the effects of the groundwater take on the hydrological functioning of the nearby Regionally Significant/Natural Wetland?

The assessment of the stream depletion effects resulting from the groundwater take have been assessed using the results of SEEP/W model which predicts inflow into the leachate drain.

The modelling results (presented in Appendix G of the Groundwater report) align relatively well with the observed leachate pumping record and indicate that inflows into the leachate trench are in the order of 1 to 2 L/s (inflow rates are very low).

The relative proportion of flow from each side of the trench was estimated using the model with 70% sourced from the landfill, 30% from the stream. Along the 1674 m trench length, this equates to ~0.5 L/s sourced from the stream side.

As a proportion of the Kaikorai mean flow (368 L/s) and mean annual low flow (81 L/s) the applicant considers this is insignificant and I agree with that conclusion.

Is the SEEP/W 2D groundwater model appropriate for use in this context? Has it been applied appropriately*?*

Two models were used for the assessment:

- The Hydrologic Evaluation of Landfill Performance (HELP) model was used to estimate rainfall infiltration through the landfill cap
- SEEP/W was then used to estimate groundwater seepage from the landfill into the leachate collection drain. The SEEP/W model used the HELP outputs as the recharge input.

Overall, I consider the application of both models to be appropriate. I have some minor reservations about the consideration of climate change effects in the HELP model rainfall data series, and whether the assumptions around hydraulic gradients across the main geological units are valid. However, overall, the models appear to be a fair representation of long-term leachate/seepage process. The validation of the model outputs to measured abstraction rates supports the validity of the models, although the ability of the model to represent storm conditions is poor (leachate pumping rates following rainfall are 7-9 L/s, compared to 1-2 L/s under normal conditions).

I questioned whether the predicted 10% increase in rainfall for the Otago region had been considered in the HELP modelling. The Applicants response (Q70) suggests that it was, however, it is still not clear to me that the stochastic modelling input does consider this. I believe the stochastic rainfall model considered current variability (which would include >10% variability from the mean), but it does not account for a 10% increase in overall average rainfall.

The SEEP/W modelling did consider the effects of sea level rise on the inflow into the leachate trench (Scenario 2C). Across all scenarios, there was negligible change in inflows between scenarios. I have no reason to disagree with the results presented, however recommend that the modelling outputs, and inherent uncertainty, are validated though a robust long-term monitoring programme of groundwater levels and leachate trench outflow rates.

Have the cumulative effects of the activity been appropriately assessed?

With regards to groundwater abstraction from the leachate trench, I do not consider there to be any cumulative effects because the long-term abstraction volumes are very small compared to surface water flows, the tidal influence on estuary levels, and likely regional groundwater flows.

Have the effects of the defence against water been adequately assessed including:

- ***effects on existing defences?***
- ***Correctly identified any diversion or secondary flow paths because of the defence/ alteration to the defence?***

The land adjacent to the landfill is low lying between 1.5 and 2.0 m msl. It is situated within a flood plain and is subject to a moderate risk of flooding from storm surge and fluvial flooding in the Kakorai Stream.

The Design Report (Appendix 3) indicates that estimates that flood flows will increase by approximately 9% by 2050. The report concludes that '*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*'. I agree with this.

Sea level rise is assessed to increase estuary water levels by 0.25 to 0.5 m. 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.

Raising the perimeter road (stop bank) may reduce the cross-sectional area of the floodplain, and result in higher flood levels as the same (or greater with climate change) amount of water must flow through a smaller area. However, it is important to note that in this case, that only a very small part of the flood plain area sites on the landward side of the existing stop bank. Furthermore, it is my understanding that the proposed increase is of an existing stop bank (road) and therefore does not change any existing stormwater flow paths.

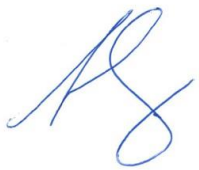
A part of the s92 request (q76), an assessment on the change in flood levels because of the increase stop bank height was carried out. This assessment was done using a simple analytical approach (not a model) and indicated the change in flood level height to be in the order of 3 to 4 cm. I consider this negligible.

4.0 Closure

In summary, the application with regards to groundwater quantity and flood risk covers the broad considerations but there remain some gaps in knowledge that need to be addressed, potentially via the use of detailed and adaptive management plans.

Regards,

SLR Consulting NZ



Tim Baker
Principal Hydrogeologist

Anna Lukey (Reviewer), CEnvP SC
Principal Environmental Consultant

cc Samantha Iles

Otago Regional Council

Appendix 3

RM23.185 – Green Island Landfill Groundwater Quality Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	Anna Lukey
Company:	Otago Regional Council	**SLR Consulting NZ**	
cc:	Samantha Iles (SLR)	**Date:**	10 November 2023
		Project No.	13556

RE: RM23.185 - Green Island Landfill Groundwater Quality Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including subsequent attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant) for the operation, expansion and closure of the Green Island Landfill.

Dunedin City Council is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

2.0 Scope of Review

This technical review relates to information primarily presented in Waste Futures – Green Island Landfill Closure – Groundwater Technical Assessment, GHD, 9 March 2023 (the Report), and some groundwater technical information is included in Surface Water Report, GHD, 7 March 2023 and Development and Management Plan, Stantec, February 2023 in addition to the Assessment of Environmental Effects. Six piezometers were installed to gauge water levels reported in the Geotechnical Investigation Factual Report, GHD, 20 February 2023.

I have completed my review of the Report and other available information in order to answer specific questions from ORC.

The Landfill Development and Management Plan (Stantec 2023) sets out proposed environmental monitoring. This is based on the consents for operation, due to expire in October 2023, and does include some discussion regarding closure monitoring proposals and has been reviewed in the context of this review.

This review considers the principles of Te Mana o te Wai in that the well being and health should be prioritised, the groundwater should be considered a receptor of importance, and on the understanding that there is a direct connection between ground and surface water.

This review considered the Waste Management Institute New Zealand (WasteMINZ) Technical Guidelines for Disposal to Land, September 2023 regarding the proposed monitoring programme.

The following is based on my understanding of the Conceptual Site Model (CSM) as generally presented in the GHD documentation. In summary:

- The landfill is unlined on the upper and lower Kaikorai Estuary members and beneath that the Abbotsford Mudstone which operates as a natural confining layer.

- The waste was deposited historically on the estuary sediments below groundwater level.
- Discharge of leachate to groundwater is controlled through the leachate interception trench, which also extracts some surface waters.
- Groundwater monitoring is completed through wells which are connected to the trench system and there is reliance on the surface water quality to determine the effectiveness of the trench performance.
- There are no downgradient wells to monitor the underlying groundwater quality outside of the trench system.
- There are also potential preferential flow paths from prior channels of the Kaikorai Stream which have not been investigated through installation of downgradient groundwater monitoring wells.

3.0 Response

ORC posed the following questions which we respond to in turn:

Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?

Yes - the technical information provided in the application documents is generally robust. The data that has been presented is clear and discussed. However, there are numerous assumptions made and assumptions of note are highlighted below:

- The historical data from the groundwater monitoring wells is not comprehensive and some assumptions are required based on well construction.
- The introduction section sets out a number of assumptions about the landfill life expectancy, which is based on filling volumes and the establishment of Smooth Hill landfill.
- Appendix D (Section 1.3) sets out assumptions which includes the Site being commercial/industrial land use until closure, and thereafter will be used for recreational purposes.
- The Report notes (Section 1.1): *"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 Runanga o Otakou, the local community and key stakeholders."*

There is no discussion presented regarding what impact groundwater quality will have on the expected recreational land use. The proposed recreational use does not include water use, however it would be expected that this should be discussed in the context of potential future receptors.

Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]

The level of detail regarding historic well construction, including screen details are not available through the reports. This would assist in understanding the CSM further.

A limited contaminated soil investigation was conducted based on opportunistic geotechnical investigation and it does not seem that there was a dedicated contaminated soils/groundwater investigation. The geotechnical works included the installation of six piezometers which bore logs included indicate submerged screens. It is understood these wells are used for water level gauging, not groundwater quality. Further discussion should be provided with respect to applicants plans for these wells, and if they will form any part of the future groundwater quality monitoring.

The Surface Water report notes in Section 3.4: the Kaikorai Stream historically ran through where the Landfill is now. However, the stream was diverted along the western boundary of the Landfill to run in a southwest and southerly direction, towards the Kaikorai Estuary and ultimately the sea. The potential for the former drainage channel(s) to be acting as a preferential pathway has not been addressed. Furthermore, there is the potential that the leachate interception trench is located above the former channel(s). In addition, there is also a gap in the leachate trench to the southern side of the landfill, which may result in leachate not being captured and ultimately discharging through the former drainage channel(s). As such, there needs to be further investigation into the previous drainage channels and how these relate to the landfill CSM.

Installation of downgradient of monitoring wells screened in the Upper Kaikorai Estuary Member (UKEM) and the Lower Kaikorai Estuary Member (LKEM) will assist in determining impact on groundwater quality. It would also be expected that deeper groundwater, in the Abbotford formation would also be monitored to confirm understanding of the aquitard function as stated in the application. At least three well locations (sets of wells in each unit should be considered to understand impact on underlying units) should be installed to cover off the former drainage channels and the impact of the landfill as a whole. These wells are to be installed outside of the leachate interception trench well system in a downgradient position before the estuary. There are limited locations based on surface water locations, however these can be installed in the southern to south western area of the landfill.

If granted, are there any specific conditions that you recommend should be included in the consent?

Further downgradient groundwater monitoring network is required in order to assess any impact on groundwater outside of the leachate inception trench system.

There are no deep wells through the lines in the southern “half” of the landfill, which is within the area which is expected to be downgradient. There is no groundwater flow direction presented in the Report, however the Kaikorai Stream ran in a southwest and southern direction, prior to diversion, it is expected that this is the regional groundwater flow direction, towards the estuary and ultimately the coast.

Long term monitoring post closure needs to be established in detail at this stage.

Does the application appropriately identify sensitive areas including affected water bodies (surface, ground and coastal water), wetlands, bores, drinking water supplies? Yes/no.

The application notes the following:

- Kaikorai Stream and estuary to N and W are identified as Regionally Significant Wetland in the Regional Plan and an Area of Significant Biodiversity Value and a Wahi Tupuna of cultural significance to mana whenua in the 2GP.
- The Site is not within a Groundwater Protection Zone or Seawater Intrusion Risk Zone. However, it is adjacent to a Regionally Significant Wetland as defined in the ORC Regional Plan (ORC, 2018).

Appendix D Landfilling History and Targeted Contaminated Land Assessment Report notes that Kaikorai Stream originally went through landfill footprint area but was diverted. The former Kaikorai Stream channel is potentially a sensitive area.

Through the Section 92 process, 49 bores were identified within the area of interest. Drinking water bores in the site vicinity were not specifically identified in the application. There was reference to no groundwater use in the vicinity throughout the application, however further discussion is required based on the identified bores.

Is the description of the sensitive areas attributes potentially affected by the activity accurate?

Water bodies are identified however very limited discussion regarding attributes (refer to ecology technical memo). The underlying groundwater requires further review and investigation; with appropriate attention given to the principles of to Te Mana o te Wai.

Has the Applicant adequately assessed the adverse effects on groundwater quality of the discharge of waste and leachate to land?

Section 4 of the Report and section 8.3.5 of the AEE discuss the effects.

In my view the applicant has not provided sufficient detail regarding the assessment of adverse effects, other than reiterating the performance and reliance on the leachate interception trench noting surface water is not indicating adverse effects from groundwater impacts.

Has the applicant proposed appropriate methods to limit contaminants, particularly leachate, entering groundwater?

The application is based on the successful operation of the leachate interception trench. The groundwater results indicate that leachate is in the wells outside of the trench, however the hydraulic gradient is pulling impacted groundwater towards the trench and away from surface waters through continuous pumping.

The trench is currently not present along the Southern side of the landfill and is planned to be extended with this work. The landfill engineer memorandum will comment on the expected performance following extension.

The application notes the trench is not tied to the Abbotsford Formation mudstone which is inferred to be an aquitard due to the very low permeability of the mudstone and effectively an impermeable barrier for any downward seepage.

It is also expected the improved landfill capping will result in less leachate being generated and requiring treatment, following closure.

Is the SEEP/W 2D groundwater model appropriate for use in this context? Has it been applied appropriately?

Refer to the groundwater quantity and flood risk memorandum.

Have the cumulative effects of the activity been appropriately assessed?

Cumulative effects have not been specifically assessed in the AEE for groundwater quality.

Do you consider that the proposed improvements to the leachate system will be effective in improving groundwater quality?

Refer to the landfill engineering memorandum.

Has the Applicant proposed appropriate groundwater monitoring for the duration of the consent?

Section 5.1 of the Report recommends that groundwater monitoring is continued in line with the current consent conditions, (with some exceptions). The exceptions are valid. The monitoring parameters have been compared with Table 8-2 of the Wasteminz Technical Guidelines for Disposal to Land and it is noted that parameters are generally consistent with recommended parameters with the exception of copper, which should be included.

