GEORGE TOWN LANDFILL

REMEDIATION OPTIONS REPORT

May 2021

Executive Summary

Introduction

This Remediation Options Report has been prepared by GHD on behalf of DECCO Consortium as part of its tender to Cayman Islands Government to provide and operate an Integrated Solid Waste Management System for the Cayman Islands.

The purpose of this report is to present the conceptual, risk-based approach to the remediation (technical closure) and maintenance (post closure) of the currently operational George Town Landfill in Grand Cayman, leading up to and following the commissioning and commencement of operation of DECCO Consortium's new solution in 2024.

The Remediation Options Report should be read in conjunction with GHD's 'George Town Landfill Environmental Risk Based Assessment' dated May 2021, with a further design submission detailing the specific capping and restoration specifications in accordance with relevant sections of the Florida Administrative Code design standards to follow.

Site Setting

George Town Landfill is located to the north of central George Town, covering a total area of approximately 73 acres. It is owned by Cayman Island Government and operated by the Department of Environmental Health.

The landfill is predominantly a land raise, formed by tipping over an area of former mangrove swamp. Tipping operations commenced in the South Mound in 1989, moving to the North Mound in or around 1999. Waste inputs comprise a combination of residential and commercial waste, plus small *ad hoc* quantities of other materials.

The existing landfill has no engineering containment (basal lining and/or capping system) and operates generally on an uncontrolled dilute and disperse basis. Previously infilled areas have been covered with a thin layer of soil and allowed to naturally revegetate.

Interim Landfill Operations

Tipping operations at George Town Landfill have been focused on the North Mound since 1999, but available space there is becoming increasingly limited. As such, Department of Environmental Health is expected to move its operations to a further disturbed area of land immediately west of the North Mound going forward, remaining there until DECCO Consortium's new solution - which includes a new Energy Recovery Facility and engineered Residual Waste Landfill - comes on line.

Thereafter, all tipping operations at the existing site will cease; with waste inputs switching to DECCO Consortium's new facilities.

Technical Closure, Remediation and Aftercare Options Appraisal

DECCO Consortium and Cayman Island Government's combined goal is to close and remediate the George Town Landfill in a safe, affordable and timely manner, reducing its impact on the environment and making use of both landfill and non-landfill areas to improve the perception of the closed and remediated site from an environmental and social perspective.

Accordingly, a spectrum of remediation options have been considered from: 'do nothing' (the *status quo*), to 'removal of source' (wholesale excavation), to 'landfill mining' (recovering potentially recyclable and recoverable materials) to 'technical closure' (capping) with a variety of after use options.

Of the remediation options, 'do nothing' has been ruled out as an option - at least for active areas of the site - on the basis of this running contrary to recognised international standards and good landfill practice. Moreover, a 'do nothing' approach ignores the existing risks to receptors in the area.

Thereafter, ‘wholesale excavation’ and/or ‘landfill mining’ have also been ruled out on the basis of technical difficulty, safety, environmental and amenity concerns, and affordability. All of these conclusions are in line with those reached previously by Cayman Island Government in the Outline Business case (Consultation Draft, Sept 2016).

‘Technical closure’ of the site therefore presents the most workable and safely deliverable form of remediation for the George Town Landfill. In the case of the newer, more active North Mound, this includes for the provision of a low permeability vegetated cap, landfill gas collection system, storm water management and long term monitoring and maintenance. In the case of the older, less active South Mound, monitoring results and risk based modelling assessments show the site is no longer having an unacceptable impact on the surrounding environment and, as such, does not warrant a low permeability cap or landfill gas management system; but does still require storm water management and long term monitoring and maintenance.

Potential after use options for the site (covering both landfill and non-landfill areas) have then been considered, cross-referencing these against a series of engineering and environmental screening criteria in order to develop a proposed after use solution for the site.

Proposed Technical Closure, Remediation and After Use Solution

Based on the above, and a further exercise to evaluate and rank various potential capping systems, DECCO Consortium’s proposed technical closure and after use solution taken forward for environmental risk assessment is summarised as follows:

North Mound (including haunch area)

Open space, including a Geosynthetic Clay Liner to cap the North Mound of the landfill to Florida Administrative Code Chapter 62-701 standards, supported by applicable leachate, gas and surface water management controls (including utilisation of the captured landfill gas from the North Mound in the new Energy Recovery Facility) for the site.

South Mound

Open space, based on the naturally revegetated existing surface, supported by applicable leachate, gas and surface water management controls for the site.

Non-Landfill Areas

Open space encouraging naturally occurring flora and fauna, potentially supported by limited new infrastructure development.

Technical closure and remediation programme

DECCO Consortium currently envisages commencing physical technical closure and remediation works for the North Mound in 2020, with a phased programme of work leading up to closure and remediation of the landfill by early 2024. Please refer to Figure 8 in the main body report for the envisaged stage-by-stage programme for the site.

Post Remediation Management

DECCO Consortium will manage and maintain all completed areas of capping and remediation - together with the supporting gas, leachate and surface water management systems - that fall under its control for the duration of the 25 year Integrated Solid Waste Management System contract period. The remainder of the site will continue to be managed and maintained by Cayman Island Government.

As part of its responsibilities, DECCO Consortium will undertake a regular programme of environmental monitoring covering air and odour, gas, leachate, groundwater and surface water quality; with the resulting findings and any resulting or required corrective actions reported back to Cayman Island Government as part of the agreed contract reporting programme.

Similarly, DECCO Consortium will be responsible for establishing and maintaining an emergency response plan for the areas of the site under its control, covering the controls and procedures to be adopted in case of an abnormal and emergency event such as landfill fire, explosion, flooding, other major environmental incident or personal injury requiring attendance by the emergency services; with a similar plan being developed for the remainder of the site by Cayman Island Government.

Risk Assessment of Proposed Technical Closure and Remediation Solution

In support of this Remediation Options Report, DECCO Consortium has assessed the merits, viability and feasibility of the proposed technical closure and remediation solution on a risk basis; evaluating the acceptability of its performance in order to satisfy stakeholder requirements in terms of protecting human and environmental health.

The results of the adopted solution have also been compared to the *status quo* (uncontrolled landfilling) arrangements to assess the environmental improvement provided by the new solution.

The risk based assessment confirms that a landfill cap with an active landfill gas management system is required to be provided over the North Mound to reduce its impact on the surrounding environment, but is not required for the older, less active South Mound.

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1. Introduction

1.1 Introduction

This Remediation Options Report (ROR) has been prepared by GHD on behalf of DECCO Consortium (DC) as part of the Cayman Islands Government (CIG)'s tender to contract for the provision of an Integrated Solid Waste Management System (ISWMS) for the Cayman Islands; forming one of the 'Early Works' tasks agreed between the parties.

The purpose of the ROR is to present DC's conceptual approach to the remediation (technical closure) and maintenance (post closure) of the currently operational George Town Landfill (GTLF) in Grand Cayman, leading up to and following the commencement of operations of DC's new ISWMS facilities.

The ROR takes into account various previous studies and data compiled on behalf of CIG, building on the findings from these reports to identify technical closure, remediation and after use options for subsequent evaluation against a defined set of objectives to determine a proposed solution for further source → pathway → receptor risk assessment and validation.

The risk assessment findings are compared to the *status quo* landfilling arrangements and used to inform DC's detailed design plan for the technical closure and remediation works. This, together with the agreed long-term aftercare plan, will form the basis of a 'living' Landfill Restoration Plan for the site.

1.2 Exclusions

The following items are excluded from this report, to be considered in separate reports:

- Management/relocation options for an existing 0.9 acre lined and capped landfill at the GTLF site containing arsenic contaminated soil and wastes (DC to report)[1]
- Remediation options and long term care for Cayman Brac Landfill (CIG to report)
- Remediation options and long term care for Little Cayman Landfill (CIG to report)
- Monitoring and long term care of South Mound (CIG to report)

[1] Although the relocation of this fill site is considered a requirement to advance the development of the Residual Waste Landfill (RWL) - one of the ISWMS facilities and subject to EIA - this work is not part of the GTLF Remediation. The presumptive solution for the relocation is to excavate the contaminated material and relocate it into the lined RWL.

2. Site setting and receptors

GTLF's site setting is well defined in Amec Foster Wheeler (now Wood)'s 'Landfill Site Environmental Review' of March 2016, which includes a preliminary conceptual model identifying various on- and off-site sources of contaminants/hazards and potential pathways to receptors. The key points from this Review as pertain to the ROR are summarised for ease of reference as follows.

2.1 Site setting

General setting

The GTLF is located to the north of central George Town, towards the western coast of Grand Cayman as shown in

Figure 1. It is owned by CIG and operated by the Department of Environmental Health (DEH). The total site area is approximately 73 acres.

The landfill is predominantly a land raise, formed by tipping over an area of former mangrove swamp that was partially excavated to recover the underlying marls (calcareous soils). The site has no engineering containment (basal lining and/or capping system), operating generally on an uncontrolled dilute and disperse basis.

Tipping operations commenced in the mid-1960s, with the waste volume being reduced by burning until 1985. Thereafter, the mode of tipping switched to placing and compacting waste with heavy equipment (with no formal landfill engineering) in 1989; which approach continues to this day.

Waste inputs comprise a combination of residential and commercial waste, with small *ad hoc* quantities of other materials. Previously infilled areas having been covered with a thin layer of soil and allowed to naturally revegetate.

Overall, the GTLF comprises six interlinking parts[2]:

- An older, inactive area known as the South Mound (approx. 8.0 acres of landfill in 10.2 acres of property to be retained by CIG)
- A newer, active landfilling area known as the North Mound (approx. 25.2 acres)
- Current tipping area referred to as Haunch Area (approx. 3.6 acres) and generally considered part of the North Mound in the technical closure considerations
- A small lined landfill that received arsenic contaminated material resulting from burning treated lumber after Hurricane Ivan (approx. 0.9 acres)
- Approximately 5.7 acres of previous pond (west of the North Mound) created by mining for marl and infilled with debris created by Hurricane Ivan in 2004
- The remaining site area, some of which has historically been contaminated by waste or waste related activities

[2] Area descriptions expanded by DC for the purposes of this ROR.

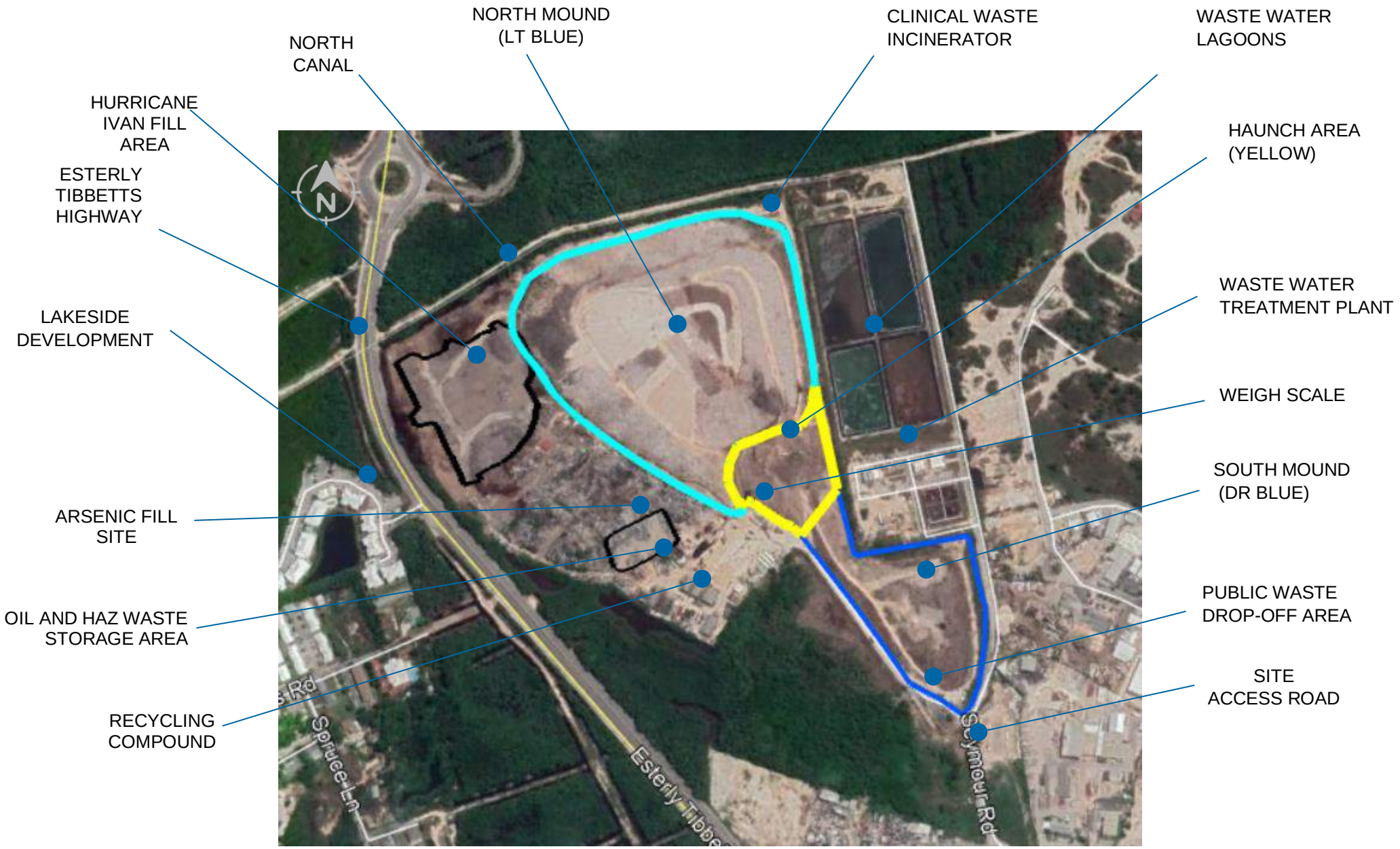

Figure 1 GTLF general site layout

Topography

The land surrounding the landfill is mainly flat. Where developed, the profile comprises reclaimed former mangrove swamp. The height of land surrounding the landfill varies between approximately 2 and 5 feet above mean sea level (MSL). The highest part of GTLF is the top of the North Mound at approximately 98 feet above MSL.

Surrounding land use

The land usage surrounding the landfill is summarised as follows:

- Immediately to the north of the site is a tidal drainage channel developed for mosquito control that connects with North Sound to the east. The area immediately north of the drainage channel is mangrove swamp. The Cayman International School and Camana Bay development are located approximately 0.2 miles and 0.5 miles north of the landfill respectively
- Beyond the eastern boundary of the site is land owned by Cayman Water Authority and comprises four large former wastewater treatment lagoons that are still used for sludge storage. The lagoons are lined and variously sludge and water filled. To the south of the lagoons is the current wastewater treatment plant including some buildings and four smaller basins. Some 0.1 to 0.2 miles east of the landfill site is land zoned for industrial use. This is mainly undeveloped or used for open storage. DEH's collections depot (comprising several trailers for staff facilities and parking for staff and collection vehicles) is located on approximately 1 acre of land to the east of the wastewater treatment lagoons
- To the south of the site is an area of mangrove with industrial and commercial development beyond. This land is occupied by a variety of businesses, including a concrete batching plant and a concrete block and paver stone manufacturer
- The Esterly Tibbetts Highway (the main arterial road to West Bay) is immediately adjacent to the fence line forming the western boundary of the site. The Lakeside residential development is located west of the road and approximately 330 ft from the landfill boundary and a further 610 ft from the area currently used for active landfilling of waste. This development comprises 12 three-storey residential apartments with car parking and leisure/landscape areas (including a small lake). The North Mound of the GTLF is visible from the easternmost lakeside buildings

Geological setting

The geology in the vicinity of the George Town site is summarised in the following Table 1:

Table 1 Geological succession adjacent to GTLF

Elevation (ft)	Thickness (ft)	Period	Series	Formation
+1.5 to +4.0	2.5	Made ground	Made ground	Imported fill
0.0 to +1.5	1.5	Quaternary	Holocene	Peat (swamp deposits)
0.0 to -3.0	3.0	Quaternary	Pleistocene	Ironshore Formation (calcareous marl)
-3.0 to -7.5	4.5	Quaternary	Pleistocene	Ironshore Formation (very soft friable limestone)
-7.5 to -25	17.5	Quaternary	Pleistocene	Ironshore Formation (soft friable limestone and marl
-25 to -45	20	Tertiary	Oligocene-Pliocene	Pedro Castle Formation (hard dolomite and limestone)
-45 to >-300	>250		Oligocene-Pliocene	Cayman Formation (dolostone)

Groundwater levels

Monitoring of on-site groundwater levels by Post, Buckley, Schuh & Jernigan (PBS&J)[3] in 1991 indicated these to be subject to tidal cycles with a tidal lag, with a head difference of between 0.45 ft and 0.68 ft (mean 0.56 ft) above the corresponding tidal level in the North Sound.

Groundwater quality

Historic groundwater quality testing in and around the GTLF (by PBS&J, DEH and Amec Foster Wheeler) shows evidence of some leachate contamination, with elevated ammoniacal nitrogen (particularly in monitoring well MW21), total alkalinity and total organic carbon (TOC) (again, particularly in MW21). Elevated lead, iron and chromium, benzene, toluene, ethylbenzene and chlorobenzene were also noted (at generally low concentration levels).

The emission of such leachate contamination into the sensitive North Sound water and marine ecosystem is of particular concern to DC. Such shallow-water marine ecosystems are usually highly sensitive to contamination. This is one of the main site risk-receptors pairings considered in this ROR.

General chemistry

The pH range of the groundwater was typically 6.7 to 7.6, with specific conductance testing indicating a saline influence. Ammonia concentrations on occasion exceeded the Florida clean-up standard for poor yield/low quality groundwater, with orthophosphate, nitrate and nitrite concentrations indicating elevated nutrients in the groundwater.

Elevated hydrocarbon levels have also been noted since a hydrocarbon release from the waste oil storage area in 2004. These still currently exceed the WHO guideline value of 0.3 mg/l for carbon bands C12-C16, i.e. diesel range), but generally appear to be declining following the remediation of oil contamination encountered in the perimeter canals.

Surface water quality

Historic surface water quality testing in and around the GTLF by PBS&J/DEH/Amec Foster Wheeler shows this to be brackish, with slightly elevated levels of nutrients, including ammoniacal nitrogen. Organic constituents are similar to those found in groundwater.

General chemistry

Historic chemistry testing in and around the GTLF by PBS&J/DEH/Amec Foster Wheeler shows that the pH range of the surface water is typically 7.3 to 8.2, with specific conductance testing at the canal mouth with North Sound indicating an increasingly saline influence from west to east. Observed ammonia concentrations in the perimeter canals reflect poor to moderate water quality (believed to be mostly due to leachate overtopping the toe ditches to the west and north of the landfill during high rainfall events, together with leakage from the wastewater treatment ponds and some impact from groundwater base flow), with some elevated turbidity as compared to the Florida marine water clean-up standard. Elevated hydrocarbon levels have also been noted on a limited basis.

[3] Environmental Assessment of Grand Cayman Sanitary Landfill, Grand Cayman Island, BWI. Post Buckley, Schuh & Jernigan Report for CIG, 1991.

Marine water quality

Marine ecology North Sound

Historic studies around the GTLF by PBS&J/DEH/Amec Foster Wheeler shows that dense turtle grass (thallassia testudinum) in the mouth of the northern canal displays moderate epiphyte growth in the grass blades, indicating elevated suspended solid concentrations. Solids are, however, rapidly dissipated as they leave the canal system. Reactive phosphate and nitrate-nitrite concentration build-up suggests that nutrients leaving the North Canal are also rapidly dispersed and bio accumulated, with nutrient loading leading to some eutrophication in the adjacent part of North Sound.

Sediment sampling

The contamination gradient of (very limited) sediment sampling by PBS&J/DEH/Amec Foster Wheeler within the northern canal indicates the GTLF to be the potential origin of some canal sediment contamination.

Biological sampling

Samples of mangrove from the sides of the north canal, algae and sea grass from the north canal at the point of discharge into the North Sound and turtle grass from the North Sound seabed collected during historic testing in and around the GTLF by PBS&J/DEH/Amec Foster Wheeler display elevated chromium and nickel levels. The presence of algae where the North Canal drains into the North Sound further evidences some eutrophication around the canal discharge.

Soil sampling

Samples of soil from the banks of the perimeter canals generally display contaminant concentrations not exceeding Florida soil clean-up standards as per previous studies by PBS&J/DEH/Amec Foster Wheeler.

Monitoring locations

Please refer to Figures 2 to 12 in the March 2016 Environmental Review report for the complete set of monitoring/sampling locations and contaminant concentrations.

2.2 Site receptors

The Amec Foster Wheeler Report includes a Conceptual Site Model (CSM) that identifies contaminants and amenity related hazards, potential pathways and receptors from both on- and off-site sources.

Potential contamination and hazards

On-Site Sources

Per Table 3.13 of the March 2016 Environmental Review report, the identified on-site sources of contamination and hazards are summarised in the following Table 2 (with DC commentary inserted to the final two right hand columns):

Table 2 Potential contamination and hazards (on-site)

Location	Source	Contaminant type (C) contaminant or (H) hazard	Type	Quantitative data source (Y) yes or (N) no	Comment	Can Risk be Eliminated By interrupting Source-Pathway-Receptor link	Confirmation of Risk Mitigation
Soils around waste area	Unknown, could be from former waste burning	C	Arsenic	Y	Exceeds Florida soil clean-up assessment criteria but generally below UK assessment criteria. Noted at three locations. Arsenic containment pit on-site	PARTIALLY - pathway for human health will be eliminated by covering and capping the contaminated material	Regular monitoring of cover to ensure no gaps, erosion, cracking etc. and maintenance when required
Waste oils storage area	Hydrocarbons	C	Hydrocarbons	Y	Oil contamination noted by Amec Foster Wheeler within well MW16. 0.84mg/l DRO in surface water at SW12	YES – source of oils will be removed	Clean up to FAC clean up standard, monitoring of ground and surface waters with potential additional action as necessary
Groundwater	Leaching from wastes	C	Ammonia	Y	The Florida clean-up standard of 28 mg/l has been exceeded in MW10 and new monitoring well MW21 which had the highest result yet recorded at the site in 2015	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Groundwater monitoring further mitigation if required, monitoring of cap integrity
Groundwater	Leaching from wastes	C	Iron	Y	Detected above the clean-up level of 3 mg/l with results ranging up to 11 mg/l	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Groundwater monitoring further mitigation if required, monitoring of cap integrity
Groundwater	Leaching from wastes	H	Orthophosphate	Y	Found at reduced concentrations in surface water	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Surface water and groundwater monitoring further mitigation if required, monitoring of cap integrity
Surface water canal	Leaching from waste and groundwater base flow	C	Ammonia	Y	The April 2015 sampling identified concentrations of between 2.0 and 6.5 mg/l in the perimeter canals	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Surface water and groundwater monitoring further mitigation if required, monitoring of cap integrity
Surface water canal	Leaching from waste and groundwater base flow	C/H	Metals	Y	The 2006 DEH sample from SW3 recorded exceedances of the relevant clean-up levels for copper and lead.	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Surface water and groundwater monitoring further mitigation if required, monitoring of cap integrity
Surface water canal	Leaching from waste and groundwater base flow	H	Elevated nutrients	Y	Nitrogen and orthophosphate in canal with potential eutrophication impact to North Sound	PARTIALLY - leaching will be significantly reduced through reduction of rain water infiltration by use of low permeability cap	Surface water and groundwater monitoring further mitigation if required, monitoring of cap integrity

Location	Source	Contaminant type (C) contaminant or (H) hazard	Type	Quantitative data source (Y) yes or (N) no	Comment	Can Risk be Eliminated By interrupting Source-Pathway-Receptor link	Confirmation of Risk Mitigation
Surface water canal	Runoff	H	Turbidity and dissolved solids	Y	Some historical issues noted	YES – pathway will be eliminated. Run-off will cease to be contaminated when waste is capped and surface water efficiently controlled	Surface water monitoring further mitigation if required, monitoring of cap integrity
Sediment at canal mouth to North Sound	Historical run-off	C	Sulphate	Y	Potentially associated with hydrogen sulphide generation	YES – pathway will be eliminated. Run-off contamination from landfill will cease to be an issue when waste is capped, however contamination could be from other source(s)	Surface water monitoring further mitigation if required, monitoring of cap integrity Monitoring and identification of other potential sources
Incinerator	Stack emission	C/H	Combustion products	N	No emission test data	YES – source will be eliminated. Incineration unit to be decommissioned.	New technology will developed to ensure negligible emissions
Landfill area	Landfill gas	C	Methane and carbon dioxide	Y	Methane potentially explosive and carbon dioxide an asphyxiant	PARTIALLY – pathway will be substantially disrupted by capping the site and collecting the gas	Landfill surface methane monitoring and perimeter ground gas monitoring
Landfill area	Landfill gas	C/H	Hydrogen sulphide	Y	Hydrogen sulphide elevated in one of the gas probes	PARTIALLY – pathway will be substantially disrupted by capping the site and collecting the gas	Landfill Surface gas monitoring
Landfill area	Landfill gas	C/H	Trace gas components	Y	Trace gases are a source of odour and a potential fire or explosion hazard within the landfill	PARTIALLY – pathway will be substantially disrupted by capping the site and collecting the gas	Landfill Surface gas monitoring
Landfill area	Municipal waste	H	Dusts	Y	Measured deposition rate less than guideline value but limited data	YES – pathway will be eliminated by capping the waste mass	Confirmation of dust mitigation through monitoring after remediation completed
Landfill area	Municipal waste	H	Smoke from fires	N	Combustion products; capping to shield waste from spark sources	YES – potential source of fires will be eliminated by capping site – oxygen will not be available to support fires in waste	Monitoring of cap integrity and maintenance as required Monitoring of gas collection system
Landfill area	Municipal waste	H	Vermin attracted to the wastes	N	Spread of food scraps and bones	YES – source will be eliminated by capping the waste mass	Monitoring of cap integrity and maintenance as required
Landfill area	Municipal waste	H	Flies and insects	N	Pest control carried out	YES – source will be eliminated by capping the waste mass	Monitoring of cap integrity and maintenance as required