There is also note that PFAS is to be included in future monitoring.

The AEE, Section 8.3.6 sets out the proposed groundwater monitoring, which is an extension of the existing monitoring regime with some reduction of frequency for quarterly parameter monitoring.

The Stantec Management Plan recommends that the monitoring programme is reviewed and updated to reflect the changes to the landfill post closure.

As this consent includes the post closure management, it would be expected that groundwater monitoring is set out at this stage and this includes installing new downgradient wells in both upper and lower Kaikorai formations and the Abbotsford mudstone, included in this monitoring to determine discharge and impact to groundwater.

Do you agree with the Applicant's conclusions as to the level of adverse effects on groundwater?

The applicant has based their conclusions on the performance and reliability of the leachate trench and the low permeability of the Abbotsford mudstone and the surface water quality. In my view there is not enough site specific downgradient groundwater data to determine the level of adverse effects on groundwater.

In my view further data is required in the form of downgradient groundwater monitoring wells which are screened within the 3 units to assess impact to groundwater at these different depths. These wells need to be located outside of the leachate interception trench.

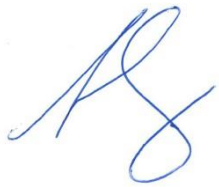
4.0 Closure

In summary, the application requires the following further detail:

- Surrounding groundwater use description and assessment;
- The assessment of effects needs address the potential preferential flow pathway presented by the former channels of Kaikorai Stream;
- The advancement of additional groundwater monitoring wells outside of the leachate interception trench system in order to assess groundwater impact;
- Reference to Appendix K of the WasteMINZ guidelines for the closure monitoring well network requirements; and
- Details of the proposed monitoring post closure schedule.

Regards,

SLR Consulting NZ



Anna Lukey, CEnvP SC
Principal Environmental Consultant

Emma Trembath
Technical Director – Environmental Services

Otago Regional Council

Appendix 4

RM23.185 – Green Island Landfill Surface Water Quality Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	Claire Conwell
Company:	Otago Regional Council	**SLR Holdings NZ**	
cc:	Samantha Isles	**Date:**	9 November 2023
		Project No.	13556

RE: RM23.185 – Green Island Landfill Surface Water Quality Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including multiple attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant) for the operation, expansion, and closure of the Green Island Landfill.

Dunedin City Council is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

2.0 Scope of Review

This review covers Surface Water Quality aspects of the application, aspects of the application considered as part of this review this review include:

- Review of the surface water quality data and assessment of effects to the receiving environment arising from the management of the leachate collection and stormwater management systems
- Review of groundwater / surface water interaction as these relate to surface water quality.
- Assessment of the proposed monitoring schedule, including locations, frequency and parameters.

The key documents reviewed were:

- AEE Appendix 6: Waste Futures - Green Island Landfill Closure Surface Water Report
- AEE Appendix 5: Waste Futures - Green Island Landfill Closure Groundwater Technical Assessment (as these relate to surface water interactions)

3.0 Response

ORC posed the following questions (in bold) which are responded to in turn below.

3.1 General response

1. Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?

The issue of hydraulic connectivity has been discussed Tim Baker in the groundwater review memo to gauge an understanding of the assumptions and reasoning around whether groundwater has the potential to act as a vector for the discharge of leachate contaminant to the surface water receiving environment. I refer to Tim Baker's memo for further discussion about the hydrogeological model.

For surface water, the key assumption applied to the surface water quality AEE is that all of the leachate generated on site is collected via the collection trench, thus prevents offsite migration. The groundwater technical review finds that this may not be the case – given the collection trench does not extend to the depths of the Abbotsford Mudstone (marine deposit basement), thus there remain the potential for groundwater flow beneath the trench, and above the low permeability mudstone.

The degree to which this contributes to potential for the migration of leachate contaminants to surface water quality in the receiving environment has not been acknowledged. Rather, the surface water report is based on the assumption that there is no leachate migration via groundwater, on the basis that there is no evidence of leachate contaminants exceeding guideline thresholds in surface water sampling programme. It is not correct to assume that if there are no guideline exceedances, this equates to no discharge of leachate.

The migration of leachate offsite is partially discussed in the ecotoxicological assessment report, undertaken by Cawthron[1]. This found the presence of leachate organics in groundwater samples, and suggested that there may also be dissolved metals in groundwater contributing to the observed ecotoxicological effects in test species. This is pending further assessment, but warrants more comprehensive assessment into the overall weight of evidence' approach to the assessment of effects.

2. Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]

Addressed above.

3. If granted, are there any specific conditions that you recommend should be included in the consent?

With regards to overall receiving environment monitoring, and particularly surface water, I recommend that an Adaptive Monitoring Plan to be developed. This should set out the objectives of the Surface Water Quality Monitoring Programme and identify contingencies to be implemented. These contingencies, for example, should link to the proposed

[1] Champeau, O. Northcott, G. and Tremblay, L. 2023. Preliminary assessment of the impacts of the Green Island landfill leachate on the receiving environment using passive samplers and toxicity texting. Prepared for Boffa Miskell Limited. Cawthron Report No. 3895, 13p plus appendices. In Appendix 12 Green Island Ecological Impacts Assessment Technical Report. March 2023.

Groundwater Monitoring and Contingency Plan, and Ecological Monitoring Plan. The plan should include:

- Details of all monitoring site locations and justifications;
- A sampling and analysis plan, including the sampling methodology to be followed;
- An approach to how the data is interpreted and assessed in conjunction with the groundwater quality monitoring (refer to Groundwater Quality memo for further details);
- A detailed Stormwater Management Plan (this may be done as a separate plan, but should integrate proposed change to stormwater management over the next 6 years of waste acceptance, establishment of the Resource Recovery Park Precinct (RRPP), and details of long term closure stormwater management, with appropriate review periods incorporated).

3.2 Surface Water Quality

4. Does the application appropriately identify sensitive areas including affected water bodies (surface, ground and coastal water), wetlands, bores, drinking water supplies? Yes/no.

The application has identified the following sensitivities:

- Surface water courses, including the existing estuarine environment, as well as contributing freshwater streams and tributaries.
- The groundwater zone appears to be appropriately identified, and please refer to the groundwater technical assessment for further details and confirmation.

Bores and drinking water supplies are not identified. Given the location of the landfill in the lower catchment, proximity to the estuary and the coastal marine area it is assumed no potable water supplies are ne are present in the vicinity of the landfill CMA.

5. Is the description of the sensitive areas attributes potentially affected by the activity accurate?

The sensitive areas attributes, with regard to surface water quality, are understood to be:

- The water quality attributes of the Kaikorai Stream; and
- The water quality attributes of the Kaikorai estuary.

Attributes (for water quality) is defined in the NPSFM as '*a measurable characteristic (numeric, narrative or both) that can be used to assess the extent to which a particular value is provided for'.*[2]

Whilst the specific values of the surface water quality aren't explicitly stated in the Surface Water AEE, it is inferred these to be waters that support ecosystem health, human contact, threatened species and mahinga kai. Ecosystem health is subject to the Appendix 12 Ecological Impact Assessment report, and is not reviewed here.

[2] https://environment.govt.nz/assets/publications/NOF-Guidance-ME1753-Final-Oct2023.pdf

The surface water report has referred to the current attribute state assessment available (on LAWA) for the site upgradient of the landfill, and which is assessed as being in a degraded/impacted state against the National Objectives Framework in the NPS-FM.

Assessment of parameters (attributes) for landfill monitoring include:

- Nutrients (nitrate, ammoniacal nitrogen, dissolved reactive phosphorus);
- Physicochemical parameters; and
- Toxicants (metals, organic contaminants).

The assessment of these parameters has been on the basis of whether attribute National Bottom Line, or default guideline values have been exceeded. As referred to in Question 10, there has been no apparent integrated assessment across the ecological effects for surface water quality, not has cumulative effects been addressed.

It is concluded, therefore, that the current description of the sensitive areas attributes, has not been fully provided.

6. Has the applicant proposed appropriate methods to limit contaminants, particularly leachate, entering surface water?

The methods to limit contaminants entering the receiving environment are identified as:

- Leachate collection trench;
- Stormwater management and sediment ponds; and
- Constructed wetlands (Eastern and Western).

Please refer to the Groundwater technical assessment for a full assessment regarding the appropriateness of the leachate collection trench system. The technical review (T. Baker) has identified that the leachate trench may not be a complete hydraulic barrier, and there is a potential pathway for flow beyond and beneath the trench into surface water As mentioned above – this warrants a re-assessment in the application.

Regarding stormwater flows and retention, Section 4.3 describes the Existing stormwater flows, with sub-catchment rainfall intensities presented in Tables 6 and 7. The calculation assumes only a 2-3% increase in intensity due to climate change for the remaining operational time (6 years) of the landfill. I have not assessed the accuracy of this, so assume (on the basis calculations are correct), there is sufficient stormwater retention capacity on site.

Long term, it is recommended the stormwater retention is re-assessed to account for longer term rain intensities, under a range of climate change scenarios. This is required to inform long term stormwater management on site and to ensure it is still fit for purpose.

The assessment of climate change in the Surface Water AEE (Section 4.4) has also identified the elevation of the perimeter berm by 1 m will be sufficient to prevent inundation of the leachate collection trench by increases to Kaikorai Stream and any flood hazards. water levels. This has been reviewed in the Groundwater Quantity & Flood Hazard Technical Review, and is not reviewed here.

7. Has the Applicant adequately addressed the risk to human health and the environment associated with PFAS?

Not reviewed here – pending further data from the Applicant.

8. Have the adverse effects on surface water quality of the discharge of stormwater to Kaikorai Stream been adequately assessed?

The assessment adverse effects on surface water quality have been assessed via the summary of monitoring data undertaken to date in the sediment retention ponds, and across sites in the Kaikorai Stream / Abbots Creek receiving environment. This has been presented as a series of line charts, as well as summary tables in the following document:

- Appendix C Water Chemistry Monitoring, in Green Island Landfill Annual Monitoring Report 2021-2022 (20 September 2022). Report provided as Appendix B in the Appendix 06 Surface Water Report

Water quality results were benchmarked against appropriate guidelines (ANZG default guideline values for the 80th percentile level of species protection, and the NPS-FM National Bottom Line for nitrate and ammonia toxicity).

It appeared that results for dissolved zinc concentrations in surface water receiving monitoring locations were not included in the annual report, and were not available to be reviewed. It is requested that these results are also provided.

The analysis has not undertaken any further statistical analyses beyond summary statistics (comparison of monitoring round against historical maximum, minimum, average, and number of guideline exceedances. It is recommended that in addition to the plots presented, the data is represented as box plots across sites (to enable assessment of variability across the sites), or that further summary statistics are provided (i.e. 95th percentile of data, median values). Given the timeseries available, it is also recommended to provide a Time Trends analyses, to assess if there are any seasonal effects to trends over time. This would also assist in giving weight to the statements in Section 5.1 of the AEE that discuss the findings of the monitoring programmes, and would assist to confirm these conclusions that on the basis of the monitoring data there are no significant or discernable effects due to any leachate / stormwater discharge from the site.

Time trend analyses would also serve to inform the recommendation for undertaking a cumulative effects risk assessment (see question 10).

9. Do you consider that the proposed improvements to the leachate system will be effective in improving surface water quality?

Overall, I agree that improvements to the leachate system will be effective in improving surface water quality. The caveats to this are described above, under question 6.

If the leachate system is functioning as per the design (with minimal infiltration to groundwater and ensuring the collection trench is not compromised), this should in effect, reduce contaminant discharge to the receiving environment, and not further degrade the already impacted receiving environment.

The proposed additional mitigation measures outlined in Section 5.3 also identify steps to prevent pond culvert leachate ingress (Section 5.3.3), Emergency Stormwater Management (5.3.4), and response to climate change (Section 5.3.5). These mitigation measures serve to maintain the integrity and function of the leachate collection trench (via flood prevention and overtopping) and identify areas for repairs/remedial works to be carried out.

10. Have the cumulative effects of the discharge activities been appropriately assessed? Do you concur with the assessment? Yes/No

Cumulative effects to surface water quality have not been addressed in the AEE. It is recommended that this be undertaken in conjunction with the consent application for he Resource Recovery Park Precinct (RRPP).

Cumulative effects are those effects (however individually minor the effects is):

- Those which result from the incremental effects of the activity; and
- When those are added to other past present and reasonably foreseeable future actions.

The potential for cumulative effects from the landfill associated discharges to receiving environment sensitivities in the vicinity of the footprint of the site are for:

- Water quality sensitivities and values;
- Ecological sensitivities and values; and
- Human health sensitivities and values, including mahinga kai.

It is acknowledged that cumulative effects across the receiving environment is a challenge and requires integrated assessment on a long term basis.

It is also acknowledged that the upper catchment is a highly modified environment and contributes significantly to the current state of water quality and ecosystem health in the Kaikorai Stream and Estuary. A key principle of Te Mana o Te Wai, is that the well being and health of water is prioritised. So even if there is evidence of upper catchment stress to downstream receiving environments, the state of water quality (in downstream receiving environments) should not be further degraded and should seek to be improved where possible.