Location	Source	Contaminant type (C) contaminant or (H) hazard	Type	Quantitative data source (Y) yes or (N) no	Comment	Can Risk be Eliminated By interrupting Source-Pathway-Receptor link	Confirmation of Risk Mitigation
Landfill area	Tyre storage	H	Combustion products from accidental fires in tyre storage areas	N	Combustion products from tyre burning have the potential to impact offsite residential users	YES – source will be eliminated by shredding and utilizing tyres or by recovering tyres in ERF	No further stockpiling of tyres
Landfill area	Municipal waste	H	Scavenging birds	N	Scavenging birds attracted to the landfill could increase the bird strike risk to aircraft	YES – source will be eliminated by closing capping the waste pile	Monitoring of cap integrity and maintenance as required

Off-Site Sources

Identified off-site sources of contamination and hazards are further summarised in Table 3:

Table 3 Potential contamination and hazards (off-site)

Location	Source	Contaminant type (C) contaminant or (H) hazard	Type	Quantitative data source (Y) yes or (N) no	Comment
Wastewater sludge lagoons	Sludge decomposition	C	Hydrogen sulphide	N	Hydrogen sulphide generation from former/active sludge lagoons indicated by monitoring
Wastewater sludge lagoons	Sludge decomposition	H	Odour	N	Odour generation from former/active sludge lagoons
Various industrial premises	Soil and aggregate storage	H	Dusts	N	Various sources of dust generation on industrial premises to the south east and south of the site

Receptors

The identified receptor groups are summarised in the following Table 4:

Table 4 Receptors

Receptor group	Comment
Site workers and visitors	Site has open access and members of the public can access out of hours
Adjacent residents	Lakeside development and Parkside Close located approximately 330ft (100m) from site boundary and downwind of the site. The Camana Bay development is located approximately 0.5 miles beyond the northern boundary.
Adjacent commercial/ industrial premises	Industrial and commercial premises to the south and east of the site. The airport is located approximately 1 mile beyond the southern boundary of the site.
Groundwater	Groundwater is brackish and in continuity with perimeter canals. There are public water supply (PWS) abstractions approximately 1 mile from the site; this water is treated.
Surface water in canals around the landfill	The canals are tidal and brackish water. There is no recreational use.
Marine water in North Sound	There is no specific water quality designation for the area of western part of North Sound adjacent to the landfill. However other parts of the Sound are used for diving and wildlife interaction and these activities indicate the quality of water required to sustain them.
Ecological receptors	Some birds were noted in the 'leachate' ponds onsite. The canals are fringed by mangroves which are a roost for birds. Iguanas swim in the canals and were also seen on the landfill. Some large fish were observed in the eastern part of the North Canal during the April 2015 water sampling. North Sound contains a diverse marine ecology.

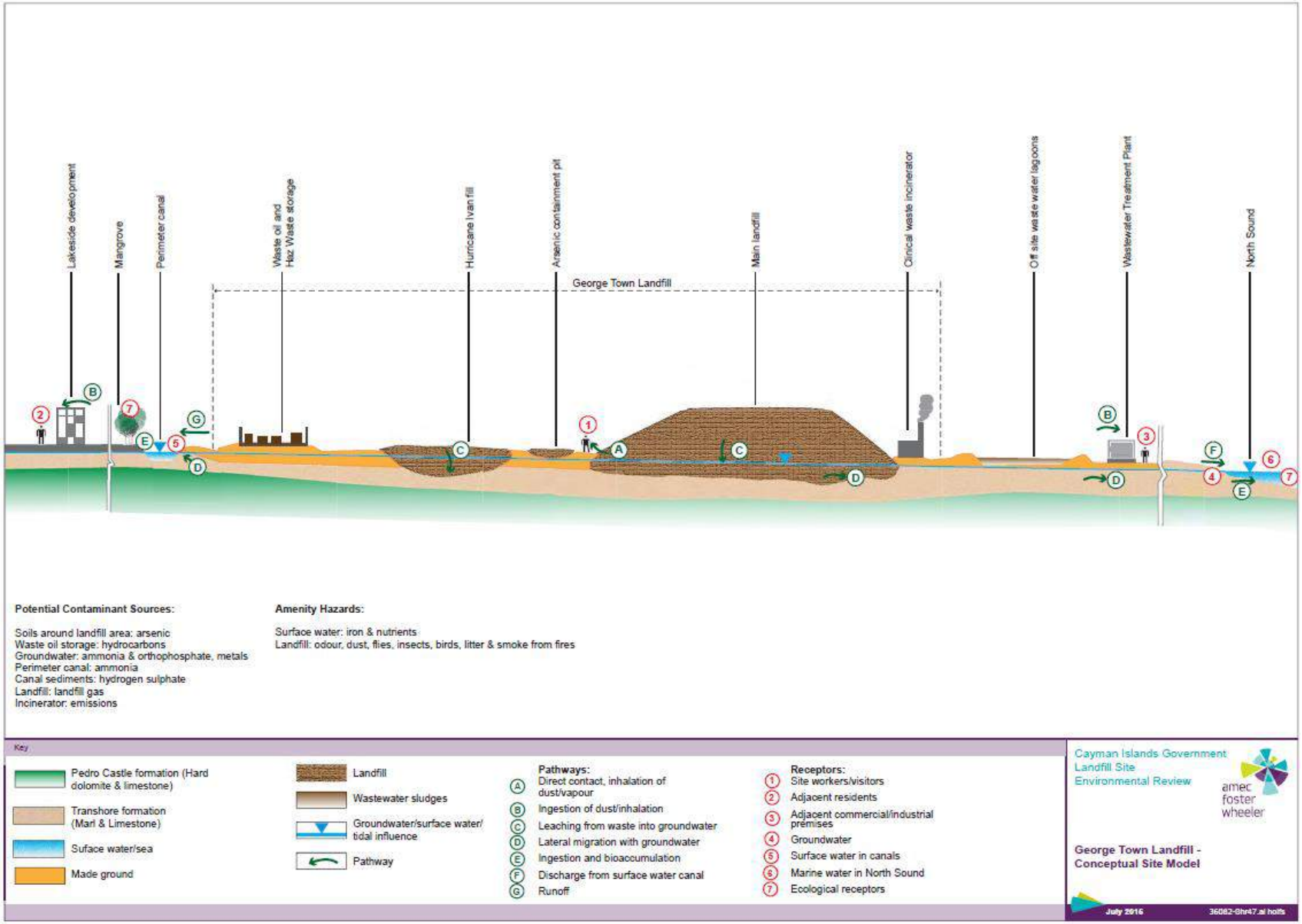

Figure 2 Amec Foster Wheeler Conceptual Site Model

Pathways

The identified potential pathways are summarised in Table 5:

Table 5 Potential pathways

Receptor	Pathway
Site workers and visitors	Dermal contact, direct contact, ingestion, inhalation
Adjacent residents	Ingestion of dusts, inhalation
Adjacent commercial/ industrial premises	Ingestion of dusts, inhalation
Groundwater (including PWS extraction)	Leaching and migration
Surface Water (canals and North Sound)	Run-off (to canal only), migration and groundwater base flow
Ecological receptors offsite	Ingestion and bioaccumulation from contaminated waters/sediments. Eutrophication from elevated nutrients affecting marine ecology in North Sound.

Additional receptors

The exact configuration of the agreed after use will be discussed and developed in conjunction with CIG following completion of the risk assessment carried out for the GTLF technical closure solution as a whole (see Section 10).

The risk assessment includes consideration of various additional sources of contamination/hazard, receptors and potential pathway(s) to the receptors introduced by the intended after use.

In general, the expanded conceptual model considers and addresses similar source → pathway → receptor risks to those associated with the landfill area that are outlined in Table 2 (including DC commentary), Table 4 and Table 5 of this report; but also includes *inter alia* the following:

- Generation of additional contaminants (especially leachate) during site reprofiling, capping and remediation activities
- Physico-chemical properties of selected capping and remediation materials (especially topsoil layer with potential for direct contact with users)
- Exposure for users to contaminants and hazards by air, water (i.e. leaching) and/or direct contact with capping and remediation materials
- Exposure of users to contaminants and hazards by air, water and/or direct contact in surrounding non-landfill areas (including gas, leachate and surface water management systems)
- Proximity and duration of exposure to contaminants and hazards for users associated with selected after use
- Additional exposure to contaminants and hazards due to deterioration (erosion, scour, settlement, etc.) of capping and remediation layer(s)
- Management of additional wastes arising from the agreed after use (e.g. grass cuttings)

Again, per Section 10, the primary intention is to address the above through a combination of engineering considerations and mitigation measures; supported by additional monitoring and/or further studies as required.

2.3 EAB screening opinion and input to ROR content

With reference to DC's overall ISWMS proposals, CIG's Environmental Advisory Board (EAB) produced an Environmental Impact Assessment (EIA) Scoping Opinion in November 2017 that included reference to the GTLF closure plan, requiring that:

> *"The closure and monitoring of the existing George Town Landfill (phased) including landfill capping, leachate collection implementation of groundwater and surface water controls as required, landfill gas collection and utilisation, and end use design/revegetation will be the subject of a* ***Landfill Restoration Plan****, informed by risk-based assessment."*

In support of this position, EAB provided further feedback in its 'Review of Suggested Content of Remediation Options Report' in May 2019, reconfirming the following:

> *"****Site Setting & Receptors:*** *It will be important for the remediation options report to consider the geology and groundwater regime at the landfill site and the surrounding areas. Within close proximity to the site there is substantial use of groundwater for various purposes including municipal water supply; these potential receptors will need to be identified and considered within the context of groundwater impacts."*

In response to this, DC and CIG responded to EAB regarding the Review in June 2019 as follows:

> *"****Site Setting & Receptors:*** *We agree with EAB's comments in this section and in addition to groundwater matters, we note that air quality and air emission impacts on nearby receptors will also be considered. The ROR will also build on the landfill site environmental review previously undertaken by Amec Foster Wheeler (now Wood) in 2015 and will consider any change to receptors that have occurred in the interim."*

3. Previous studies and environmental monitoring summary

CIG has developed an extensive suite of studies and reports relating to GTLF's environmental setting. This ROR summarises and builds on the findings of these reports and in particular is responsive to the risks identified by AMEC in the "Landfill Site Environmental Review; March 2016". The historical reports, include *inter alia* the following:

- Amec Foster Wheeler Landfill Site Environmental Review, Task 1: Environmental Review (February 2015)
- Amec Foster Wheeler Landfill Site Environmental Review, Task 2: Environmental Investigations Interpretive Report (March 2016)
- Amec Foster Wheeler Technical Note: Review of DEH Monitoring Report (June 2017)
- Wood Technical Note: George Town Landfill Site: Surface Emissions Survey (September 2016)
- Wood GasSim Model Update (February 2018)
- Wood Technical Note: George Town Landfill Site: Surface Emissions Walkover Survey (April 2018)
- DEH environmental monitoring data (2016 and 2019)

A brief summary of the contents of each of these reports is set out below.

3.1 Amec Foster Wheeler Landfill Site Environmental Review (February 2015)

Precursor to the Task 2 Environmental Review. Historical data and environmental risk assessment findings from the Task 1 Review updated and incorporated within the Task 2 Review.

3.2 Amec Foster Wheeler Landfill Site Environmental Review (March 2016)

Please refer to Section 2 above.

Landfill gas quality (2015)

Limited landfill gas monitoring data from 6 probes within the landfill show methane and carbon dioxide concentrations indicative of landfill gas (~50-60% methane and ~25-45% carbon dioxide) with no or little (~2% or less) oxygen.

3.3 Amec Foster Wheeler Review of DEH Monitoring Report (June 2017)

In June 2017, Amec Foster Wheeler undertook a review of a DEH groundwater and surface water sampling exercise from December 2016; comparing the results to the findings of its 2015 investigation. The results of the comparison showed metals concentrations in the 2016 round of sampling to be of a similar magnitude to those recorded in 2015, as were inorganics in the groundwater and surface water samples. Where results registered exceedances of the Florida groundwater and surface water clean-up standards, the locations and parameters (predominantly sulphates and total dissolved solids) displaying exceedances were also broadly the same in the 2015 and 2016 samples.