For the landfill discharges, this means that discharge of chronic, low-level contaminants should be minimised where possible. Even though results of long-term water quality show that for toxicants, there are few exceedances of receiving environment criteria (i.e. ANZG default guideline values), the discharges still represent chronic long term sources of contaminant exposure to the receiving environment.

An assessment of the ecological sensitivities is set out in Appendix 12 Ecological Impact Assessment Report. This is not reviewed here, bit I note the following findings:

- Sediment contaminants in the downstream sites (GI3 and GI5) are likely to be sourced from both the upper catchment well as potentially landfill stormwater discharges;
- Ecological effects are difficult to discern due to the influence of saline waters;
- Ecotoxicological effects of groundwater sources organic contaminants near GI5 show indications of ecotoxicity – noting follow up results are pending; and
- The ecological report has not integrated any findings from the surface water quality assessment into the overall ecological assessment of effects.

Given the lack of integrated assessment between the ecology AEE and surface water quality AEE that is required for the assessment of cumulative effects, it is recommended that this be addressed.

11. Has the Applicant proposed appropriate monitoring for the duration of the consent?

Monitoring Sites

The applicant has proposed appropriate sites for surface water quality monitoring, these are listed in Section 5.4 of Appendix 06 Surface Water quality report, and are identified as follows (noting the addition of several new sites):

- Surface water monitoring at 5 sites (GI1, GI2, GI3, GI5, GI6 (new site at the Brighton Road Bridge Kaikorai Estuary);
- Eastern Sedimentation Pond;
- Western Sedimentation Pond;
- Three New sites: South Western Pond, Eastern Constructed Wetland, South Eastern Constructed Wetland; and
- Water level monitoring (GI3, also identified as Site ST4 pressure transducer, next to GI3)

Parameters

I have cross referenced the current WasteMINZ guidance[3] for monitoring parameters, referring to Table 8.2 in the guidelines. This is referred to because the landfill will be accepting municipal water for another 6 years, prior to closure.

It is noted the proposed suite includes major ions (including magnesium and calcium). It is recommended the total hardness also be reported (noting it is a different APHA reporting method, and should be requested separately. This should be included at no cost, as it's a calculation rather than an analytical method).

It is also recommended to include dissolved organic carbon in the laboratory analytical suite. This is to enable DGV for select metals to be adjusted according to local conditions (noting also that there is new guidance on the application of DGV for receiving waters, available from Envirolink[4]).

The metal contaminant copper is missing from the proposed suite – it is recommended this to be included.

Monitoring Schedule

Given the continue operation of the landfill, it is recommended that the quarterly monitoring for the following be retained as follows:

- pH;
- Electrical conductivity;

[3] https://www.wasteminz.org.nz/files/Disposal%20to%20Land/TG%20for%20Disposal%20to%20Land_12Oct22_FINAL.pdf

[4] https://www.envirolink.govt.nz/assets/2307-HZLC166-Implementing-bioavailability-based-toxicity-guideline-values-for-Cu-and-Zn.pdf

- Dissolved oxygen;
- Major ions sodium, potassium, magnesium, calcium, bicarbonate, sulphate and chloride);
- Nutrients (ammoniacal-nitrogen, nitrate-nitrogen, dissolved reactive phosphorus);
- Metals (aluminium, arsenic, cadmium, chromium, iron, lead, manganese, nickel, zinc, **copper**);
- Boron;
- Chemical Oxygen Demand;
- Biological Oxygen Demand;
- Hardness (calculated from Mg+Ca); and
- Dissolved organic carbon.

The current WasteMINZ Guidelines do not include E. coli as a routine parameter for monitoring, and it is acknowledged that E. coli has not been a parameter in the historical monitoring suite.

It is anticipated that *E. coli* will form part of the monitoring suite required under the RRP consent (as it will include the composting facility), therefore consideration is required to ensure consistency in monitoring across the two consents to avoid double-ups in effort.

12. Do you agree with the Applicant's conclusions as to the level of adverse effects on surface water?

Any adverse effects are likely to be a result due to cumulative impacts, rather than acute toxicological effects from the landfill. This is supported by the available water chemistry data which notes very few exceedances of DGV/NBL attribute criteria.

The assessment is confounded to some extent by the influence of the upper catchment contributions of contaminants to the downstream receiving environment, and the limited integration of the surface quality data into the ecological impact assessment.

The assessments have been based on the assumption that there is no discharge of leachate from the site to the receiving environment (i.e. the leachate collection trench is 100% effective), but and uses the rationale that since the guideline thresholds are not exceeded, there is no evidence for leachate contamination in the receiving environment.

I disagree with this logic, as there can be low level and diffuse discharges of leachate contaminants via groundwater, to the surface water receiving environment. This will result in chronic, long term cumulative impacts, which have not been assessed. Further to this, there is some suggestion in the ecotoxicology assessment (included in the Appendix 12 Ecological Impact Assessment Report) that there may be ecotoxicological effects due to leachate entering groundwater in the vicinity of site GI5. This warrants further investigation to determine f this poses a risk to sensitive ecological receptors, beyond the routine assay test organisms in the ecotoxicology assessment.

4.0 Closure

In summary, the application with regards to surface water quality covers the broad considerations and issues. The overall assessment is considered thorough and presents a solid amount of robust data, the assumptions and conclusions set out in the technical assessment would be strengthened by additional statistical analyses. Careful consideration is recommended to be given to how cumulative effects are to be assessed, as it is acknowledged this is a challenging area. The use of adaptive monitoring plans following the closure, to ensure monitoring remains responsive to unforeseen changes in leachate management and effects to the receiving environment.

Regards,

SLR Holdings NZ

Dr Claire Conwell
Principal Consultant

Tim Baker (Reviewer)
Principal Consultant

Otago Regional Council

Appendix 5

RM23.185 – Green Island Landfill Ecology Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	Elizabeth Morrison
Company:	Otago Regional Council	**SLR Consulting NZ**	
cc:	Samantha Isles (SLR)	**Date:**	9 November 2023
		Project No.	13556

RE: RM23.185 - Green Island Landfill Ecology Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including subsequent attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant or DCC) for the operation, expansion and closure of the Green Island Landfill.

DCC is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

I have reviewed ecology aspects of the application as outlined in the Ecological Impact Assessment, Bird Risk Assessment Report and Draft Southern Black Backed Gull Management Plan. I attended a joint site visit with Otago Regional Council and other reviewing technical specialists on 4 April 2023.

An assessment of ecotoxicity is provided separately in the surface water quality technical memorandum.

2.0 Response

ORC posed the following questions which I respond to in turn in the table below:

All technical disciplines	
Q:	***Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?***
R:	The ecological assessment clearly indicates the methods used, where data was collected from and how it was analysed. There was minimal discussion on the constructed channel and ponds on site with the ecological assessment focusing mostly on the receiving environments upstream and downstream of the landfill. The scope and scale of the ecological assessment is considered appropriate for the size and scale of the proposal.
Q:	***Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]***
R:	The wetland extents in proximity to the landfill were not shown on any of the plans provided, nor were any additional waterbodies on the site that are associated with the

	Kaikorai Stream channel. As part of the S92 response a plan titled Constructed waterbodies and landfill boundaries (Boffa Miskell 29/8/23) was provided with Areas of Significant Biodiversity Value (DCC) and Regionally Significant Wetlands (ORC) which indicate the wetland extent at a very coarse scale. No onsite wetland delineation was undertaken to clearly define the wetland edges. This would ideally have been provided to get a more accurate picture of the site, however as the works do not extend into the wetland and tributary channels the assessment was able to be made without this level of desired detail.
Q:	***If granted, are there any specific conditions that you recommend should be included in the consent?***
R:	I support the ecological conditions proposed related to the revegetation plan and updated bird management plan. In the case of the Vegetation Management and Restoration Plan the condition should be worded to require a Vegetation Management and Restoration Plan to be provided, in accordance with the draft Vegetation Restoration Management Plan Framework. No additional ecological conditions, in addition to those already proposed, are recommended. However, a condition for ecotoxicity monitoring is recommended, with ecotoxicological monitoring undertaken every 5 years, unless there is evidence of significant contamination, or downward trends in groundwater quality or surface water quality. Monitoring should be undertaken in accordance with the method outlined in the Cawthron report. Silt and sediment control requirements, surface water monitoring and ecotoxicity monitoring should be conditioned as outlined in other technical specialists' review memos.
Ecology	
Q:	***Does the application appropriately identify sensitive areas including values within the Kaikorai Stream, upstream and downstream of the proposed activities, wetlands and any other affected water bodies (surface, ground and coastal water)? Yes/no***
R:	The Kaikorai Stream and estuary which extend along the site's north and west margins are located within an area identified as a Regionally Significant Wetland in the Otago Regional Plan and an Area of Significant Biodiversity in the Dunedin City Council Plan. These areas are both discussed at a broad level in the reports alongside the fauna found in these areas as part of survey data. Freshwater ecology and monitoring includes sites both up and downstream of the site. Any potential impacts related to the historic estuary reclamation which could adversely impact groundwater quality (see groundwater quality technical memo) have not been addressed in the ecological report.
Q:	***Is the description of the sensitive areas attributes potentially affected by the activity accurate?***
R:	The attributes of the sensitive areas are only discussed very broadly and the report does not clearly describe other potentially sensitive areas such as the drainage channels in the wetland areas and small tributary channels alongside it. Water quality, sediment quality, macroinvertebrate community and fish community data were provided and discussed. Overall, the description of the sensitive receiving environments is considered appropriate and identifies key features.
Q:	***Has the instream ecology of both the wetland and the Kaikorai Stream been appropriately assessed including both native and sport fish values? Please include details on the appropriateness of the method of assessment***

R:	Aquatic ecology was assessed as part of field assessments and instream sampling, in addition to a desktop assessment. This provided an appropriate assessment of the macroinvertebrate community, instream habitat and native fish communities in the vicinity of the landfill. Brown trout were identified as having been recorded from the Kaikorai Stream catchment, however no specific assessment of potential effects of the landfill on these fish was provided. It is anticipated that the Kaikorai Stream in proximity of the landfill is unlikely to be an important habitat for sport fish such as brown trout.
Q:	***Has the natural character of the watercourse and the wetland been appropriately assessed? Please include details on the appropriateness of the method of assessment***
R:	The ecological assessment only describes the natural character of the watercourse and wetland at a very broad scale. Further detail was sought on the actual extent of wetland habitats including updating the plan to show tributaries and channels associated with it, but this was not provided, with just the overlay extent marked on the plans. A correctly delineated plan would have provided more rigour to the application's ecological assessment particularly in regard to identifying the setback areas of the landfill activities. It is noted however that the wetland itself is not directly impacted by the proposed continuation of the landfill operation (having already been partially reclaimed by historic landfill activities), being located just beyond the operational landfill extent and designation area. In addition, leachate is not directly discharged to this area with the leachate trenches being treated via the wastewater treatment plant located adjacent to the site. As such the information provided is considered sufficient to describe the natural character of this area. While the ecological impact assessment provided did not consider any residual ecological effects remained that necessitated offset or compensation measures, I do not concur as the continued operation and closure of the landfill should take into account impacts from the operation of the landfill thus far. Historically, part of the landfill extended into the estuary itself thus reclaiming part of this area and watercourses within the site and associated terrestrial vegetation have been modified or reclaimed as part of ongoing landfill operations. As such the restoration of the site as part of landfill closure is considered important to compensate for the overall impacts of the operation of the landfill. The Cultural Impact Assessment also sought the restoration of ecological values of the Kaikorai Estuary. A draft Vegetation Restoration Management Plan Framework (Boffa Miskell, 30/9/23) has been provided as part of the S92 response to the ecological and landscape queries however their response noted that it is being proposed only as a requirement related to the Landscape and Visual assessment of effects and is not considered a requirement of the ecological effects assessment. This seeks to ensure the successful restoration of the site following closure of the landfill. Revegetation and restoration at the site alongside closure will provide a significant ecological benefit to the receiving environment by creating a large, vegetated area that will aid in buffering the Kaikorai Stream, in addition to increasing terrestrial ecological values and fauna habitat.
Q:	**Has the Applicant proposed appropriate monitoring for the duration of the consent? I note that ecotoxicology monitoring is mentioned as being ongoing.**
R:	The method and analysis of monitoring ecotoxicity is considered appropriate however the frequency of monitoring is recommended to be every 5 years, unless there is evidence of significant contamination, or upward trends in groundwater quality or surface water quality. The consent conditions should be worded to reflect this.
Q:	***Have the cumulative effects of the activity been appropriately assessed? Yes/no***
R:	No. Cumulative effects have not been discussed in the ecological assessment.
Q:	***Do you agree with the Applicant's conclusions as to the level of adverse ecological effects within the aquatic environment?***

R:	Overall, the ecological assessment accompanying the application indicates the level of effect to the aquatic environment and fauna is very low due to a negligible magnitude of effect on moderate-high ecological values. I agree that the groundwater drawdown will have a negligible effect on the aquatic environment and that no discernible effects have been found in surface and groundwater quality monitoring. There are however indicators of some unaccounted-for leachate loss to the receiving environment. Ecotoxicity tests recorded increased toxicity downstream of the landfill. The ecological assessment assigned the cause of this to other ecological stressors not associated with the landfill. This conclusion is likely to be incorrect as old stream channels beneath the landfill, in conjunction with the leachate trench location, may provide pathways for unrecognised leachate loss. This is discussed further in the groundwater technical review. The results indicate there may be effects that have been identified as being associated with the landfill leachate, that would otherwise not have been detected or been identified if only the surface or groundwater water chemistry results themselves were assessed in isolation. Further analysis and/or modification to the leachate trench in some places is required to be able to quantify and/or minimise potential effects of leachate loss. I also agree that appropriate sediment erosion and sediment control measures are required related to the earthworks activities associated with the landfill.
Bird Management	
Q:	***Do you agree with the applicant's assessment of effects on birds, including threatened species, resulting from the proposed activities?***
R:	Yes, a comprehensive assessment has been undertaken on potential effects to birds as it relates to the landfill and the airport. I agree that risks to birds will reduce as the population decreases with the reduction in putrescible waste and eventual closure of the landfill but also that without mitigation the increased bird strike risk from dispersal due to habitat loss in the landfill will increase. International guidance generally looks at activities within 13 km of an airport in regard to potential impacts on airports. The Green Island landfill is 16 km away from the airport. There is the risk however that as landfill operations reduce the large bird population may search for food further afield as the landfill operations change as part of closure, hence why bird strike risk at the airport is being considered as part of this application. The report indicates that the airport's bird strike is already considered to be high.
Q:	**Does the Applicant propose appropriate mitigations to reduce the risks posed by birdlife, for example on the Dunedin Airport?**
R:	A draft Southern Black-backed Gull (BBG) Management Plan has been developed as part of the new Smooth Island landfill (which is located further south of Dunedin) consent conditions – noting that the Smooth Hill consents are currently under appeal. A final plan is proposed as a condition of consent.
Q:	**Do you agree with the Applicant's conclusions as to the level of adverse ecological effects on birds?**
R:	The bird risk assessment focuses on the risk of bird strike at the airport as a result of disbursement from the landfill as it is progressively capped. It included a survey of birds present at the airport and within the landfill, taking note of those most likely to be at increased risk of bird strike. I agree with the conclusions based on the observed abundance of different species at each site, specific species behaviour and records or bird strikes to date at the airport.

	I agree with the level of adverse effects to birds as a result of the ongoing use of the landfill followed by closure as summarised in the ecological assessment that the operation of the landfill has negligible impacts on birds with a positive impact in the short term for food supply reducing to low as the food supply sources decrease. The closure of the landfill in the long-term will have a positive effect on avifauna as sedimentation and contaminants entering the receiving environment are reduced.
Q:	**Do you agree with the Applicant's conclusions as to the level of risk to the airport posed by birds?**
R:	I agree that without the application of measures to reduce ongoing bird establishment at the site the closure of the landfill may increase the risk of bird strike as active areas of the landfill are closed and they disperse further from the landfill in search of food resources. A draft Black Billed Gull Bird Management Plan has been provided which suitably outlines methods to manage the risk of dispersal from the site.

3.0 Closure

In conclusion, while there are aspects of the proposal where further detail of the existing site would have been desirable, the information provided is generally sufficient to describe terrestrial and aquatic ecological values of the site and the impacts of the landfill operations on these.

No new native vegetation areas or watercourses will be impacted in comparison to those already impacted by the historic and current landfill operations as the landfill will continue within the current active landfill area.

Freshwater ecological values have been described through comparing to upstream monitoring sites. Ecotoxicology approaches and analysis are appropriate for the site.

Ecological impacts related to the increased risk of bird strike at the airport appear to have been appropriately considered and actions proposed to reduce this risk.

However, cumulative impacts have not been addressed in the ecological report.

Regards,

SLR Consulting NZ

Elizabeth Morrison
Principal Ecologist

Keren Bennett
Technical Director - Freshwater

Otago Regional Council

Appendix 6

RM23.185 – Green Island Landfill Landscape Assessment, Technical Review

Memorandum

SLR

DRAFT

To:	Shay McDonald, Senior Consents Planner
Council:	Otago Regional Council
From:	Rachael Annan, Principal | Landscape Planning Lead
CC:	Samantha Iles, Principal Environmental Consultant
Date:	20 November 2023 **Project No.** 13556

RE: RM23.185 - Green Island Landfill Landscape Assessment, Technical Review

1.0 INTRODUCTION

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including subsequent attachments and request for information (RFI) responses submitted by Dunedin City Council (DCC, the applicant)) for the operation, expansion and closure of the Green Island Landfill.

DCC is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2023, following which closure operations and landfill aftercare will commence.

The '*Green Island Landfill Closure Landscape Assessment*' was prepared by Boffa Miskell Limited (March 2023). A Section 92 response on landscape matters was provided within the 'Tranche 4' information (October, 2023). Unless otherwise stated, quotes following are from the assessment document.

2.0 REVIEW MATTERS

ORC posed the following questions in relation to the Landscape Assessment, which I have responded to in this memo. For clarity, these are addressed in two question groups to help avoid the inherent overlap of some qualitative landscape matters.

> *A. Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?*
>
> *B. Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [explain]*
>
> *C. If granted, are there any specific conditions that you recommend should be included in the consent?*
>
> *D. Is the assessment provided by the Applicant in accordance with relevant best-practice guidelines?*
>
> *E. Has the Applicant adequately addressed the potential effects on landscape, natural character, and visual amenity, both during the (expanded) operation and closure of the landfill? Please explain.*
>
> *F. Do you agree with the Applicant's conclusion as the level of adverse effects on landscape values, natural character, and visual amenity? Please explain.*

3.0 RESPONSE

Review Questions Group A.

Is the assessment provided by the Applicant in accordance with relevant best-practice guidelines? Is the technical information provided in support of the application robust? Are there any other matters or additional information that appear relevant to you that have not been included?

Response:

At p.3, the assessment sets out that an approach, and internal peer review, have been undertaken

> *'…following the concepts and principles outlined in Te Tangi a te Manu: Aotearoa New Zealand Landscape Assessment Guidelines'*

These are the Tuia Pita Ora, New Zealand Institute of Landscape Architects, best practice guidelines for landscape assessment (TTTM, July, 2022). I generally agree with this statement. However, the following aspects are noted.

In describing the landscape character of the surrounding environment the assessment draws on existing landscape character studies of the wider area (BML 2007; Mike Moore, 2015). This approach though can limit project and place specific consideration derived from the author's own assessment of the receiving environment. This would afford more tailored consideration to inform assessment findings.

Best practice sets out that distinct landscape characteristics form the basis of consideration rather than generic terms, i.e. '*Effects on amenity and landscape values of rivers and wetlands*' (p.38). This is of relevance regarding landscape sensitivity.

> *'Sensitivity and capacity (and other such generic parameters) derive from a landscape's specific attributes (the generic depends on the specific) and relate to a certain type of activity (a landscape is sensitive to something).'* (P. 124, TTTM)

I agree with the assessment's general description that the site's character is highly modified and that it is identified as such within a composite landscape setting. However, noting also the time past since the above referenced landscape material was written, aspects such as the extent to which vegetation is established in different areas or more recent development areas can differ from the time of writing (reference material noted above) to that of the current situation.

I also consider that in determining landscape support of the application, the assessment has overtly focused on the level of modification of the adjacent estuary (and stream areas). This can in turn imply a lowering of landscape sensitivity to the proposal as a way of setting out capacity for the development.

Further to this, such a focus does not provide a complete basis for considering natural character. Consistent with TTTM, the assessment methodology's natural character definition notes these two aspects (emphasis added):

> *'Natural character effects consider the characteristics and qualities <u>and</u> associated degree of modification relating specifically to waterbodies and their margins, including the coastal environment.'*

The assessment does however, also acknowledges that (emphasis added):

> *'Kaikorai Estuary is a key feature adjacent to the Site, modified but recognised as holding important values, including to mana whenua as well as important bird habitat.'* (p. i)
>
> *'However, although modified, natural character of the adjacent Kaikorai Stream, Abbotts Creek and Estuary is higher* [than that of the site], *particularly in regard to the birdlife it supports and scenic qualities present.'* (p. 25)

Relevant identified landscape values associated with the estuary therefore involve sensory (experiential, i.e. scenic) values, associative values (particularly for mana whenua) and bird-life habitat, *despite* the level of landscape modification.

Focusing on these key localised landscape values, and referencing specific provisions would have also helped contribute to a more robust assessment of effects in relation to Statutory Provisions (from p. 37 of the assessment). More specific reference to distinct reconsigned natural character provisions of RPS would be anticipated and discussed with regard to local estuary and stream characteristics. This is of particular importance given the RMA and underlying Otago Regional Policy Statement weighting to such matters.

The approach of basing the development area's form and location on protecting lower adjacent Clariton Avenue neighbours views towards Pukemakamaka/Saddle Hill (also noted for its value to mana whenua) is also understood (p.9). However, more discussion regarding the weighing up of this approach and related landscape values against the outcomes of the proposed development area and it's proximity to Kaikorai Stream and Estuary (as a regionally significant wetland) would have provided greater clarity. Alongside this is the consideration of the proposal as an appropriate landscape outcome in proximity to these water bodies.

Ultimately, this has become an agreed point. This is largely due to discussion and understanding of the proposal, it's relationship to these adjacent water bodies, mitigating factors and other project outcomes gained by visiting the site and surrounds, albeit that underlying assessment rationale provided was considered to be limited. The effects discussion and resultant recommendations could also have more appropriately drawn on greater place specific consideration of the relationship between the proposal area and these adjacent highly valued areas.

The landscape assessment would have provided more robust findings from further analysis of the relationship between the application site (and development area) with the adjacent estuary; possibly including related cross sections and photographs. These matters warranted greater emphasis in the assessment, and also involving greater reference to relevant matters of the cultural impact assessment (or iwi management plans), and also to the ecological assessment findings.

It was from visiting the site (and project discussions held there), more than reading the assessment, that the sense of separation between the development area and these adjacent highly valued areas is understood, and appreciated as appropriate with regards to this application. In the same way, the overall landscape findings support for the project arrived at by the assessment has been appreciated and supported.

Review Questions Group B.

Has the Applicant adequately addressed the potential effects on landscape, natural character, and visual amenity, including being clear about uncertainties and any assumptions? Do you agree with the conclusions regarding the level of adverse effects on landscape values, natural character, and visual amenity? And do you recommend any specific conditions that should be included in the consent?

Response:

Additional Information has been provided in the S92 Response. This has been checked and summarised in Appendices 1 to this memo, p. 7.

The S92 Response included computer modelled images from viewpoint locations, which have been provided where surrounding dwellings are closer to the site than the adjacent road (as a representative public viewpoint). While this can provide an appropriate alternative solution, these are provided as annotated screen shots (file names indicate the address view depicted). There is however, no supporting methodology information given such as if the comparative focal length is known or the height these are taken at above ground level. Such information could have also confirmed any relevant limitations of this modelling.

It is understood, from discussions onsite that DCC (landfill management/communications staff) have a level of communication established with surrounding neighbours. On this basis, it would seemed a reasonable approach to visit these closer neighbours for viewpoint and visual simulations photography.

Issues Remaining - Recommended Conditions

The assessment heavily relies on a mitigation strategy of the **'Vegetation Management and Restoration Plan**'. This document is not yet available in it's final form and is understood that this is to be provided through partnership and engagement with mana whenua. It is acknowledged that a draft version has been provided with the S92 response. This document is both relied on by the assessment and not yet available to confirm outcomes sought.

Overall, it appears that the management plan also has two roles:

- Providing vegetative mitigation (landscape character and visual amenity), and;
- Responding to cultural values.

There are also tensions in this; that cultural outcome are effectively documented and achieved, but also that landscape mitigation, including visual amenity outcomes are provided for. The ability and opportunity to align these outcomes will follow on from a clear appreciation of them both.

It is anticipated that there may be alignment between ecological values (habitat health and function, i.e. for valued bird life) and outcomes sought by mana whenua.

A Vegetation Management and Restoration Plan is proposed to continue the effective ongoing visual screening with potential long-term visions for the Site, after closure, in mind. It is also recommended to plan for a gradual transition to predominantly native plantings over time as set out in) the Cultural Impact Assessment (Aukaha 2023) and in collaboration with mana whenua. (p.10)

Given the focus of landscape relevant policy matters and values associated with the estuary, the assessment makes limited reference CIA findings; referenced directly only once, as quoted above.

The assessment sets out that over time exotic trees could gradually be felled and removed. The typically greater height of exotic trees to native species needs to be accounted for. If direct replacement is sought, a considerable amount of time is required for legacy scale native trees to reach a comparative height.