Two monitoring wells (MW9 and MW13) were also reported as being lost or compromised, with a recommendation that these be replaced.

Looking forward, Amec Foster Wheeler recommended that routine monitoring of groundwater should be undertaken at least annually for groundwater and six monthly for surface water at the GTLF. For hydrocarbon analysis, an alternative test suite was recommended to help identify where vehicles may have been landfilled without being drained of fuel and oil.

3.4 Wood Surface Emissions Survey (September 2016)

Over a 5 day period in September 2016, Amec Foster Wheeler undertook a monitoring survey aimed at measuring methane emissions from the surface of the GTLF. The survey consisted of two elements: a brief walkover survey and a further flux box survey.

Methane flux

The results of the surface emissions survey showed the average methane flux in soil covered and/or vegetated areas to be around three times that of areas of uncovered waste (at around 0.45 mg/m^2/second and 0.18 mg/m^2/second respectively). This suggests that the soil is helping allow the underlying waste to become anaerobic more quickly and increase landfill gas generation, particularly in newer areas of the site.

Comparison with modelled site emissions

Comparing the surveyed methane emissions with Wood's (theoretical) GasSim model value, the recorded (snapshot) results equate to approximately 1,777 tonnes of methane per year against a bulk gas model estimate of 1,922 tonnes per year.

3.5 Wood GasSim Model Update (February 2018)

Landfill gas generation

GasSim[4] modelling of the GTLF shows total bulk gas increasing over time, peaking in the final year of landfilling before gradually reducing over time.

The resulting estimate, based on Wood's 2018 modelling, shows bulk gas generation at the GTLF peaking at around 640 m^3/hr (377 cfm) in 2019 assuming average moisture conditions (considered reasonable for modelling purposes) within the landfill; followed by a relatively steep tail due to the age of the majority of the waste in the landfill.

[4] UK Environment Agency endorsed landfill gas estimating tool.

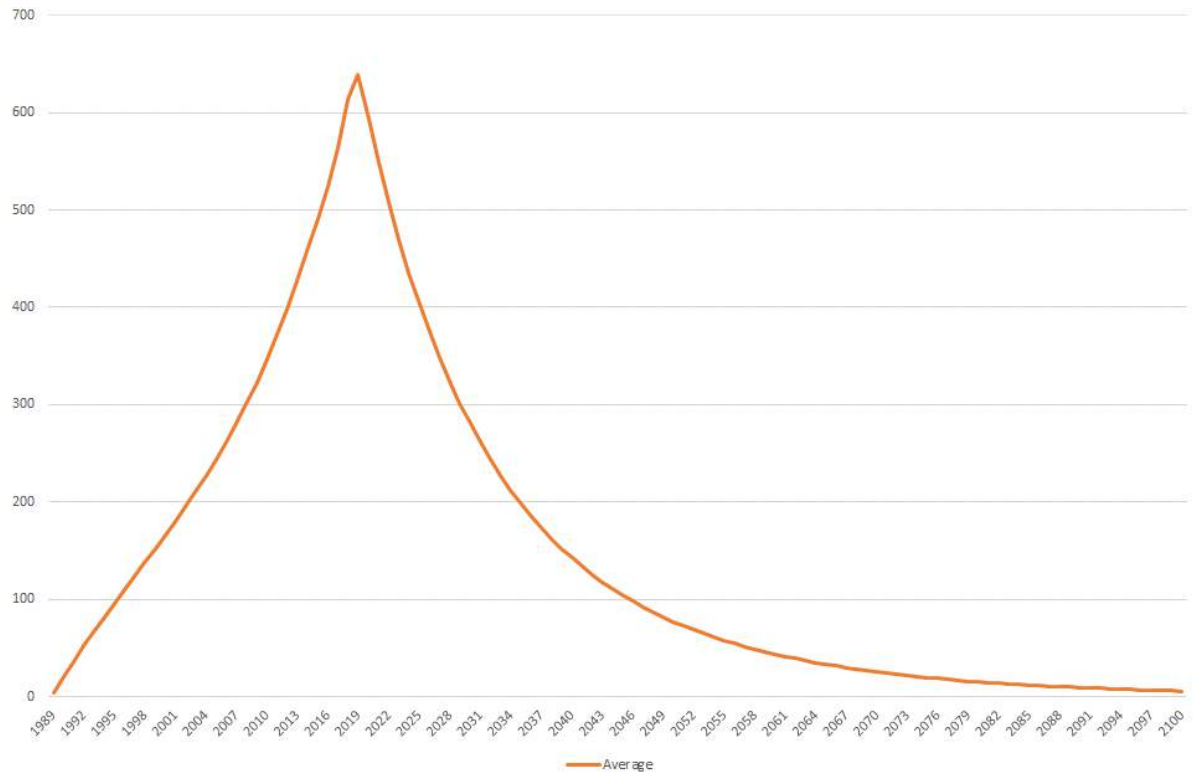

Figure 3 Wood 2018 bulk gas generation estimate (m^3/hr)

DC notes that the 'bulk gas generation curve' does not represent the recoverable gas resource, but rather the total quantity of gas available if the gas collection efficiency was 100%.

3.6 Wood Surface Emissions Walkover Survey (April 2018)

A further up monitoring survey aimed at measuring methane emissions from the surface of the GTLF was undertaken by Wood over 4 day period in April 2018, this time consisting of a brief walkover survey and further gas probe monitoring.

Survey results

The results of the 2018 surface emissions survey were broadly comparable with the 2016 findings, with the higher methane concentrations being found in the newer (less than 2 year old) waste deposits. Various non-landfill areas were also surveyed, but methane was not detected in these areas.

3.7 DEH Environmental Monitoring Data (2016, 2019 and 2020)

Minimal change from previous results, data reviewed and reported in the risk based assessment produced in support of the ROR.

4. Interim landfilling operations

4.1 Sequencing

The anticipated tipping and capping plans for the remaining parts of the existing GTLF have been sequenced into seven phases as described below.

4.2 North Mound filling (Phase 1)

Waste disposal operations have recently been focused on top of the North Mound of the GTLF, being substantially completed in March 2020. The top of the tipping area currently finishes in a plateau sloping north-south from approximately 98 ft aMSL to approximately 94 ft aMSL. Moving forward, the plateau surface (approximately 2 acres) will be gently mounded to promote surface water run-off from the future landfill capping system. The additional material placement is expected to be completed by September 2020, raising the maximum landfill height to approximately 102 ft aMSL.

During this time, an initial 6 inch layer of cover material will be placed over approximately 6 acres of the northern and eastern side slopes of the North Mound.

4.3 North Mound haunch filling (Phase 2)

General landfill operations transferred to the haunch area of the North Mound in or around April 2020, utilising additional airspace above the existing waste between the North and South Mounds. This additional airspace is expected to provide around fifteen months of extra filling capacity, lasting to around July 2021.

During this time, a 6 inch layer of cover material will be placed over a further 5 acres of the North Mound side slopes and the 2 acres of the completed surface of the North Mound plateau.

The Phase 2 operations will include the clearance of stockpiled metals and other materials from the northwest landfill extension area of the GTLF, allowing the area to be prepared for future landfilling. This area is at approximately 2 to 5 feet aMSL and is underlain, in the most part, by wastes arising from Hurricane Ivan (2004) which were deposited in a former marl borrow pit in this area. The northwest extension area will cover an area of approximately 6 acres and will be the final area for landfilling of municipal wastes. The existing ground surface in the extension area will be levelled and compacted as possible and perimeter bunds of inert waste constructed to contain the first few lifts of waste. There will be no engineered basal containment of the waste[5].

4.4 North Mound capping (Phase 3)

Phase 3 will mark the commencement of capping works over the North Mound side slopes and plateau. This will comprise a rolling programme of regulating layer placement, gas well installation, installation of an artificial sealing layer and restoration soils over around 13 acres of landfill. Waste disposal will continue in the haunch area.

[5] The rationale for not providing basal containment to the proposed north west extension of the landfill is summarised as follows:

- The area is underlain by pre-existing (Hurricane Ivan) waste, being an estimated 10 to 12 feet thick and largely saturated; hence the extension is over previously deposited waste rather than virgin ground
- The geotechnical characteristics of the existing waste are very poor, and unsuitable for supporting a lining system that would then be surcharged with up to 50 feet of new waste with considerable differential settlement
- The existing landfill does not have any basal lining system and the impact on surface water and groundwater is limited
- The extension will be filled at the same time that the existing landfill is being restored. Therefore the total uncapped area of landfill will not increase relative to the current condition; by the time filling commences in the extension area of 6 acres some 15 acres of the existing landfill will be in the process of being capped
- The extension area will operate for no more than 3 years and be capped on completion; hence this capping will also isolate the existing Hurricane Ivan wastes

4.5 Northwest landfill extension (Phase 4)

During Phase 4, landfilling will commence in the northwest extension area. There will be over-tipping over existing wastes where the extension abuts the North Mound, an operation known as piggybacking, with the maximum height of the extension tying into the 60 ft contour on the North Mound. The side slopes of the northwest extension area will be at 1:3 vertical to horizontal.

Landfill operations will continue in the extension area until the ISWMS ERF becomes operational.

During this time, a 6 inch layer of cover material will be placed over the completed surface of the North Mound haunch (circa 10 acres) and remaining North Mound side slopes (circa 3 acres).

4.6 North Mound haunch capping (Phase 5)

Phase 5 will mark the commencement of capping works over the North Mound haunch. This will comprise a rolling programme of regulating layer placement, gas well installation, installation of an artificial sealing layer and restoration soils over around 10 acres of landfill, together with the final 3 acres of North Mound side slope. Waste disposal will continue in the northwest extension area.

4.7 Capping of northwest extension (Phase 6)

Phase 6 will see landfilling completed and blinding, regulating and capping works commencing in the northwest extension and associated piggyback area, comprising some 8 acres in total.

4.8 Completion of restoration (Phase 7)

Phase 7 marks the completion of capping and restoration works to the landfill. The restored area is approximately 34 acres in total.

5. Monitoring and mitigation during landfilling operations

5.1 Landfill monitoring and mitigation

In order to reduce, control and measure the risk posed by landfill and its proposed development, the interim operation of the landfill by DEH will meet the requirements of the Florida Admin Code 62-701.500 as modified for use in the Cayman Islands. This operation will be conducted according a landfill operation monitoring and management plan ('the plan'). A copy of the operational plan will be held on site in the landfill office alongside all landfill records.

The full content of the plan will be prepared prior to the operation of the north west landfill extension. Prior to preparing the plan, proposed summary content is provided here. The plan will account for the landfill's operation in the following areas:

- Site arrangement
- Site roles and responsible persons
- Site access and security
- Site Emergency Plan
- Waste Acceptance Criteria
- Waste reception
- Waste tipping plan and temporary capping
- Landfill gas management
- Leachate management
- Surface water management
- Fugitive emissions
- Vermin and mosquito / insect control
- Recordkeeping and reporting

A summary of the above is provided in the following sections.

5.2 Site arrangement

The landfill site is accessed from Seymour Drive via the main gate. The main gate leads to the main site access road and the scale house. The landfill is accessed via temporary unpaved haul roads which lead to the waste placement areas. The waste placement areas will vary dependent on the phase of the waste placement. The site arrangement is shown in

Figure 1. The proposed phasing plan is described in Section 4.

5.3 Site roles and responsible persons

The site will have the following roles and duties assigned to persons:

Table 6 Landfill roles and responsibilities

Receptor	Pathway
Assistant Director Solid Waste	Overall responsibility for all Solid Waste activities
Operations Manager	Overall responsibility for Solid Waste operations including the landfill
Landfill Foreman	Overall responsibility for the management of landfill operation and management
Heavy Equipment Operators	Operating heavy equipment such as excavators, dozers, compactors and other waste processing equipment
Landfill Attendants	General activities on and around the landfill inclusive of "spotting" that is directing waste traffic to the correct area of waste placement, checking loads as they are discharged for non-compliant or problem materials.
Scalehouse Attendants	Operating the weighscale and recording of the details of the incoming and outgoing loads and providing scalehouse reports

When the landfill is receiving wastes, the landfill will have at least one trained operator and one trained spotter at each working face.

5.4 Site access and security

The landfill site will be open from 7 am until 6 pm Monday to Saturday. The landfill site container drop off area in front of the main gate is open 24 hours per day 7 days per week.

The site shall be bounded by a permanent fenced structure to prevent unauthorized disposal of waste onsite and to discourage trespass to site.

The site will be accessed by main gate and gate house which will be manned and controlled at all times with a security barrier in place. Access to persons will be restricted to workers, to those with appointments on site and to persons or entities transporting waste materials for disposal. A procedure for signing in and out will be in place with records taken and retained of those persons entering and leaving each day.

When the site is closed, a full height lockable gate will be used to prevent access to the main landfill area.

5.5 Site emergency plan

As part of the operational plan, a site emergency plan will be in place to cover landfill fires or natural disasters and hurricanes. The emergency plan shall be kept at the facility at all times and shall be accessible to facility operators. The emergency plan shall include:

- Designation of persons responsible for implementation of the emergency plan
- Procedures for notification of appropriate emergency response persons, including the department, the local government, and Cayman Islands Fire Service (CIFS)
- A description of emergency procedures to be followed, including the location of fire-fighting equipment and explanations of how to use this equipment
- Procedures for notification of customers, neighbours and local government officials of the potential impacts of the emergency, and provisions to minimize those impacts.

5.6 Waste acceptance criteria

The landfill will accept waste materials for disposal, in this case it is understood that "waste" is any substance or object which the holder discards or intends or is required to discard.

The types of waste accepted will include but not limited to general non-hazardous household, putrescible, commercial, industrial and agricultural wastes, dead animals, yard trash, waste tires, carpet, textiles, metal, cardboard, paper, glass, plastic, furniture other than appliances. This also includes construction and demolition wastes which are discarded materials including but not limited to steel, glass, wood, brick, concrete, soils, asphalt material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a structure. In addition, rocks, soils, tree remains, trees, and other vegetative matter which normally results from land clearing or land development operations for a construction project.

Prohibitions and Exclusions

- Burning – open burning of solid waste is prohibited
- Hazardous wastes – no hazardous waste shall be disposed of in the landfill except small amounts of household generated materials contained within residential collections
- Biomedical waste – no biomedical waste shall be knowingly deposited in the landfill unless the biomedical waste has been properly incinerated or treated so that little or no biohazardous material remains in the residue. Inevitably, there may arise biomedical waste generated by an individual as a result of self-care, or care by a family member or other non-health care provider. However, in order to reduce the chance of exposure to the public, home generators will be advised to segregate and package such waste before disposal and provide to the hospital
- Oils – automotive, cooking and other oils
- Automotive Waste – such as automobile, motorcycle, truck, trailer, semitrailer, truck tractor etc. and their parts of components thereof shall be segregated at the scalehouse and stockpiled in other locations for processing and recycling
- High energy content materials – these materials typically used tyres and wooden pallets will be identified and segregated at the scale house and diverted to a stockpile area. These materials will be stockpiled for future addition to the ERF. The materials may be shredded using onsite processing equipment to enable more efficient storage. The storage of the stockpiles will be managed in accordance with Cayman Islands Fire Service guidance

5.7 Waste reception

All waste accepted into the landfill shall be transported into site by road going vehicles. Each vehicle entering the site shall report to the gatehouse and sign in and then be directed to the scale house.

Information from each load of materials for deposition shall be recorded at the site weigh scale. The information recorded shall include:

- Date and time
- Ticket number
- Gross weight
- Tare weight
- Net weight
- Waste type
- Customer ID
- Unique Vehicle identifier

The records will be recorded on an electronic database.

Upon completion of the above information, the scale house operator will indicate to the driver the tipping location for their materials and any other relevant instructions.

5.8 Waste tipping plan and temporary capping

The placement of waste will be constructed according to a tipping plan which will detail the proposed layout, arrangement, height and estimated timings in accordance with the overall phasing plan. The tipping area shall be maintained as a small as reasonably practicable for the access, tipping and egress of waste collection vehicles. The waste shall be spread in layers of approximately 2 feet and compacted using a waste compactor or bulldozer to 1 foot thickness or as reasonably practicable.

Temporary cover materials shall be placed such that compacted waste materials are secured. The temporary cover materials will be composed of imported granular soil whether placed as is or mixed with shredded vegetation or soil fines to produce a binding cover to the waste. These materials will be stockpiled onsite and transported to the tipping area for use during cover operations. The option to use proprietary cover products such as sheeting or spray-on cover systems may also be considered dependent on their suitability.

Waste shall be constructed in “lifts” of height of approximately 10 feet before placement of waste in the area ceases and approximately an 6 inch thickness of temporary capping material shall be placed over. The temporary capping materials shall be composed of inert fill. The tipping operations shall be moved to another area adjacent to the previous one. Once the waste has reached the required height for the sideslopes and the landfill top; interim capping materials will be placed over the top of the waste.

5.9 Landfill gas management

The anticipated remediation proposals will be to install a low permeability cap to enclose the landfilled waste. Despite this enclosure, the landfill gas will be produced by the waste. The landfill gas is a primary source of landfill odour and represents a risk of fire or explosion if not managed. Therefore this gas will need to be managed throughout the operational phase of the landfill and during the post closure period. If managed correctly, however, the risk posed from odour to surrounding receptors and of landfill fire is greatly reduced.

The anticipated means of landfill gas management will be through the installation and operation of a landfill gas collection system. This system would be based on vertical collection wells drilled into the waste and sealed through the low permeability landfill cap. These wells would then be connected to sub horizontal transmission pipework buried in the restoration soils. The landfill gas would be conveyed through this pipework to either a high temperature flare or to the proposed ERF. For further information refer to Section 6.

The management of the landfill gas system will be undertaken by DC during the phased remediation and landfill operation phases leading into long term management post closure.

The landfill gas system will require routine balancing of the gas flows and inspections and maintenance to ensure integrity and efficient operation.

Furthermore, to monitor any lateral migration of landfill gas; perimeter boreholes (at locations to be determined) and onsite structures will be sampled and monitored.

5.10 Leachate management

The GTLF currently operates as a dilute and disperse landfill, with no engineering containment or leachate collection system. Despite this lack of leachate collection, monitoring of receptors in surface waters indicates a low impact from the landfill (see Section 2 for details).

The main source for the landfill leachate is rainfall derived. Given the proposals for installation of a landfill cap, the generation of leachate is expected to be reduced significantly. Based on this expected reduction (or virtual elimination), no active leachate collection or treatment is proposed.

However, periodic inspections of the landfill will be undertaken to assess if localised leachate issues, such as surface outbreaks, have arisen. In the event of such issues, remediation measures will be proposed and carried out. These will likley utilise the use of recirculation of leachate back into the waste at the top of the landfill making use of the absorbative capacity of the waste.

Groundwater monitoring will be carried out from boreholes around the perimeter of the site and the results of this monitoring will provide information on the performance of the capping system. Should this monitoring indicate potential issues, further monitoring would be undertaken as required to identify the source of the issue and to enable rectification works to be carried out.

5.11 Surface water management

The landfill will have an internal surface water management system. The purpose of the surface water management system is to ensure that surface water is controlled particularly under storm conditions. This controlled flow ensures that surface water flows do not erode landfill capping materials, damage the site infrastructure, become contaminated with waste or leachate or leave the site in an uncontrolled way.

The design of the surface water management system is to be confirmed. However, it is anticipated that this will be based on a series of surface water intercepting ditches which transmit surface water at low velocity to designated discharge points. These ditches will be emplaced in and around the perimeter of the remediated landfill.

The surface water will be monitored for composition at designated monitoring locations both with the landfill system and externally in the surrounding watercourses. This monitoring will be carried out to primarily to monitor for and to mitigate against contamination of the surface water by landfill derived leachate or from suspended solids. Should this monitoring indicate such, further monitoring would be undertaken as required to identify the source of the issue and to enable rectification works to be carried out.

5.12 Fugitive emissions

The management of fugitive emissions shall be undertaken to prevent waste materials or their derivatives from egressing the site. The following types of emissions will be managed accordingly:

Dust

Measures will be taken to reduce the risk of dust generation from landfill operations, either from the site's unpaved access roads or other activities in the management of the site. To limit the mobilization of dust from roads, the movement of traffic will be restricted to the tipping area and the site speed limit will be restricted to 10 miles per hour.

The primary means of controlling dust will be through the use of a water truck.

The site will be monitored visually for dust generation by the landfill personnel and if required, the water truck will be employed to travel around the site to spray water on the roads and working areas to wet down materials and prevent dust from mobilizing.

Litter

Measures will be taken to reduce the risk of litter leaving site. The composition of landfill litter is mainly light waste materials. These materials can be sourced from waste delivery vehicles or from the landfill itself. These loose waste materials will become litter if they are conveyed by wind or water.

The sheeting of vehicles will be encouraged and drivers will be advised not to remove sheeting until they are at the tipping face. If loads are known to comprise low density materials liable to be dispersed, tipping at high levels or during high wind speeds will be avoided.

For the landfill, the progressive remediation and capping of the completed landfill and the use of cover for the tipping face will significantly reduce the risk of windblown litter in the long term.

Daily site inspections and walkovers will focus on identifying any stray litter and its sources. Should this be recognized, the litter materials will be collected and the source addressed – for example by applying more cover materials to problem areas.

Odour

The likely main sources of odour from a landfill are landfill gas from uncapped areas of waste and from odorous offensive wastes as they are tipped.

The progressive remediation of the landfill by capping and installation of a landfill gas collection system will significantly reduce the volume of landfill gas emissions. For the areas of ongoing filling, the application of cover materials and temporary capping materials will provide temporary encasement and reduce the risk of odour releases from these areas.

To mitigate the risk from potentially malodorous waste materials, the waste will be assessed at the scale house point of entry. If the waste materials to be accepted pose a likely risk of odour, then waste placement will be amended to ensure these materials are either buried or covered immediately after deposition.

Daily site inspections and walkovers will seek to identify any objectionable odours at the site boundary. Should these be recognized an investigation into the source will take place and a mitigating course of action undertaken – for example by applying more cover materials or burial of potential sources.

5.13 Vermin and mosquito / insect control

The progressive capping of the completed landfill will discourage vermin from accessing the site. For the operational areas temporary cover materials will be placed to perform the same function. If the placement of particular types of wastes will encourage scavenging pests or insects, these shall be covered immediately after placement.

For the management of mosquitos, the Mosquito Control and Research Unit (MRCU) will be consulted and engaged in the preparation of the landfill management plan. In advance of that, it is anticipated that the following measures will be employed:

- The landfill and surrounding access roads and site environment will be graded to minimize ponding and landfill cover materials will enclose waste items that can hold water such as containers
- Proposed surface water management systems will be designed to fully drain if possible. If this is not possible, water bodies where mosquitos could breed will be treated with pesticides
- Reduction to a minimum of the storage of those materials which can hold water such tyres, scrap metals, derelict vehicles etc. Where the storage of such is unavoidable, direct application of pesticides could be carried out

Overall the site will be part of the island wide programme carried out by MRCU.

The site will be monitored through daily inspections for signs of vermin and insects / mosquitos and suitable action taken to minimize their activity, such as the measures proposed above in greater quantity or focused on particular problem areas.

5.14 Recordkeeping and reporting

Records will be kept pertaining to the operation of the landfill such as the security log, daily site inspections and logs, all landfill monitoring and scalehouse data. This information will be stored in hard copy on site or electronic copy as appropriate.

In addition, the landfill will be subject to periodic land surveying to understand the estimate of the remaining life and capacity in cubic yards. This estimate will be made and reported annually.

All records will be kept for a period no greater than 5 years prior to archiving.

6. Technical closure, remediation and after use options appraisal

6.1 Options appraisal objectives

A fundamental part of the ISWMS project is to ensure the GTLF is technically closed and restored to a beneficial after use, as well as reducing (and subsequently managing) its impact on the environment.

The technical closure, remediation and after use of the site must, however, be tempered by a recognition that this should be affordable, workable and safely deliverable within a reasonable timescale; taking into account the site's preceding landfill setting (and temporal settlement characteristics).

Accordingly, the eventual after use should make best use of the available landfill and surrounding non-landfill areas; delivering a technical closure solution that reduces the impact and improves the perception of the closed and restored GTLF site from an environmental and social perspective.

6.2 Technical closure and remediation options

Do nothing

The GTLF has no engineering containment (basal lining and/or capping system) and operates generally on an uncontrolled dilute and disperse basis. Landfilling operations also typically exclude the provision of daily cover. Both practices are at odds with accepted international standards and good practices. Accordingly, the landfill or 'dump' currently exhibits exposed garbage across both the operational and non-operational areas of the site; encouraging vectors to carry pathogens and contaminants into the neighbouring community, increasing surface emissions of landfill gas and significantly increasing the potential for landfill fire (with an associated release of toxic contaminants by air and surface water into the surrounding environment).

Based on the above, a 'do nothing' option is unacceptable - at least for active areas of the site - in respect of recognised international good practice and standards, loss of local amenity and loss of opportunity to reduce greenhouse gas emissions.

Removal at source

The existing GTLF contains approximately 1.4 million tons of household, commercial and other solid and liquid waste, deposited over a period of 30 years. One potential solution is to excavate the deposited wastes in their entirety and redeposit these in a new, lined landfill to modern containment standards.