This process also needs to account both for the value the surrounding community may place on areas of exotic or specimen tree planting, and also the potential habitat provided by established exotic tree species. While some exotic trees may be a nuisance factor there are also species and specimen trees from which amenity value is derived. They can contribute to the rural character of scenic outlooks.

In summary, this document and mitigation strategy provided should both focus on key landscape values and outcomes as well as effective landscape mitigation.

<u>The following matters are recommended conditions (regarding the proposed Vegetation Management and Restoration Plan).</u>

The following matters should be confirmed (by relevant technical review):

- The effectiveness of the management plan in relation to ecological restoration and habitat health;
- Alignment with mana whenua outcomes sought derived from partnership discussions and the CIA;
- An effective approach to landscape character and visual amenity outcomes for surrounding residents (which draws on community consultation), including review of planting plans and schedules, and;
- Planting implementation shall be signed off by a landscape architect, arborist or other suitably qualified expert, with subsequent monitoring of vegetation health (and any replacement required).

4.0 CONCLUSION

Concerns raised in this technical review are not fatal flaws in confirming support for assessment findings. Agreement with final conclusions reached has been arrived at by having read the assessment, and then visiting the site and surrounds and having the opportunity to discuss the project there.

As noted in the preceding section, the BML landscape assessment relies on the yet to be provided Vegetation Management and Restoration Plan. The preceding recommendation should be incorporated.

The management report will need to clearly demonstrate a mitigation approach responsive to the project's magnitude (scale), and *place specific* landscape values. Technical review of the final management plan is also recommended.

Regards,

SLR New Zealand

Author

Rachael Annan,
Registered Landscape Architect

Principal | Landscape Planning Lead

Peer Review / QA

Melissa Davis,
Registered Landscape Architect

Landscape Architecture Manager

NZILA Registered

Appendix 1

Landscape Related RFI Matters - Summary	
S92 Questions	Notes on Feedback supplied
1. Q49: Please provide and reference (in the assessment) photographs taken from within the site to demonstrate the comparative existing landscape character, and as a relevant basis for effects discussion. These should also illustrate reciprocal views to relevant surrounding locations.	Supplied as screen shots - Computer modelled
2. Q50: Photographs and graphics should set out the existing and proposed extent of the borrow pit area, with accompanying reference in text (Figure 7 - Staging Plan does not clarify this point).	Supplied via screenshots
3. Q51: Figure 1 (graphic supplement) does not illustrate the access route into the site (or other key roads) as stated at p. 13. Please add these in, aligning with assessment descriptions.	Provided in Draft Vegetation Restoration Plan Framework, Figure 1
4. Q52: Please provide a visual simulation for Viewing Location E, noted in the assessment as having higher visual effects than locations A and B from where simulations are provided.	Screenshots supplied showing final height of borrow pit extension
5. Q53: Figure 3 - Topography Plan (of the graphics supplement) requires annotation of landscape features as described in text, p. 16-17. For clarity, please also provide LIDAR contours (or similar) for the surrounds illustrating comparative information for the landscape setting. We note the final contours shown on Fig 3 within the assessment, however this is too small a view of the surrounding area.	Updated topography plan supplied
6. Q54: Figure 4 – Illustrative Cross Section (within the assessment) lacks horizontal dimensions, please provide these for greater clarity.	Spot heights added to cross section: existing height and proposed extension
8. Q55: Some relevant views from dwellings are closer to the site than their representative public viewpoints provided. Further focus has been given in relation to Clariton Avenue properties. We request further consideration in relation to other Viewing Areas/ Locations. As observed while visiting the site and surrounds, this is particularly sought for properties in the vicinity of Blanc Ave, Wavy Knowes Drive and Paterson Street (and roads just above). ZTV analysis may be necessary to address the viewshed more broadly, and through development stages.	Screenshots supplied showing final height of borrow pit extension
9. Q56: 'The Vegetation Management and Restoration Plan' is referenced in the text as both being proposed and recommended. This document needs to be provided to ascertain its effectiveness for mitigation and enhancement.	High level objectives supplied
10. Q57: Please provide a concluding statement on the appropriateness of the application to be integrated into this landscape setting (with reference to Te Tangi a te Manu). Please clarify the concluded finding on landscape effects, described as limited.	Concluding statement provided

Otago Regional Council

Appendix 7

RM23.185 – Dunedin City Council – Technical Audit Responses; Air Discharges

Jacobs

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3 November 2023

Attn: Rebecca Jackson
Team Leader Consents (Acting)
Otago Regional Council

by email: Rebecca.Jackson@orc.govt.nz

Project name: Green Island Landfill Consent Applications
Project no: IS452400

Subject: RM23.185 – DUNEDIN CITY COUNCIL – TECHNICAL AUDIT RESPONSES; AIR DISCHARGES

Dear Rebecca

Jacobs New Zealand Ltd (Jacobs) was engaged by Otago Regional Council (ORC) to complete a technical audit of a Resource Consent application for air discharges submitted by Dunedin City Council (DCC) for the extension and closure of the Green Island Landfill.

Further information was requested in accordance with Section 92 of the Resource Management Act to enable us to make a full assessment of the application, and was supplied by the DCC in four tranches over the period July-September 2023.

In conducting this audit, we have reviewed the technical information related to air discharges from the landfill as detailed in the following reports:

- Waste Futures – Green Island Landfill Closure – Air Quality Assessment, Rev01; report prepared by GHD dated 13 March 2023 (herein referred to as the "AQ Report Rev01").
- Waste Futures – Green Island Landfill Closure – Air Quality Assessment, Rev02; report prepared by GHD dated 27 September 2023 (herein referred to as the "AQ Report Rev02").

We have also referred briefly to the following documents but have not conducted a full review as that is beyond the scope of the air quality assessment:

- Landfill Gas Masterplan Green Island Landfill, version 3; report prepared by Tonkin & Taylor Ltd dated September 2023 (herein referred to as the "LFG Masterplan")
- Green Island Landfill Development and Management Plan, September 2023; prepared by Stantec (herein referred to as the "LDMP")

Jacobs has not reviewed the landfill gas (LFG) modelling and production forecasts, and assumes that the design and operation of the landfill gas (LFG) collection system at the landfill is sufficient to maximise the collection of LFG as far as practicable. Similarly, we have assumed that the engine and proposed new flare have sufficient capacity (at 800 m^3/hr) to handle all LFG collected at peak generation as well as any digester gas from the Green Island Wastewater Treatment Plant (GIWWTP) that would be blended with the LFG for combustion.

Our technical audit of the air discharge consent application is detailed on the following pages, following the question and response framework requested by ORC.

General	
Q1:	Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?

Yes, for the most part the technical information provided in support of the application, including the S92 responses, is robust. In our opinion, there are a small number of issues that were raised in our S92 request that have not been adequately dealt with, however none of these issues are sufficiently significant to prevent us from completing our technical audit. These issues are described in the following sections of this letter where relevant. In addition, the following comments are noted:

- AQ Report Rev02 contains no substantive changes compared to Rev01, such as the inclusion of the two sensitive receptors located within the landfill designation area, despite the S92 information [response to question 84] saying this would be included.
- Errors in the AQ Report Rev01 acknowledged through the S92 process have not been rectified in Rev02, such as:
    - reference to NSW OEH guidance in Section 4.4.3,
    - reference to a 500m^2 working face area in Section 6.1.1 which DCC advised was an error that would be corrected in the Rev02 update to the AQ Report, but has not been rectified.
- The update to the AQ Report from Rev01 to 02 presented the opportunity for the applicant to provide and analyse a further eight months of onsite meteorological data and another year of complaint data, however this was not included.
- The S92 response to question 88 about the applicability of AERMOD in complex terrain is not correct, as there is complex terrain between the site where the LFG is combusted and the receptors.

Q2:	Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]

No further information is required.

Q3:	If granted, are there any specific conditions that you recommend should be included in the consent?

Yes, Jacobs recommends some specific conditions as well as edits to the proposed conditions. This question will be addressed at the end of this letter.

Air Quality	
Q4:	Has the applicant accurately assessed odour effects associated with the operation and management of the landfill?

Sources of odour emissions at the landfill are appropriately identified in Section 3.1 of the AQ Report Rev02.

The odour assessment methodology focused on a risk assessment approach, considering the FIDOL factors (frequency, intensity, duration, offensiveness and location) to identify receptors at highest risk of odour impacts. The FIDOL assessment was conducted for the existing operations, and also with a range of additional management and mitigation measures in place. This approach is considered to be appropriate, albeit with the need to acknowledge that the FIDOL assessment approach is qualitative and identifies relative risk rather than absolute risk of occurrence of offensive or objectionable odours.

Existing odour effects were reviewed primarily by analysing complaint history from July 2017 - August 2022. Complaint frequencies peaked in 2018 and 2019, and DCC attributes this to installation of new landfill gas extraction wells and receipt wastewater treatment plant sludges (for which onsite management practices were subsequently reviewed to reduce odour emissions). It is plausible that these activities could have caused an increase in complaints.

Complaint numbers provided in the AQ Report Rev01 for 2022 were only for the first 7-8 months of the year, and were higher than received in 2020 and 2021. This data was not updated in the AQ Report Rev02, so the total number of odour complaints attributed to the landfill in 2022 (or in 2023 to date) is not known. However, the increase in complaints in 2022 does indicate that the existing odour impacts from the landfill are ongoing. This is also supported by the community odour survey results reported in Section 5.3 of the AQ Report Rev02, where the latest odour survey conducted in 2022 indicates a high level of annoyance from landfill odours in the Clariton Avenue area.

The frequency part of the FIDOL assessment detailed in Section 5.4 of the AQ Report Rev02 takes wind speed and direction frequency data measured at the landfill (a small dataset of 11 months) and applies a classification from an odour assessment guideline published by EPA Victoria in 2022 to identify likelihood of impact. This classification scale proposed by EPA Victoria in an impact assessment context is a new concept that is untested in New Zealand and still being tested in Victoria. The frequency analysis in Section 5.4 of the AQ Report implies a "low" likelihood of receptors around the Receptor 1 cluster (Clariton Avenue) being impacted by odour – however this area does report a high annoyance to odour impacts as evidenced by the 2022 community odour survey. In addition, the frequency analysis does not account for meandering winds under low wind speeds due to the variable terrain around the landfill and offsite to the east of the landfill, which may increase the effective frequency of exposure to odour from the landfill for receptors to the east. This meandering wind was observed by Jacobs during the site visit with pockets of stronger odour being observed near the eastern boundary of the landfill under light wind speeds.

The intensity, duration, offensiveness and location parts of the FIDOL assessment detailed in Section 5.4 of the AQ Report Rev02 were reviewed by Jacobs, and are considered to be appropriate.

Jacobs agrees with the conclusion in the AQ Report Rev02 that a range of mitigation measures (existing and new) are required to manage future odour impacts.

The new mitigation measures proposed are described in Section 6.1.2 and Table 7.1 of the AQ Report Rev02. Jacobs agrees that these measures are appropriate and should be adopted at the site as soon as possible to reduce odour emissions.

The proposed mitigation measures are grouped by source and assessed using the FIDOL approach in Table 7.1 of the AQ Report Rev02 to provide a qualitative assessment of how the mitigation measures will aid in reducing emissions and impacts. Jacobs agrees with this qualitative assessment.

Jacobs agrees with the statement in the AQ Report Rev02 Section 7.1.2 that "based on the implementation of the proposed mitigation measures, odour discharges will reduce in terms of both intensity, frequency and duration". However, Jacobs does not agree that the assessment has demonstrated the statement in the last paragraph in that section that "While odours may still be detectable on occasions at or near the site boundary,

providing the proposed mitigation measures are rigorously implemented, the likelihood of off-site odours being considered offensive and objectionable is low. Consequently, odour discharges are unlikely to cause more than a minor effect."

Overall, Jacobs considers that whilst the proposed measures should result in a reduction in the frequency, duration and intensity of odours noticed by sensitive receivers, evidence has not been provided to demonstrate that off-site odour impacts will reduce to the extent that there is no offensive or objectionable odour effect due to landfill activities. Due to the nature of landfill activities at the site, it is unlikely that such evidence could be provided.

Q5:	Have the effects on air quality including specific effects on neighbouring landowners been appropriately identified and assessed?

Potential air pollutants and their potential air quality effects are appropriately identified in Section 2.3 of the AQ Report Rev02. In essence these potential air quality effects are:

- Amenity effects from discharge of odour or dust from the landfill (discussed above in response to Q4), and
- Human health effects from discharge of combustion gases from the energy centre at the GIWWTP where the LFG is burned in the engine and flare.

The methodology for assessment of combustion gases relies on the use of atmospheric dispersion modelling to assess downwind ground level concentrations of discharged pollutants nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and particulate matter (PM_{10} and $PM_{2.5}$). Jacobs has reviewed the methodology used in the AQ Report Rev02 to conduct the modelling and assess the results, and the following comments are noted:

- Meteorology setup for model:
    - The meteorology for AERMOD was established using the upper air estimator tool included in the Lakes AERMOD modelling program, however no analysis of the suitability of the outputs from this tool was included in the air quality assessment.
    - Wind direction data in AERMET is rounded to the nearest 10 degrees rather than the common convention of randomizing the last digit of the direction to avoid stratification of model results.
    - All surface data in AERMET (wind, temp and RH) is specified at 10m above ground level, rather than the usual convention of specifying wind at 10m and temp/RH at 2m. In addition, the surface station primary met tower base elevation is set at zero metres. These settings may affect the upper air estimator tool outputs.
    - Wind speed and direction is based on Dunedin airport measurements, rather than the onsite data due to the short duration of the onsite dataset. It is noted that by the time AQ Report Rev02 was published sufficient data would have been available for a 12-month dataset to compare with the Dunedin airport data and this would have helped resolve some uncertainty in the model interpretation due to the meteorological inputs.
- Sulphur dioxide (SO_2) assessment using AERMOD
    - SO_2 emissions were calculated assuming a hydrogen sulphide (H_2S) maximum concentration in the biogas of 500ppm, which DCC advised is based on testing of LFG from the Green Island

landfill for the Smooth Hill consent application where a typical H_2S concentration of 400-500 ppm was observed. No data was provided by DCC to support this advice. DCC did not advise whether this testing also included H_2S contributed by the biogas from the GIWWTP which could increase the overall sulphur content of the biogas mix.

- "US NAAQS special processing" was not disabled in the AERMOD setup, which means that model results are based on daily maximum 1-hour values across the year rather than considering all 1-hour values which is not appropriate for New Zealand. However, as the highest rank of 1-hour concentrations was extracted from the model, the use of US NAAQS special processing does not affect the assessed model results.

- 24-hour averages for SO_2 are reported as 99.9th percentiles. The usual convention for reporting 24-hour averages is to use the 100th percentile. This means that the incremental or "site contribution" SO_2 concentrations listed in Table 7.9 of the AQ Report Rev02 for 24-hour averages are under-reported by up to 37%, based on Jacobs' own replication of the GHD model from the model files supplied by GHD.

- The assessment criteria adopted for SO_2 are listed in Table 4.2 of the AQ Report rev02. The source of the assessment criteria is the National Environmental Standards for Air Quality (NESAQ) and the New Zealand Ambient Air Quality Guidelines (NZAAGQ). Whilst the NESAQ and NZAAQG are currently the prevailing regulations and guidelines in New Zealand, the health advice now provided by the World Health Organisation (WHO, 2021 Global Update) recommends a lower assessment criteria for 24-hour average SO_2 of 40 µg/m^3 with 3-4 exceedances allowed per year (rather than the value of 120 µg/m^3 in the NZAAQG).

- New Zealand has not currently moved to revise the NESAQ and NZAAQG in response to the WHO recommendations, however other countries internationally including Australia have done so. If the model results for 24-hour average SO_2 in Table 7.9 of the AQ Report Rev02 were assessed against the WHO criteria of 40 µg/m^3, and taking into account that the listed 24-hour concentrations are 99.9th percentile which accommodates some exceedances, one would still conclude that the risk of adverse effects is minor because the predicted cumulative concentrations at a sensitive receptor are less than one third of the WHO recommendations.

- However, overall it is noted that there are uncertainties in the predicted model results because of the limitations in the meteorology used in the model (as described above), the assumed H_2S composition of the LFG, the use of assumed background concentrations, and the use of AERMOD in complex terrain. Jacobs considers that the sensitivity of the model results to these uncertainties is unlikely to result in predictions of ground-level cumulative concentrations exceeding either the WHO or NZAAQG/NESAQ assessment criteria, however some control on the concentration of H_2S in the biogas burned in the engine and flare is appropriate.

- It is therefore recommended that the concentration of sulphides (expressed as H_2S) in the blended gas burned in the engine and flare be limited to 500 ppm as a consent condition. This would include mixtures of biogas combining LFG from the landfill and digester gas from the GIWWTP.

- Nitrogen dioxide (NO_2) assessment using AERMOD

  - In the AQ Report Rev02, NO_2 emissions were assumed to comprise 100% of the NO_X emission. This provides a very conservative approach to assessing NO_2. The predicted

incremental and cumulative NO_2 concentrations are well below the assessment criteria adopted in the report.

  - The assessment criteria for NO_2 are adopted from the NESAQ and NZAAQG, however as with SO_2 these criteria are now quite large in comparison to criteria recommended by WHO and adopted overseas for 24-hour and annual averages. The NO_2 concentrations now recommended by WHO for air quality guidelines are 10 and 25 µg/m^3 for annual and 24-hour averages respectively (compared to values of 40 and 100 µg/m^3 respectively adopted in AQ Report rev02).

  - Adopting the WHO-recommended annual and 24-hour concentrations for this assessment would be problematic, because the assumed background concentrations are higher than the WHO-recommended concentrations for both annual and 24-hour averaging periods. However, the incremental concentrations from site contribution are much smaller than the assumed background, and also conservatively assume that 100% of the NO_X is converted to NO_2.

  - Therefore, Jacobs agrees with the conclusion in the AQ Report Rev02 that there is limited potential for adverse effects on the environment due to NO_X emissions.

- Carbon monoxide (CO) assessment using AERMOD

  - Incremental carbon monoxide ground-level concentrations predicted by the AERMOD model are very small relative to background and the assessment criteria.

  - Jacobs agrees that the potential for adverse health effects associated with CO emissions is expected to be low.

- PM_{10} assessment using AERMOD

  - Site contributions to ground-level PM_{10} concentrations are very low relative to background concentrations, the assessment criteria, and the requirements in Regulation 17 of the NESAQ. This finding is unlikely to change even taking account of the limitations to the meteorology described above under the discussion for SO_2.

  - Jacobs agrees that the potential for adverse health effects associated with PM_{10} emissions is expected to be low.

- $PM_{2.5}$ assessment using AERMOD

  - Site contributions to ground-level $PM_{2.5}$ concentrations are very low relative to background concentrations and the assessment criteria. This finding is unlikely to change even taking account of the limitations to the meteorology described above under the discussion for SO_2.

  - Jacobs agrees that the potential for adverse health effects associated with $PM_{2.5}$ emissions is expected to be low.

Q6:	If monitoring of the air quality is required, where should monitoring be undertaken, how should monitoring be undertaken, what parameters should be monitored, and how often?

LFG monitoring at Energy Centre

- Monitoring of gas flow rates to the engine and flare(s) should be conducted continuously, including separate monitoring of LFG and biogas from the GIWWTP.

- Monitoring of H_2S composition of the combined LFG/biogas feed to the engine and flare should also be carried out. For the Tirohia Landfill consent applications and appeals, Waste Management proposed a condition (which was adopted in the recommended consent conditions for the appeal) to monitor the concentration of hydrogen sulphide (ppm) in the blended LFG prior to combustion at least weekly. Jacobs recommends a similar consent condition for Green Island.

Odour monitoring

- Jacobs agrees with the proposal by DCC to monitor odour at the site boundary by odour scouts. However, the methodology described in the S92 information response (Tranche 4, question 108 response) indicates that the monitoring would be conducted by on-site staff. These staff would not be independent and are likely to have a low sensitivity to interpret findings of landfill odour and therefore any findings of "no odour" or "weak odour" would have low credibility.

- The application is unclear about the frequency of odour surveys that would be carried out. In the AQ Report Rev01, "regular odour scouting" is identified as a proposed mitigation measure for irregular odorous activities. In the S92 request, the applicant was asked to clarify whether scouting would be used regularly or just for irregular loads. No response to this question was provided and there was no change to the text in the AQ Report Rev02. Odour scouting is not mentioned in the LDMP, but the Tranche 4 response to Question 108 says that it would be included in the LDMP if consent is granted, which provides no certainty about frequency and methodology for scouting.

- Jacobs considers it appropriate to have some independent odour scouting in addition to the site-sourced odour scouting proposed by the applicant. Consent conditions are recommended to incorporate this requirement, following a similar structure to that agreed with Waste Management for the Tirohia Landfill.

Landfill surface monitoring

- The AQ Report Rev02 recommends the following frequency of landfill surface monitoring:

    - instantaneous surface monitoring (ISM) on a quarterly basis until closure (increased regularity to existing operations) to identify any areas of capping that need to be remediated.

    - monthly walk-over inspection of the landfill cap/cover to identify any damage to the cover system and to monitor the effectiveness of the mitigation measures.

- Jacobs agrees with the use of these monitoring measures, but disagrees with the recommended frequency. Monitoring of the landfill cap is important to minimize opportunities for fugitive emissions of odour, both before and after closure.

    - Jacobs recommends using ISM on a monthly basis until closure, and then quarterly after closure.

    - Jacobs also recommends conducting walk-over inspections of the landfill cap/cover on a weekly basis until closure, and then monthly after closure.

- The integrity of the cover system will need to continue to be monitored after closure for some period of time until ORC is satisfied that the risks of LFG migration or cap deformation with associated fugitive emissions of LFG are minimal.

Q7:	Have the cumulative effects of the activity been appropriately assessed? Yes/no

Combustion gases

- Jacobs understands that the LFG engine at the adjacent GIWWTP can burn biogas sourced either from the landfill or from the GIWWTP. This is referred to both in the AQ Report Rev02 and in the LFG Masterplan. It is also understood that the GIWWTP also burns biogas generated at the GIWWTP in boilers.

- The emissions from all biogas and LFG combustion at the GIWWTP should be assessed cumulatively as the activities are essentially one site. The respective generation rates for digester gas from the GIWWTP and LFG from the landfill and the interaction between these two gas sources as feedstock for the engine (and flare) have not been detailed by the applicant, despite a request for further information (Question 106). In the response to this question in Tranche 2, DCC stated that "Combustion of biogas from the WWTP was not included in the modelling undertaken for the engine and flare as it is a separate operation to combustion of landfill gas. Emissions from the biogas boilers have not been assessed."

- Emissions of CO, NO_X, PM_{10} and $PM_{2.5}$ from the biogas boilers are likely to be much smaller than the emissions from the engine due to the type of combustion device, and therefore including these emissions in the AERMOD simulations would have been unlikely to change the assessment conclusions.

- However, emissions of SO_2 from the boilers are unknown because the H_2S content of the biogas is not known. In addition, discharges from the boilers are likely to be of lower temperature than the emissions from the flare and engine and therefore may have different dispersion behaviour.

- Therefore, Jacobs considers that the cumulative effects of SO_2 emissions from the GIWWTP energy centre have not been appropriately assessed. A concentration limit of 500ppm sulphides (expressed as H_2S) in the combined biogas feed to the engine and flare is recommended as a consent condition.

Odour

- The cumulative assessment of odour emissions does take into account odour emissions from the GIWWTP, but does not consider odour emissions from future proposed composting operations on the site. Cumulative effects including the future proposed composting operations will be considered under the consent application for the proposed Resource Recovery Park.

Q8:	Has the applicant accurately assessed the combustion emissions associated with the operation and closure of the landfill associated with flaring of LFG and operation of vehicles and machinery onsite

The assessment of combustion emissions associated with LFG is addressed under question 5 above.

The assessment of combustion emissions associated with operation of vehicles and machinery onsite is provided in Section 3.3 of the AQ Report Rev02 and is appropriate.

Q9:	Has the Applicant correctly assessed the requirements of the NESAQ, with particular regard to Regulations 17, 26, and 27?

In Jacobs' opinion, Regulation 17 of the NESAQ has been correctly assessed.

Regulation 26 is referred to in Section 4.3.1 of the AQ Report Rev 02, although it has not been directly addressed in the AQ Report Rev02 other than to defer to the LFG Masterplan. Consent conditions should ensure that monitoring is appropriate to ensure that any discharge of gas from the surface of the landfill does not exceed 5000 parts of methane per million parts of air. The AQ Report Rev02 states that this monitoring by a commonly used technique known as instantaneous surface monitoring or "ISM" is currently conducted annually, and recommends that this monitoring should be done quarterly. However Jacobs is aware that many landfills are required to conduct ISM monitoring monthly. Given that this monitoring can also detect fugitive odour emissions from the landfill and allow these to be remedied in a timely manner, a monthly frequency is recommended by Jacobs.

Regulation 27 is also referred to in Section 4.3.1 of the AQ Report Rev02, and also defers to the LFG Masterplan as evidence that the site complies with Regulation 27. Whether the flare at the GIWWTP can be regarded as a principal flare for the purposes of Regulation 27, and whether the proposed new flare complies with the design requirements in Regulation 27, is beyond the scope of Jacobs' review.

Q10:	Has the applicant accurately assessed the effects from dust associated with the operation and closure of the landfill?

Sources of dust emissions at the landfill are appropriately identified in Section 3.2 of the AQ Report Rev02.

The assessment of dust impacts is provided in Section 7.2.2 of the AQ Report Rev02. GHD states that they are not aware of any historic complaints in relation to dust from the landfill, and similarly Jacobs is not aware of any complaints nor any other anecdotal evidence of off-site issues related to dust emissions. Given the absence of existing impacts, Jacobs agrees with the conclusion by GHD that based on the operational activities of the landfill, it is unlikely that operation dust emissions will cause any adverse effects beyond the site boundary.