Whilst theoretically possible, this option presents a number of significant technical obstacles: from the space requirements and logistical demands associated with establishing a rolling 'dig and dump' operation, to the ability to safety excavate non-hazardous and potentially hazardous materials (with a corresponding increase in landfill fire/hazardous gas/explosion risk), to the loss of amenity associated with excavating, moving and redepositing partially decomposed organic and other waste). Furthermore, the capital and operational costs associated with this option are likely to be prohibitive, potentially approaching the capital cost of DC's new ERF.

As such, this option is non-viable from both a technical and financial perspective.

Landfill mining

Landfill mining involves excavating select previously deposited wastes and subjecting them to additional processing and/or treatment to realise additional value recovery, returning the remaining residual wastes to landfill as rejects.

CIG previously considered landfill mining for the ISWMS project, but subsequently eliminated this as an option for further consideration due partly (but not limited) to public health and environmental concerns. Accordingly, Amec Foster Wheeler issued the following erratum notice in the Outline Business Case issued September 2016:

> *"At the time the Consultation Draft Outline Business Case (OBC) was being drafted and the financial models were being run by Amec Foster Wheeler and KPMG, the potential to mine waste at the George Town landfill was considered as a possible component of the Reference Project and the future Integrated Solid Waste Management System (ISWMS) for the Cayman Islands.*
>
> *Since that time, a policy decision has been made to exclude mining of waste from the Reference Project, as the potential of long-term nuisance conditions from mining, such as odours, outweigh the benefit of gaining back the small area of landfill space. Therefore, while financial information regarding the mining of waste at the George Town landfill is addressed in the draft OBC document, readers should be aware that it is no longer under consideration for inclusion in the ISWMS, and the Final OBC will reflect this."*

Along these lines, this option is again concluded to be non-viable from a technical (and financial) perspective.

Landfill capping

Whilst not providing basal engineering containment, landfill capping allows for the covering and entombment of previously emplaced wastes. This prevents direct exposure to the waste materials and significantly reduces the ingress of rainfall into the waste mass (and, hence, leachate generation for transmission to surface water and groundwater), as well as enabling the effective capture, management and utilisation of landfill gas. Landfill capping further allows for the improved control of odours, flies and vermin commonly associated with uncovered wastes, as well as promoting the separation and management of clean surface water run-off from the capped (and restored) surface. Following capping and remediation, the vegetated site can be utilised for a range of after use options, providing additional local amenity and benefit for the community of Grand Cayman.

Considering the age and quantity of previously emplaced waste at the GTLF, capping generally presents the most workable and safely deliverable form of remediation for the George Town Landfill. In the case of the older, less active South Mound, however, monitoring results and risk based modelling assessments (see Section 10) show the site is no longer having an unacceptable impact on the surrounding environment and, as such, does not warrant a landfill cap. As such, low permeability capping is only required for the newer, more active North Mound.

The list of potential capping options is included in the qualitative screening process as set out in Section 6.5.

These options are then further considered by area of the site to develop a proposed technical closure solution as set out in Section 7.

6.3 After use options

A range of potential after uses - covering recreational and commercial applications - are available to improve the aesthetic appearance of the GTLF site and provide some additional benefit to the Cayman Islands community.

Against this backdrop, DC has grouped potential after use options for the GTLF (covering both landfill and non-landfill areas) into a number of broad categories as follows[6]:

- Recreational open space[7]
- Agriculture/horticulture
- Built environment
- Infrastructure development

This list of potential options has then been reduced to a proposed after use using a qualitative screening process as set out in Section 6.5.

6.4 Capping, cover, gas and leachate management system options

DC has taken the after use options listed in Section 6.3 and cross-referenced them to a series of engineering and environmental management options (as set out in Table 7), grouped into the following broad categories:

- Capping and remediation options (for the North Mound) - from a 'do nothing' option through to the provision of a fully engineered capping and remediation system
- Gas management options (for the North Mound) - from a 'do nothing' option through to providing a high density gas field and collection system
- Leachate management options - from a 'do nothing' option through to providing a high intensity monitoring programme, pro-active leachate management and on-site leachate treatment system

6.5 Options screening matrix

DC has then applied a series of qualitative 'screening' criteria to the listed options on the basis of the following:

- Is the listed capping and remediation option suitable for the identified after use?
- Is the listed gas management option suitable for the identified after use?
- Is the listed leachate management option suitable for the identified after use?
- Is the listed option deliverable from a technical, environmental and commercial (positive cost/benefit) perspective?

The outcomes from this qualitative screening exercise are again shown in Table 7.

[6] All categories/options to include a focus on creating and maintaining a diverse natural habitat encouraging naturally occurring flora and fauna.
[7] Note Section 7.3.

Table 7 Technical closure, remediation and after use options screening matrix

After Use	Capping & Remediation							Gas Management				Leachate Management				Deliverability				Scoring
	None	Mineral Layer (Non-Engineered)	Mineral Layer (Partially Engineered)	Mineral Layer (Fully Engineered)	Geosynthetic Clay Liner	Flexible Membrane Liner (Lap And Lay)	Flexible Membrane Liner (Welded)	None	Passive Venting	Low Density Extraction Well Coverage	High Density Extraction Well Coverage	None	Monitoring Only	Monitoring and Reactive Management	Monitoring and Proactive Management	Technical Deliverability	Environmental Acceptability (Short Term[8])	Environmental Acceptability (Long Term[9])	Positive Cost / Benefit	
Recreational Open Space	✗	TBC	✓	✓	✓	✓	✓	✗	✗	TBC	✓	✗	TBC	TBC	✓	✓	✓	✓	✓	26
Other Amenity (E.g. Trails)	✗	TBC	✓	✓	✓	✓	✓	✗	✗	TBC	✓	✗	TBC	TBC	✓	✓	✓	✓	✓	26
Agriculture/Horticulture	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	TBC	✗	✗	✗	TBC	✓	TBC	TBC	✗	6
Built Environment	✗	TBC	TBC	TBC	✗	✗	✗	✗	✗	✗	TBC	✗	✗	✗	TBC	TBC	TBC	✓	✗	9
Infrastructure Development	✗	TBC	TBC	TBC	✗	✗	✗	✗	✗	✗	TBC	✗	✗	✗	TBC	TBC	TBC	✓	✗	9

Scoring:

✗	**= 0**
TBC	**= 1**
✓	**= 2**
	Low score, eliminated from further consideration

TBC = To Be Confirmed

[8] 25-year concession period.
[9] Post 25-year concession period.

7. Proposed technical closure, remediation and after use solution

7.1 Proposed technical closure and remediation solution

CIG has recognised that continuing landfilling at the GTLF is not a sustainable long-term solution for Grand Cayman, with the current absence of engineering containment and constrained operational practices running contrary to generally recognised international standards and landfill good practice - leading to the development of the ISWMS project. This 'direction of travel' is reconfirmed in the OBC published by Amec Foster Wheeler: effectively ruling out 'do nothing', 'remove at source' and 'landfill mining' options from further consideration for the Cayman Islands.

DC concurs with the stated drive to develop a sustainable long-term alternative to landfill for the Cayman Islands, and associated desire to technically close and restore the GTLF. As such, of the various options listed in Section 6.2, landfill capping of the active area of the site (i.e. the North Mound) presents the most affordable, workable and safely deliverable solution for CIG and, as such, is DC's proposed technical closure solution for the site as discussed further in this report.

Site decommissioning and clean-up works

In order to create a safe and attractive setting for the technical closure and after use, one of the key preliminary activities will be to undertake a general site clean-up, covering over or removing unwanted surface detritus to the active landfill where possible.

The timing and extent of this clean-up will be coordinated with CIG to suit CIG's on-going site activities and landfilling operations, but is anticipated to start in 2020 and continue through to commencement of the final phase of capping and remediation of the GTLF in 2024/2025.

Prior to the commencement of these clean-up works, DC will agree with CIG any large scale operations it expects to fall under the responsibility of CIG (e.g. removal of the current scrap metal stockpile) and the anticipated timeline for the completion of these works. Thereafter, DC/CIG will agree specific responsibility for all other clean-up works as part of its technical closure and remediation plan[10].

In addition, various of the existing site infrastructure that are not required as part of the technical closure and remediation works will be decommissioned. Again, a list of the proposed facilities/structures to be demolished will be discussed in advance with CIG (in case CIG wishes any of these to be retained) and the final decommissioning plan and programme agreed accordingly.

Engineering considerations

Given the history and profile of the GTLF, it is important to ensure that the agreed upon engineering solution improves the aesthetic and environmental standing of the site for the Cayman Islands, its residents and visitors alike.

The previous history of the site also needs to be taken into consideration in order to develop a fit-for-purpose yet value-for-money solution going forward, particularly in respect of:

- The age of the site - or parts thereof
- The absence of detailed historic records regarding the types and quantities of materials deposited in the landfill
- The absence of any historic (basal) engineering containment

[10] In the event that additional clean-up of materials allocated to CIG remain on site at the time of hand-over, DC will confirm the nature and extent of these materials with CIG; including any additional consideration in respect of the required works.

- The current absence of gas and leachate management systems
- The relatively limited current impact of the site on the surrounding environment - as evidenced by the previous GQRA and preliminary CSM findings by Wood

DC has consequently focused on developing an engineering solution that enables the previously emplaced waste to be left where it is, but reduces its impact on the surrounding environment in accordance with recognised standards. As such, DC's proposed engineering solution centres on:

- Limited regrading of the site to help improve its aesthetic appearance, minimise erosion and promote surface water run-off
- Providing an engineered cap as required to reduce the rate of rainfall infiltration (and, hence, leachate generation) into the waste mass
- Installing gas management controls with a view to minimising fire or explosion risk within the waste mass, reduce the GHG emissions, reduce fugitive emissions of odour and contaminants associated with landfill gas, inhibit lateral migration of gas beyond the limits of the landfilled areas, and support possible gas utilisation for energy recovery
- Improving environmental monitoring and management, with a view to early identification of any unfavourable trends in environmental emissions

Design standards and codes

After consultation with CIG, DC has made a guiding decision to make the required capping, gas management, leachate management, and all other aspects of the technical closure project conform - with as few exceptions as possible - to FAC 62-701.

Selection of capping materials

DC has considered the full spectrum of engineered capping options, from a mineral (compacted soil) layer, to an artificial sealing layer comprising a Geosynthetic Clay Liner (GCL) or Flexible Membrane Liner (FML). In all cases, given the overall decision to comply with FAC 62-701 with as few exceptions as possible, the capping system must deliver a maximum permeability of $1x10^{-7}$ cm/s. Each of the capping options have various strengths and weaknesses covering technical performance, availability of materials (on- and off-island), ease of installation, durability and cost. As such, DC has again applied a series of qualitative 'screening' criteria to the identified capping options on the basis of the following:

- Can the proposed option meet the requirements of FAC 62-701
- Suitability for local site setting
- Ease of installation
- Strength of impact on gas management
- Strength of impact on leachate management
- Availability of materials in the quantities required at economic commercial rates

The outcomes from this qualitative screening exercise are further shown in Table 8.

Table 8 Capping options screening matrix

Capping Options	Screening Criterion						Scoring
	Compliance with requirements of FAC 62-701	Suitability for local site setting	Ease of installation	Strength of impact on gas management	Strength of impact on leachate management	Availability of materials in the quantities required at economic commercial rates	
Mineral Layer (Non-Engineered)	✗	2	2	0	0	0	**4**
Mineral Layer (Partially Engineered)	TBC	2	1	1	1	0	**6**
Mineral Layer (Fully Engineered)	✓	2	0	1	1	0	**6**
Geosynthetic Clay Liner	✓	2	2	2	2	2	**12**
Flexible Membrane Liner (Lap And Lay)	✓	1	2	1	2	2	**10**
Flexible Membrane Liner (Welded)	✓	1	1	2	2	2	**10**

Scoring:

Pass/Fail	
✗	**= 0**
TBC	**= 1**
✓	**= 2**

Performance	
Poor	**= 0**
Average	**= 1**
Good	**= 2**

Low score, eliminated from further consideration

TBC = To Be Confirmed

7.2 Proposed after use solution

Based on the applied screening criteria, the following after uses have been ruled out from further consideration on the basis of technical deliverability, complexity and cost at this time:

- **Agricultural/horticultural** after uses - both on and around the landfill - on the basis of likely public concerns over crop contamination/health issues, questionable cost/benefit and general operational concerns
- **Built environment**, **infrastructure development** after uses - on the landfill - on the basis of constructability/landfill settlement, environmental protection, cost/benefit and general operational concerns; but with potential (albeit limited) merit on non-landfill areas of the site

As such, DC's proposed after use solution is as per the requirements of CIG, comprising the following:

- Recreational open space (and other amenity uses)

These uses may be supplemented by some new infrastructure development on non-landfill areas of the site, but such development is expected to be substantially limited at this time.

7.3 Public access to recreational open space

Given the site's landfill setting, public access will need to be carefully managed even after the landfill's closure (particularly during the early years after capping and remediation) in order to:

- Minimise exposure to hazards commonly associated with closed landfills (e.g. waste materials, leachate, landfill gas, confined spaces, environmental management infrastructure, etc.)
- Avoid introducing potential additional management risks associated with public access (e.g. vandalism of infrastructure, surface fires due to barbeques, slips/trips/other accidents relating to the landfill setting and environmental management infrastructure)

As such, public access to the site will be restricted in the first instance; with no access envisaged at least until all capping works have been completed, the covering vegetation has become very well established, settlement activity has reduced to a manageable rate and environmental emissions reduced to safe exposure levels. In addition, public access will still be limited to restricted areas thereafter.

7.4 Landfill gas management

North Mound

DC has updated Wood's 2018 GasSim modelling to reflect the expected extension of landfill waste inputs to 31 December 2023 and re-run the model based on alternative dry and average moisture conditions within the landfill. The outputs from this modelling show bulk gas generation increasing overall, now peaking at between 555 and 840 m^3/h (relating to dry and average moisture conditions) in 2023 as shown in Figure 4.

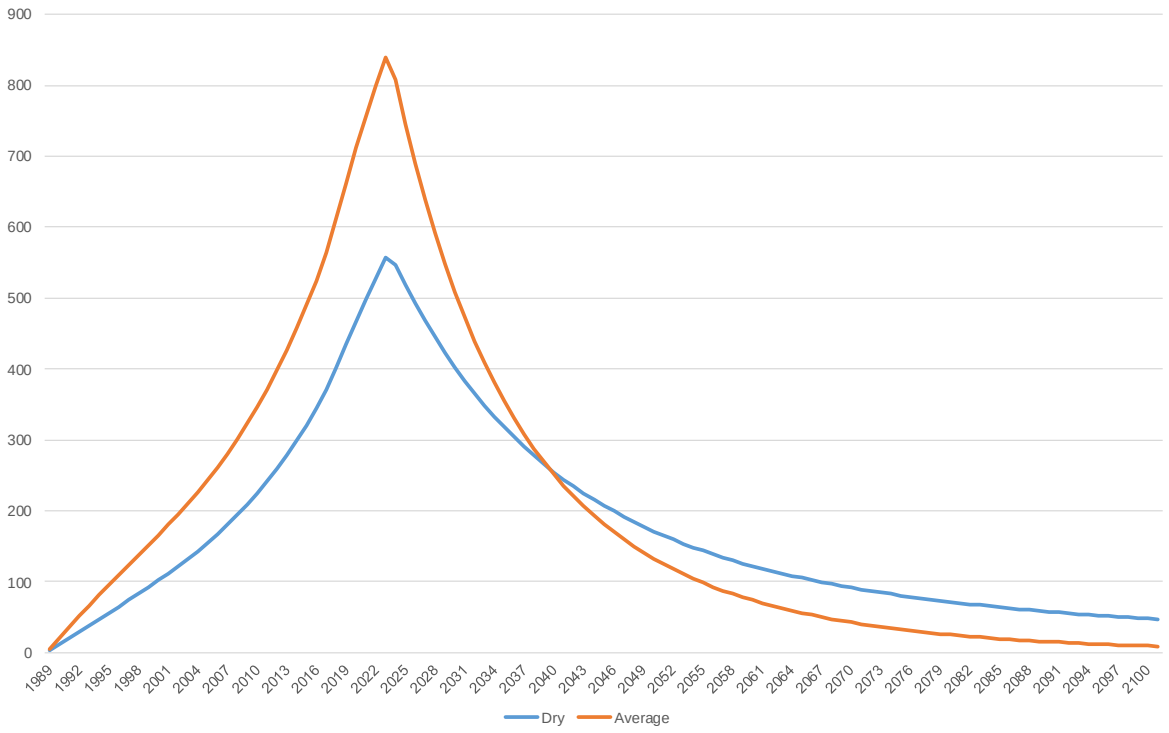

Figure 4 DC bulk gas generation estimate (m^3/hr)

Based on these data, DC has then estimated the gas recovery potential, taking account of the uplift in gas collection efficiency due to the planned capping and remediation enhancements between 2021 and 2024, as further shown in the following Figure 5:

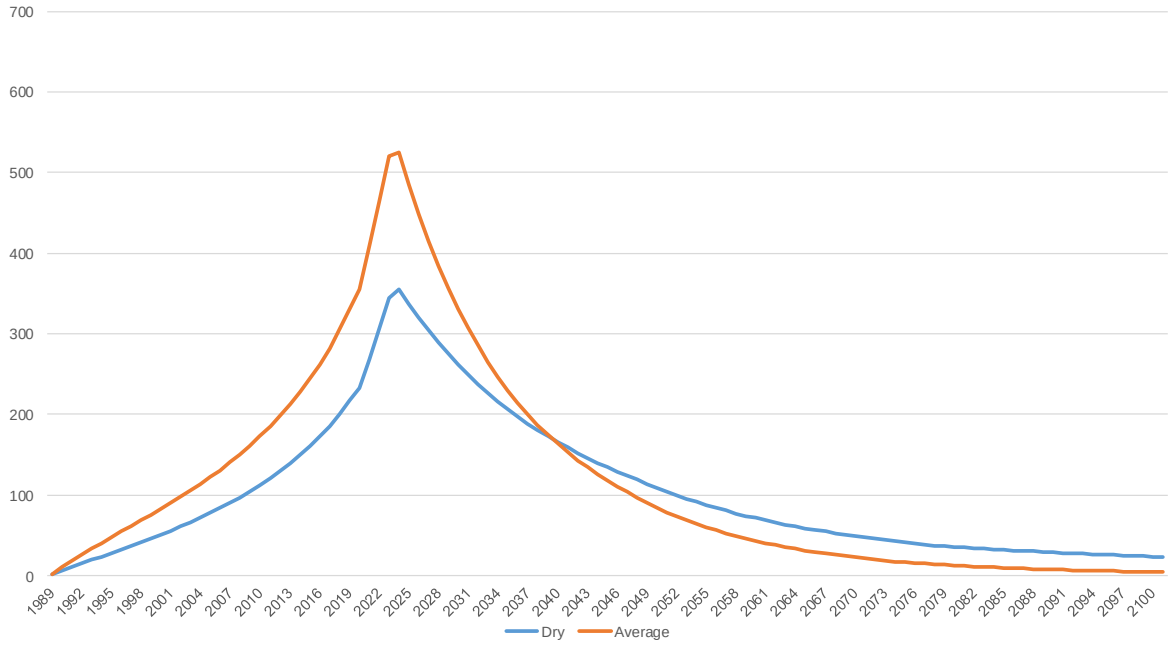

Figure 5 DC bulk gas recovery estimate (m^3/hr)

The above levels of gas generation support DC's qualitative assessment that the historically uncovered condition of much of the waste mass makes landfill gas energy recovery by means of a dedicated engine-generator unit generally unfeasible. In the case of DC's ISWMS solution, however, a second option exists: directing the recovered landfill gas to the ERF furnace for energy production and utilising the ERF grid connection for power export over at least the life of DC's ISWMS project concession. This is currently considered the most cost effective and environmentally preferable solution: deriving additional value from (the methane in the) landfill gas that would otherwise be vented to atmosphere or burned in a gas flare without recovering the energy potential.

In support of the above, DC will provide an enclosed flare to manage the landfill gas during the ERF's construction and commissioning; maintaining this on-site thereafter for periods of ERF non-availability (e.g. during maintenance).

The utilisation potential is directly linked to actual conditions (biological activity) within the landfill and achieved rate of gas recovery (currently conservatively estimated at 70%). This is currently estimated as set out in Figure 6.

To this end, an array of gas wells will be installed over the surface of the North Mound, connecting these via a series of manifolds to a gas ring main supplying the ERF or the gas flare.

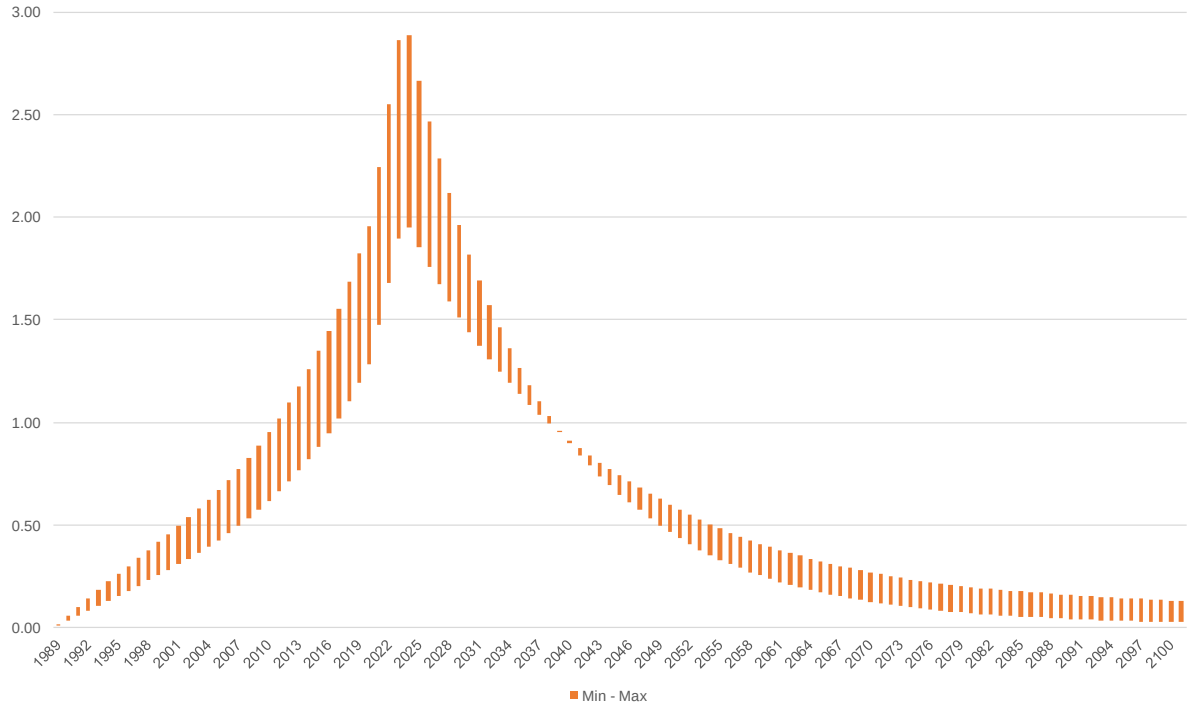

Figure 6 DC bulk gas energy supply estimate (MWth)

South Mound

Recent gas studies appear to confirm that gas production from the older wastes in the South Mound has largely ceased, with only low flow/low quality emissions of gas remaining.

Pending confirmation at detailed design stage (including further limited investigation as required), a passive approach to landfill gas management is therefore expected to be adequate for the South Mound. A passive approach that allows gas to vent naturally to atmosphere could include measures such as the installation of passive venting (e.g. vent trenches, spike wells) in the first instance if required, using perimeter monitoring to confirm there is not lateral migration of landfill gases outside the footprint of the landfill area. The adequacy of these basic initial provisions could then be upgraded as required to address any apparent issues going forward.

7.5 Leachate management

North Mound

The GTLF currently operates as a dilute and disperse landfill, with no formal engineering containment (basal liner) or leachate collection system. Despite the absence of engineered systems, the impact of landfill leachate on the surrounding environment appears generally limited (see Section 2 for details).

Accordingly, and given the expectedly significant reduction in (or virtual elimination of) leachate production following the capping and remediation of the North Mound, a reasonable approach going forward is to monitor and track any changes in contaminant loading on the environment in the first instance; increasing the site's monitoring capabilities to provide additional data and early warning of any negative changes - and thereafter addressing issues as required.

Potential mitigation measures thereafter may include *inter alia* one or a combination of the following:

- Confirming the integrity of the emplaced cap
- Locally reducing leachate levels in the event of discrete perched leachate lenses
- Promoting downward travel of leachate in the event of discrete perched leachate lenses
- Further reprofiling the site in the area of leachate outbreak
- Locally remediating groundwater and surface water receptors (i.e. 'pump and treat')
- Considering the cost/benefit of installing more active leachate management controls on a longer term basis

South Mound

Current monitoring results indicate that leachate from the South Mound is so far having little if any unacceptable impact on the surrounding environment. Accordingly, it is expected that a passive approach will be taken to leachate management in the South Mound in the first instance; with the potential to upgrade monitoring or management provisions as required over time.

7.6 Surface water management

The completed GTLF will be reprofiled as required to facilitate the interception and run-off of clean surface water from the surface of the landfill. Separation of surface water from any leachate accumulations will remain a primary priority. FAC 62-701 requires the management as leachate of any surface water that has come into contact with leachate.

Pending confirmation at detailed design stage, the intercepted surface water will be controlled and directed on site via a series of perimeter collection ditches, feeding to a balancing pond before being discharged off site (provisionally expected to be to vertical drains, with any overflow during storm events being directed to the surrounding canals).