Jacobs also agrees with the dust mitigation measures outlined in Section 6.2 of the AQ Report Rev02 and considers that these measures are appropriate for the site.

Q11:	Do you consider that the mitigation measures proposed by the applicant are appropriate? Please explain.

Yes, Jacobs agrees with the mitigation measures proposed by the applicant for both odour and dust. Our reasons for this conclusion are outlined in the relevant sections above.

No mitigation measures are recommended for combustion gas emissions, and no measures are considered to be necessary by Jacobs other than the proposed consent condition limiting the sulphide concentration in the blended gas fed to the engine and flare.

Q12:	Do you agree with the Applicant's conclusions as to the level of adverse effects on air quality?

Jacobs agrees in part with the applicant's conclusions, for reasons elaborated in the previous sections of this letter. To summarise:

- Jacobs agrees with the applicant's conclusions regarding the potential impacts of dust emissions.
- Jacobs agrees with the applicant's conclusions regarding the potential impacts from combustion emissions from the engine and flare; provided that the condition that the permitted concentration of sulphides (expressed as H_2S) in the blended gas feed to the engine or flare is limited to 500 ppm or less.

- Jacobs does not agree with the applicant's conclusion regarding the potential impacts of odour emissions, insofar as we are not able to agree that the impacts from odour emissions after the implementation of recommended mitigation measures are unlikely to cause more than a minor effect. In our opinion, whilst the proposed measures should result in a reduction in odour emissions, the applicant has not established that off-site odour impacts will reduce to the extent that there is no offensive or objectionable odour effect due to landfill activities.

Q3:	If granted, are there any specific conditions that you recommend should be included in the consent?

Jacobs recommends specific conditions relating to the following:

- Monitoring of the sulphide content of the biogas feed
- Monitoring of gas flow rates to the engine and flare
- Monitoring of stack discharges from the engine
- Monitoring of odour at the site boundary and at sensitive receptors by odour scouts, both by independent contractors and by site-staff, with adaptive management of on-site operations and mitigation measures in response to monitoring outcomes.
- Restrictions on the size of the working face
- Periodic independent review of landfill operations
- Maintaining wind monitoring at the site
- Ensuring that the full range of mitigation measures detailed in AQ Report Rev02 are carried through into the LDMP.

In addition, some modifications to the wording of some of the proposed conditions (version supplied with the application in April 2023) are recommended, and we will provide these recommendations as well as recommended wordings for the items listed above in a tracked-changes version of the latest proposed conditions once that can be supplied.

Yours sincerely,

Tracy Freeman
Principal Air Quality Specialist

tracy.freeman@jacobs.com

Otago Regional Council

Appendix 8

RM23.185 – Green Island Landfill Geotechnical Technical Review

Technical Memorandum

To:	Rebecca Jackson	**From:**	Matthew Adamson
Company:	Otago Regional Council	**SLR Consulting NZ**	
cc:	Sam Isles (SLR)	**Date:**	8 November 2023
		Project No.	13556

RE: RM23.185 - Green Island Landfill Geotechnical Technical Review

1.0 Introduction

SLR Consulting NZ (SLR) has been engaged by Otago Regional Council (ORC) to conduct a technical review of the resource consent application (including subsequent attachments and request for information (RFI) responses submitted by Dunedin City Council (the applicant) for the operation, expansion and closure of the Green Island Landfill.

Dunedin City Council is proposing to continue to extend the life of the Green Island Landfill to allow acceptance of waste until between December 2029 and March 2031, following which closure operations and landfill aftercare will commence.

2.0 Response

ORC posed the following questions relating to general technical matters and specific to geotechnical matters. The subsequent SLR responses to both sets of questions are presented in **Table 1** and **Table 2**.

The objectives of the geotechnical assessment, scope of works, reviewed material and assessment are provided in **Section 3.0** to **Section 8.0** of this technical memorandum.

Table 1 ORC General Technical Matter Questions

All technical disciplines	
Q:	***Is the technical information provided in support of the application robust, including being clear about uncertainties and any assumptions? Yes, or no. If not, what are the flaws?***
R:	The methodology used to perform the slope stability assessment is considered reasonable. The interpretations of the geotechnical parameters based on in-situ field testing and lab results are considered reasonable, with any review comments on the parameters deemed not critical to the overall findings of the slope stability and liquefaction assessment.
Q:	***Are there any other matters that appear relevant to you that have not been included? Or is additional information needed? Please specify what additional info you require and why [please explain]***
R:	The interpretations of the key geotechnical parameters (undrained shear strength, effective friction angle, effective cohesion) were provided upon request. The raw CPT data and laboratory results were also provided to assist with the geotechnical review.

All technical disciplines	
Q:	***If granted, are there any specific conditions that you recommend should be included in the consent?***
R:	No further conditions.

Table 2 ORC Specific Geotechnical Questions

Geotechnical	
Q:	***Is the geological and geotechnical information provided sufficient to understand the site and the land stability effects from the continued operation, closure, and aftercare of the landfill?***
R:	The desktop study and intrusive geotechnical investigations (boreholes and CPTs) performed provided sufficient detail to inform the subsoil layering and geotechnical characteristics. In addition to investigation data and laboratory test results, literature reviews and past local experience was used to determine the design parameters. The closure landfill design geometry was used to model the long-term static, seismic and post-seismic load cases.
Q:	***Does the Liquefaction and Stability Report (appendix 11) adequately address potential effects on landfill stability?***
R:	The natural soils were assessed for their liquefaction potential and their behaviour post-earthquake considered in the slope stability assessments. Where the required slope stability factors of safety were not achieved, seismic slope displacement and lateral spreading analysis was performed. Based on the assessment and findings, proposed remedial measures were discussed. Expected differential settlements due to liquefaction were calculated to be reasonably small and anticipated impact on infrastructure was considered to be minimal.
Q:	***Do you agree with the conclusions reached as to slope stability assessments?***
R:	The slope stability assessment methodology and the cross-sections selected to represent the full range of conditions across the site are considered acceptable. The required factors of safety were met for the static, long-term load cases for all cross-sections. Under SLS seismic, non-liquefaction conditions cross-sections 1, 2 and 6 did not meet the target FoS however the anticipated slope displacements were below the allowable limits. Under ULS seismic, non-liquefaction conditions, all cross-sections did not meet the target FoS however the anticipated slope displacements were below the allowable limits. Lateral spreading was calculated for the ULS seismic, liquified load case with the slope displacements below the allowable limits.
Q:	***Are the measures proposed in the Design Report (appendix 3) appropriate to minimise the release of contaminants to the environment during and following an ultimate limit state seismic event?***
R:	Localised damage to infrastructure (e.g., pipe work, capping) was identified during and post a ULS seismic event. For the section of the landfill that will experience the largest lateral deformation (but within the tolerable limits), the leachate trench has not been installed. It is recommended that the proposed trench be designed with resilience to these deformations. For the remaining sections of the landfill where leachate trenches already exist, differential settlements were expected to be minimal with redundancy measures put in place should a seismic event occur. Where the leachate pipes discharge into a buried header pipe and sewer system, remedial actions are proposed in which existing buried sewer systems be replaced with surface pipes which can accommodate ground displacement and movement. These measures are considered reasonable to mitigate the effects of a ULS seismic event.

Geotechnical	
Q:	***In your opinion, are the proposed conditions of consent appropriate to mitigate adverse effects on persons and the environment?***
R:	Yes, the slope stability and liquefaction assessment have provided an understanding of the associated risks and anticipated ground displacements and movements. All cross-sections satisfy the target slope factors of safety together with the displacement tolerance limits for all SLS and ULS load cases considered. Remedial measures have been recommended which minimise the level of adverse effects on people and the environment.
Q:	***Do you agree with the Applicant's conclusion as the level of adverse effects (associated with land stability risks) on persons and the environment?***
R:	Yes, no adverse effects are expected due to non-seismic stability conditions. Any differential settlements experienced by subsurface drainage due to liquefaction are expected to be minimal. Lateral spreading and ground movement due to a ULS seismic event can be designed for (for new sections of subsurface drainage) or mitigation and monitoring procedures can be put in place for existing subsurface drainage infrastructure to limit adverse effects on persons and the environment to within acceptable tolerance levels.

3.0 Objective

The objective for this geotechnical scope is to perform a technical review on the previous work undertaken associated with the planned extension of the landfill sites design life. As the landfill height increases, the overburden stresses on the underlying ground so to increase. As a result, the stability of the landfill embankments must continue to satisfy the factor of safety requirements for both operation and closure conditions.

This review includes the intrusive geotechnical investigations performed, ground condition classifications, geotechnical design parameter interpretations and slope stability analysis and assessments.

4.0 Scope of Work

To address the above objective, the following geotechnical scope of works as part of this review include:

- Review of relevant documents made available by ORC and associated consultants;
- Review of the interpreted geotechnical parameters used to classify the existing geotechnical conditions;
- Review of the slope stability assessment, including the seismic and liquefaction analysis; and
- Review the assessment of lateral stresses and displacements to be induced on the subsurface drainage and infrastructure due to the proposed increase in landfill height.

Following a review of the Application, a Section 92 Request for Further Information was submitted to the Applicant. This review considers the information presented in the RFI response.

5.0 Available Documentation

SLR has reviewed the following background documentation to inform the geotechnical assessment:

- Green Island Landfill Closure: Assessment of Environmental Effects (Boffa Miskell Limited), version 0, dated 16 March 2023;
- Appendix 02, General Arrangement Plan at Closure (Boffa Miskell Limited), revision D, dated 16 March 2023;
- Appendix 03, Design Report: Waste Futures – Green Island Landfill Closure (GHD), revision 1, dated 16 February 2023;
- Appendix 10, 2022 Geotechnical Investigation Factual Report: Waste Futures – Green Island Landfill Closure (GHD), revision 3, dated 5 March 2023; and
- Appendix 11, Liquefaction and Stability Assessment: Waste Futures – Green Island Landfill Closure (GHD), revision 3, dated 20 February 2023.

The following material was requested and provided to SLR to supplement the design documentation listed above:

- Ground Design Parameter Derivation (GHD), dated 17 November 2022;
- Laboratory test data – Particle Size Distributions, Water Content and Plasticity Index Results (provided by GHD); and
- Cone Penetration Testing raw data files (provided by GHD).

6.0 Assessment of Geotechnical Conditions

6.1 2022 GHD Geotechnical Investigations

Geotechnical investigations were undertaken by GHD between 17 October 2022 and 11 November 2022 to assess the ground conditions of the site. The intrusive ground investigations consisted of seven cone penetration tests (CPTs) and twelve boreholes. The location of the CPTs were performed around the toe of the landfill to classify the geotechnical conditions outside the extent of the landfill embankment. In addition, laboratory testing (Atterberg limits and particle size distribution (PSD)) was performed on samples extracted from the boreholes from varying depths and geological units.

6.2 Geology

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), are likely to be approximately 11 m thick in the landfill area based on previous studies. The KEF was divided into upper and lower layers (members), that being the Upper Kaikorai Estuary Member (UKEM), approximately 4.5 m thick, and the Lower Kaikorai Estuary Member (LKEM), approximately 6.5 m thick.

The engineering geological units encountered around the toe of the landfill are presented in **Table 3**. Note, not all boreholes were conducted around the landfill toe. The boreholes and CPTs used were: BH100 to BH104, BH108, BH111, CPT100 to CPT105, and CPT108.

Table 3 Encountered engineering geological units (Appendix 11, GHD)

Geological Unit	Description	Depth to top of unit [mbgl]	Thickness [m]
Bund	Silty, sand, and clay with MSW and wood fragments	0.0	1.3 - 13.5
UKEM	Sandy silt with minor to some clay and trace to some organics	1.3 - 5.5	0 - 3.2
LKEM	Silt, sand, and clay with pockets of organic, trace seashell	3.95 - 13.5	0 - 8.55
Abbotsford mudstone	Weathered mudstone or siltstone extremely to very weak	4.5 - 16.2	unproven

6.3 Geotechnical Design Parameters

The geotechnical design parameters adopted by GHD for the slope stability assessment are presented in **Table 4**. These parameters were derived based on the available geotechnical investigation data, laboratory test results, literature review and their past local experiences.

Table 4 Geotechnical design parameters adopted by GHD (Appendix 11, GHD)

Geological unit	Unit weight [kN/m^3]	Effective friction angle [^{o}]	Effective cohesion [kPa]	Undrained shear strength [kPa]	Liquefied shear strength ratio
Bund	17	27	1	75	-
UKEM	16	26	0	-	0.08
LKEM	15.5	24	0	15kPa + 0.23*σ_v'	-
Abbotsford mudstone	18	32	10	200	-
Waste (Fill)	14.5	25	3	-	-
Final capping	17	29	2	100	-
Sludge/biosolids	13	24	0	-	-

6.4 Assessment

6.4.1 Geological Unit Stratification

Based on the interpretation of the CPT data, the geological unit stratification determined by GHD (Liquefaction and Stability Assessment, Appendix D) are considered accurate. There are distinct changes in cone resistance (q_t) with depth when the UKEM, LKEM and Mudstone units are encountered below the bund fill. The depth of the units below ground level are summarised in **Table 5**.

Table 5 Geological units encountered in CPT boreholes

Geological unit	Depth to top of unit [mbgl]						
	CPT100	CPT101	CPT102	CPT103	CPT104	CPT105	CPT108
Fill	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UKEM	1.9	1.1	1.4	1.5	1.0	0.6	2.6
LKEM	3.3	4.2	3.6	4.4	2.6	4.0	3.8

Geological unit	Depth to top of unit [mbgl]						
	CPT100	CPT101	CPT102	CPT103	CPT104	CPT105	CPT108
Mudstone	11.7	10.5	11.1	12.6	6.2	12.0	10.8

6.4.2 Geotechnical Parameters

The geotechnical design parameters adopted for the slope stability assessment were "*derived based on the available geotechnical investigation data, laboratory test results, literature review and/or our past local experiences*." (Appendix 11, GHD). GHD have provided their geotechnical parameter derivations based on the borehole data and their CPeT-IT and CLiq results output. The GHD calculation sheet is presented in **Appendix A**. The assessment of the GHD geotechnical design parameters is provided in **Table 6**.

Commentary

Generally, the geotechnical design parameters used in the slope stability analysis for the UKEM, LKEM and Abbotsford mudstone units are considered reasonable. It should be noted that similar to LKEM, the UKEM unit would have an undrained behaviour under certain conditions given the soils high silt and clay content and low cone resistance values as observed from the CPT results. No undrained shear strength was provided.

It should also be noted that without the presence of advanced geotechnical laboratory tests (such as undrained triaxial tests) on samples from the UKEM and LKEM units, the selection of effective parameters (friction angle and cohesion) would be based on literature review and past local experience. Similarly, no geotechnical information was provided on the waste material, sludge/biosolids or final capping material. Therefore, no review can be undertaken on these design values however they appear reasonable.

Table 6 SLR assessment of the GHD geotechnical design parameters

Geotechnical Parameter	Geological Unit			
	Bund	UKEM	LKEM	Abbotsford mudstone
Unit weight [kN/m^3]	The output ranged from 16.4 to 18.5. A design value of 17 is considered reasonable for a silty sandy clayey material.	The output ranged from 15.7 to 16.4. A design value of 16 is considered reasonable for a sandy silt material.	The output ranged from 14.8 to 15.9. A design value of 15.5 is considered reasonable for a sandy silt material.	The output ranged from 19.3 to 20.3. A design value of 18 is considered reasonable for weathered mudstone.
Effective friction angle [^{o}]	The output ranged from 38.3^o to 43.5^o. A design value of 27^o is considered conservative and reasonable.	No friction angle output were provided. A design value of 26^o is considered is reasonable for a sandy silt material.	No friction angle output were provided. A design value of 24^o is considered reasonable for a clay material.	The output ranged from 39.4^o to 41.3^o. A design value of 32^o is considered conservative and reasonable.
Effective cohesion [kPa]	No cohesion output were provided. A design value of 1 is considered reasonable for a silty sandy clayey material.	No cohesion output were provided. A design value of 0 kPa is considered conservative but reasonable for a sandy silt material.	No cohesion output were provided. A design value of 0 is considered conservative but reasonable for a clay material.	No cohesion output were provided. A design value of 10 is considered reasonable for weathered mudstone.
Undrained shear strength [kPa]	The output of 131.3 was provided. A design value of 75 is considered reasonable.	The output ranged from 30 to 60.9. No design value was provided however the PSD results (FC > 52 % minimum), and q_t data (0.1-3.2 MPa) suggest a clay soil. It is therefore reasonable to assume undrained behaviour and undrained strength could be provided.	The output ranged from 25.7 to 44.5. A design SHANSEP relationship of 0.23 x overburden stress, with a minimum strength of 15 kPa was used. Given the overburden (UKEM) layer is up 3.2 m thick and groundwater close to ground level, the relationship is considered reasonable.	The output of 444.8 was provided. A design value of 200 is considered reasonable.
Liquified shear strength ratio	The output of 0.08 was provided. The material was considered to behave like a clay and classified as non-liquefiable.	The output of 0.08 was provided. A design value of 0.08 is considered reasonable.	The output of 0.08 was provided. The material was considered to behave like a clay and classified as non-liquefiable.	The output of 0.08 was provided. The material was considered to behave like a clay and classified as non-liquefiable.

7.0 Assessment of Liquefaction Risk

7.1 Liquefaction Assessment

A total of 38 Atterberg Limits were carried out for UKEM, LKEM and Weathered Abbotsford Mudstone samples ranging in depth from 1.95 m to 17.5 m below ground level. The samples tested are predominately low-plasticity clays (CL), low-plasticity silty (ML) or high-plasticity clays (CH). The results of the index testing are shown on the plasticity chart in **Figure 1**.

Liquefaction potential screening criteria has been included based on Seed et al., where Zone A soils (highlighted in red) are considered potentially susceptible to liquefaction. Zone B (highlighted in blue) may be susceptible to liquefaction. Soils plotting outside zone A and B are generally not considered to be susceptible to liquefaction triggering but may be sensitive.

The criteria is applicable for soils with fines content ≥ 20 % and plasticity index > 12 % or fines content ≥ 35% and plasticity < 12 %. Based on the particle size distribution tests, all geological units have fines contents > 35 %.

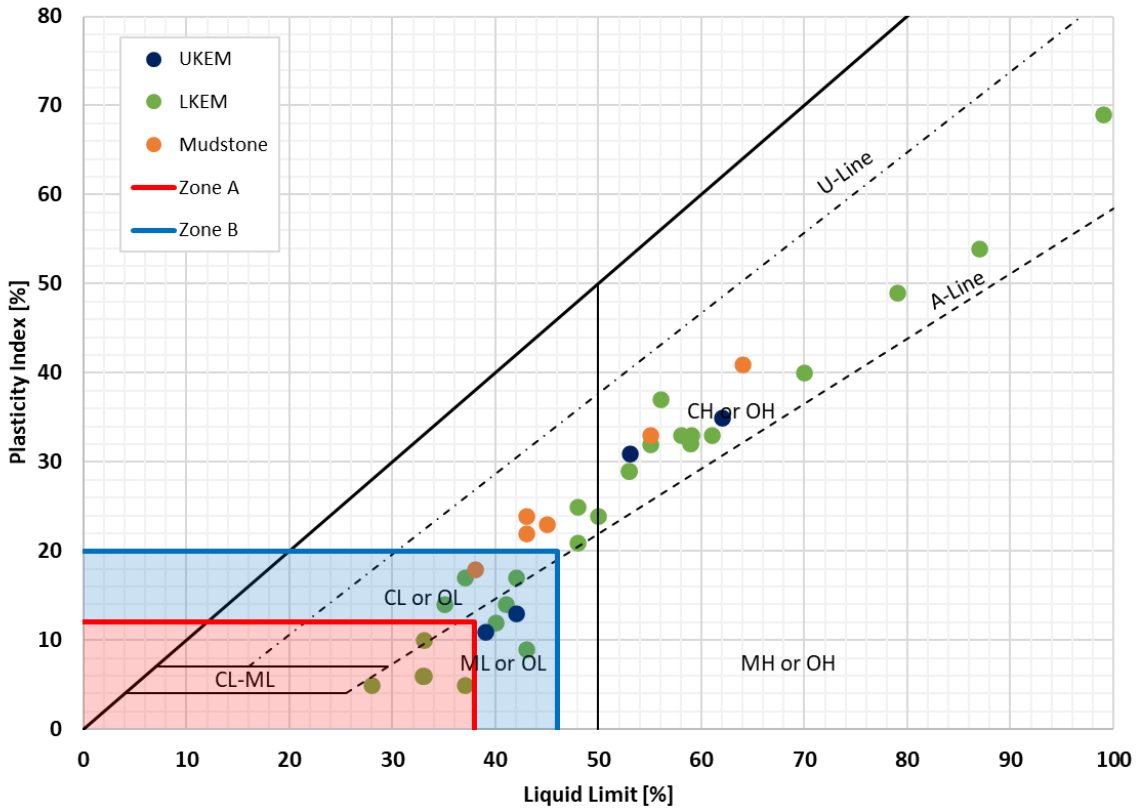

Figure 1 Plasticity Chart

Commentary

Based on the Seed classification, a number of samples from both the UKEM and LKEM units reflect liquefaction potential (Zone A and B). These samples have a higher level of sand content (sandy clay, sandy silty clay, sandy silt, silty sand).

The UKEM unit is predominantly characterised as generally ‘sand like with occasional thin lenses of clay’ while LKEM is generally ‘clay like with occasional thin lenses of sand’. As a result, it is reasonable to assign the UKEM with a ‘High’ liquefaction risk, and the LKEM unit with a ‘Low’ risk.

7.2 Settlements and Risk to Underground Infrastructure

A maximum ULS free field settlement of 35 mm (CPT103) as a result of liquefaction for a return period of 2500 years was documented. SLS free field settlement was considered negligible.

As reported by GHD (Appendix 3, Design Report), "*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*."

Commentary

Given the leachate interception trench (gravel-infilled trench with a slotted PVC drainage pipe) is constructed around the toe/perimeter of the landfill embankment, it is considered reasonable to assume there will be little to no impact on the leachate drainage systems from increasing the landfill embankment height.

8.0 Assessment of Slope Stability Analysis

8.1 Slope Stability Methodology

Six geological cross-sections were generated around the perimeter of the landfill and used for the slope stability assessment on the landfill closure landform. The cross-sections were selected to represent a range of internal landfill structures, which vary across the site and include general changes in fill characteristics and final fill height, and account for the different thickness of underlying estuary sediments.

As the landfill is unlined but capped, the acceptable displacements for SLS and ULS events were considered to be < 0.3 m and < 1.0 m, respectively.

The slope stability load cases and design criteria used by GHD to perform their assessment have been summarised and presented in **Table 7**.

Table 7 Summarised slope stability load cases used by GHD (Appendix 11, GHD)

Load case	Design Criteria	Geotechnical behaviour modelled	Groundwater conditions modelled	Target FoS
Static	Local and global slip planes	Drained soil parameters to be adopted.	long term groundwater and leachate levels	≥ 1.5
			elevated groundwater and leachate levels	≥ 1.2
Seismic - SLS - non liquefied	-	Bund, final capping, LKEM and weathered mudstone units to adopt the undrained parameters. Drained parameters for the remaining units (UKEM, waste/fill and sludge/biosolids).	long term groundwater and leachate levels	≥ 1.0 (or displacement < 0.3 m)
Seismic - ULS - non liquefied	This load case is only valid when liquefaction is not anticipated.			
Seismic - ULS - liquefied	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 < 1.0 m)
Post-earthquake - flow failure	This load case is only valid when liquefaction is anticipated.	Bund, final capping, LKEM and weathered mudstone units to adopt the undrained parameters. UKEM unit to adopt the liquefied soil strength. Drained parameters for the remaining units (waste/fill and sludge/biosolids).	long term groundwater and leachate levels	≥ 1.05

Commentary

Given the significantly high fines contents in the UKEM unit and cone penetration testing profiles, it is not reasonable to assume that the soil would behave drained after a seismic, non-liquefaction event. It can not be concluded if adopting the drained parameters for the UKEM layer for seismic analysis is conservative or not without modelling both scenarios. That being said, the slope stability analysis for both the SLS and ULS seismic, non-liquified load cases yielded unsatisfactory factor of safety (FoS) for the majority of cross-sections. Therefore, the behaviour of the UKEM layer during seismic, non-liquefaction can be considered non-critical and hence the analysis methodology can be considered acceptable.

8.2 Slope Stability Results

Commentary

The slope stability assessment was performed using the limit equilibrium analysis based on the Morgenstern-Price method. The static condition load cases resulted in satisfactory FoS for all cross-sections for long-term and elevated groundwater levels. Under SLS seismic, non-liquefaction conditions cross-sections 1, 2 and 6 did not meet the target FoS however the anticipated slope displacements were below the allowable limits. Under ULS seismic, non-liquefaction conditions, all cross-sections did not meet the target FoS however the anticipated slope displacements were below the allowable limits. Lateral spreading was calculated for the ULS seismic, liquified load case with the slope displacements below the allowable limits.

The parameter interpretations (yield accelerations, shear wave velocity) and the calculations for the displacements and lateral spreading were not included in the reporting so comment can not be made on the accuracy of the assessment however the design criteria and methodology outlined are considered reasonable.

9.0 Closure

SLR trusts that this technical memorandum is adequate for its purpose. We are happy to discuss any aspects of our assessment and work collaboratively with you to undertake additional revisions if required. We also draw your attention to our standard limitations (**Section 10**), which provides additional detail about the utilisation of this memo.

Regards,

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Appendix A – GHD Geotechnical Design Parameters Derivation Documentation