8. Detailed technical closure, remediation and after use proposals

8.1 Waste regrading

Limited regrading of the existing landfill surface will be undertaken to improve the aesthetic appearance of the GTLF, removing surface detritus and eliminating peaks and troughs in the regraded surface that would inhibit the subsequent capping and remediation works.

Such works are anticipated to be undertaken using a combination of tractor dozers and bucket arm excavators, dressing the surface of the completed landfill to cover over exposed waste, remove large humps and hollows and/or otherwise improve the finished profile to control and direct surface water run-off.

Such works are not anticipated to involve wholesale excavation and removal of waste, as this could potentially allow unwanted oxygen ingress to the exposed waste mass; inviting the possibility of landfill fire.

8.2 Capping and remediation

North Mound

A low permeability GCL capping layer will be utilised for the North Mound of the landfill, with accompanying restoration material and surface flora as follows:

- Native grasses and other flora
- 6 inch topsoil layer - nominally DC generated topsoil material
- 18 inch subsoil layer - nominally crushed and lightly compacted Cayman Rock
- Low permeability GCL
- 12 inch regulating/cover layer to the waste - nominally crushed and compacted Shot Rock
- Waste mass (waste placement by CIG)

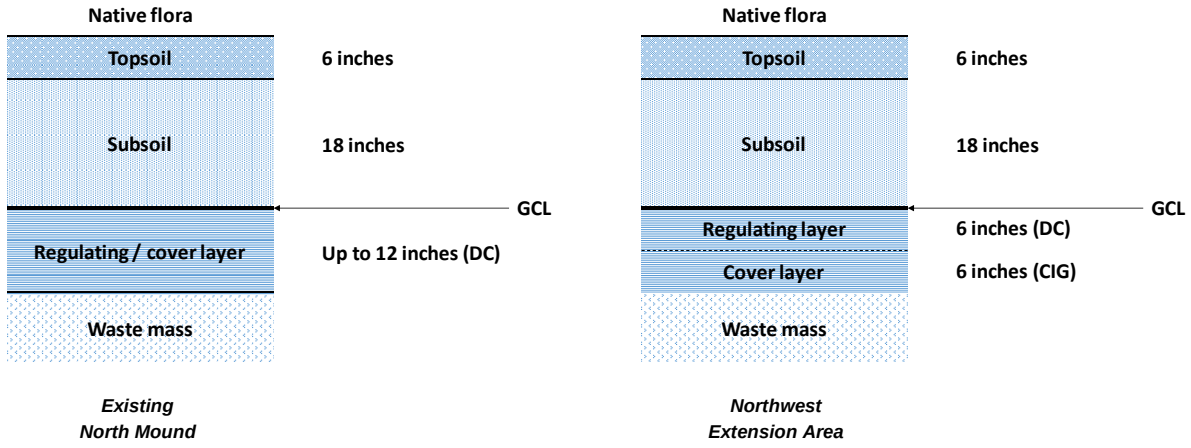

Figure 7 Illustrative sections through capping and remediation layers

The final profile will be addressed in the detailed design submission.

Additional waste infill to west of North Mound

As noted above, the GTLF site includes approximately 5.7 acres of previous pond (west of the North Mound) created by mining for marl and infilled with debris created by Hurricane Ivan in 2004. This area will be further infilled as part of the North Mound landfilling operations, and thereafter included in DC's landfill closure works; resulting in approximately 7 acres of additional capping and remediation.

South Mound

In the case of the older, less active South Mound, monitoring results and risk based modelling assessments show the site is no longer having an unacceptable impact on the surrounding environment and, as such, does not warrant a landfill cap.

8.3 Landfill gas management

North Mound

The selection of a low permeability cap requires that landfill gas be vented as a minimum, but venting alone will continue to generate volatile organics and odour emissions concerns as well as greenhouse gas emissions. As such, an array of gas wells will be installed over the surface of the North Mound, connecting these via a series of manifolds to a gas ring main supplying the ERF. The density of gas wells will be determined through the detailed design process.

The general configuration of the anticipated collection system is:

- Gas well field:
    - Borehole array to 85% landfill depth or phreatic surface as possible
    - Well screen and casing, surrounded by gravel annulus c/w bentonite seal to top section
    - Gas well heads including throttle valves, sampling ports and means of measuring gas flow
    - Spur pipework
    - Perimeter manifolds including control valves and sample ports
    - Condensate knock-out pots (recirculated to landfill)
- Gas ring main to ERF
- Blower/booster c/w additional condensate knock-out pot
- Feed supply to ERF including chiller for dehumidification as required
- Enclosed flare for use during ERF construction and thereafter as a back-up for periods of ERF downtime
- Perimeter monitoring wells (number to be determined by technical closure option risk assessment)

South Mound

A passive approach to landfill gas management will be taken for the South Mound; being limited to the reactive installation of passive venting (e.g. vent trenches, spike wells) to address any apparent issues going forward.

8.4 Leachate management

North Mound

Based on the reported levels of groundwater contamination at the boundaries of the GTLF, a low permeability cap - with the subsequent reduction in leachate generation - is expected to be sufficient to allow ground water contaminant levels to naturally attenuate to acceptable levels over time. Consequently, a natural attenuation monitoring and reactive management approach to leachate management will be adopted for the North Mound of the GTLF.

In order to support this approach, DC will install additional perimeter wells to monitor and track changes in contaminant loading on the environment in the first instance: increasing the site's monitoring capabilities to provide additional data and early warning of any negative changes, and thereafter reacting to any issues as required. The final number and configuration of wells will be informed by the findings of the technical closure option risk assessment and thereafter agreed with CIG.

South Mound

As for the North Mound, a passive approach to leachate management will be adopted for the South Mound. This approach notwithstanding, CIG will continue to monitor the area going forward via the increased monitoring capabilities provided by DC to provide additional data and early warning of any negative changes

8.5 Surface water management

Surface water run-off from the completed remediation is expected to be controlled and directed on site via a combination of the finished landfill contouring and a series of perimeter collection ditches, feeding to a settling/balancing pond before being discharged off site (provisionally expected to be to vertical drains, with any overflow during storm events being directed to the surrounding canals). The exact configuration of the surface water control scheme, size and location of the balancing pond, point of discharge and monitoring arrangements, etc., will be determined during the detailed design phase.

8.6 Non-landfill areas

Non-landfilled areas outside of the remediation works will be incorporated into the final after use scheme. DC/CIG will consider the merits of providing additional/new infrastructure on non-landfill areas as part of the overall after use plans for the site, but any such development is expected to be substantially limited at this time. As such, in the first instance, non-landfilled areas will be levelled, cleared of debris and allowed to revegetate naturally. Should other environmental issues be encountered during these works, DC will discuss the matters and agree a way forward with CIG as necessary.

8.7 Phasing and programme

The fundamental goal is to ensure the GTLF is remediated and restored in a timely manner, reducing and subsequently managing its impact on the environment. To this end, preliminary clean-up works, regrading and capping and remediation works will be delivered in line with the timeline and phasing as shown in

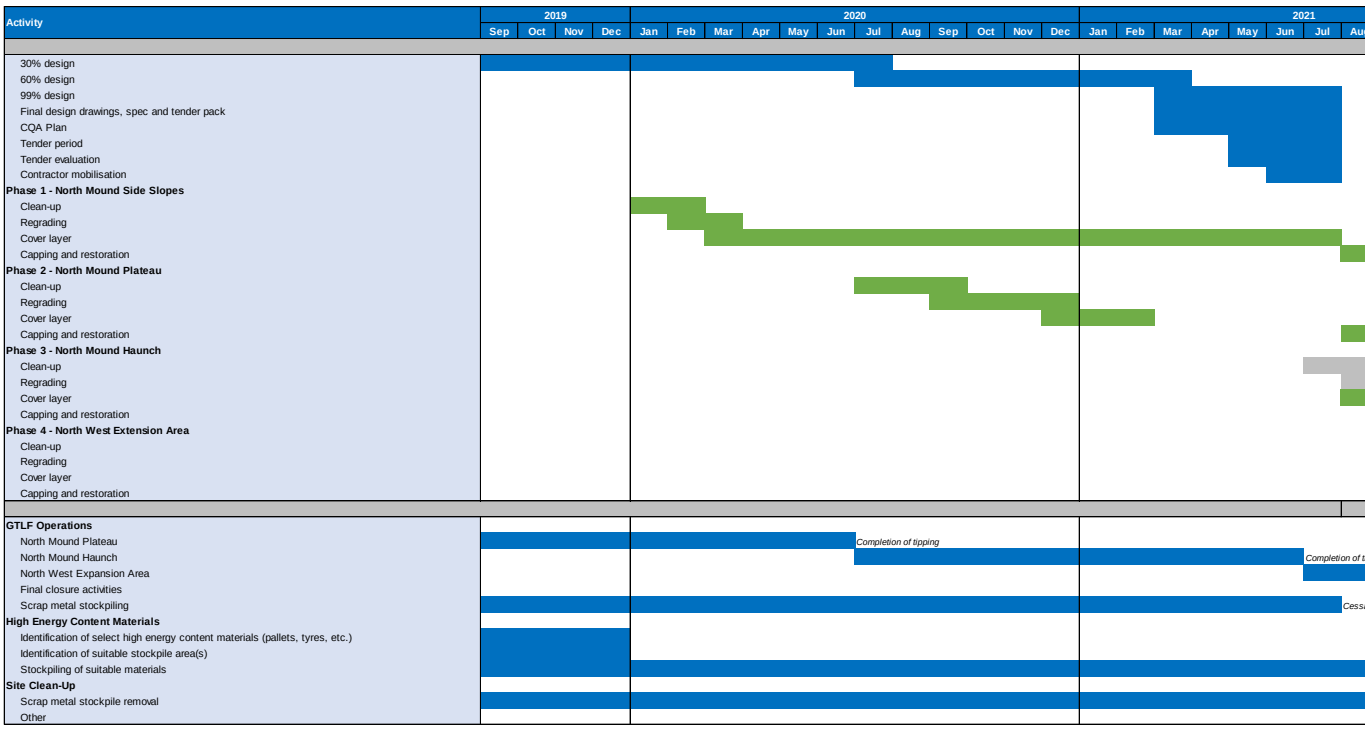

Figure 8.

8.8 Execution Plan

DECCO will be providing management support to the remediation works and as such, in keeping with standard DECCO practice for construction projects, a Project Execution Plan (PEP) will be developed.

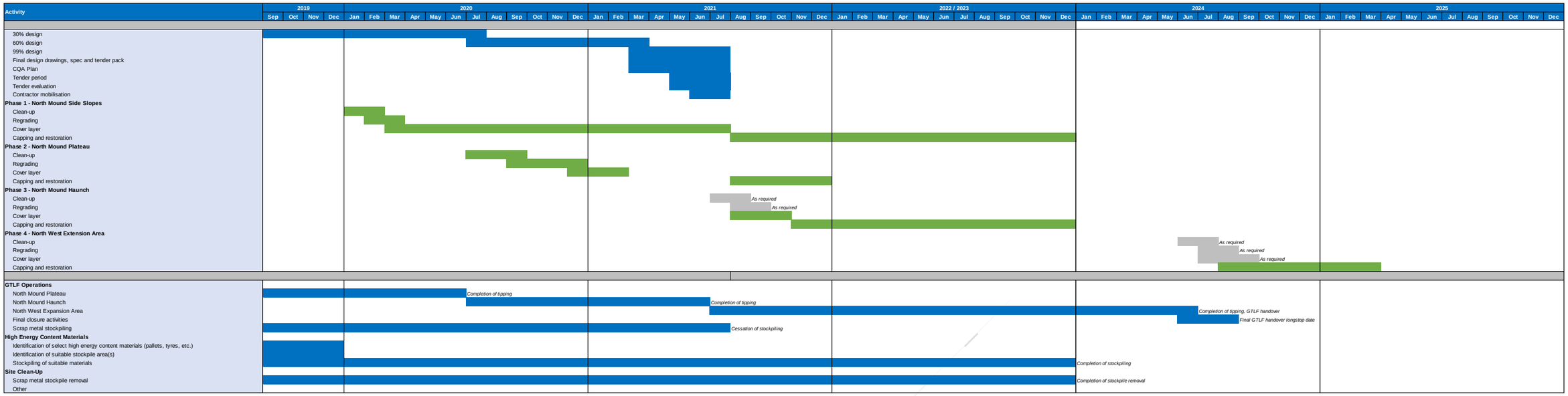

Figure 8 Indicative GTLF technical closure and remediation programme

9. Post remediation management

9.1 Introduction

DC's post-remediation landfill management plan will be based on the Florida Department of Environmental Protection Guidance Document SWM-04.45: Long Term Care (LTC) at Solid Waste Disposal Facilities, as related to the agreed after use for the site.

9.2 Maintenance of capping and remediation system

North Mound

DC will monitor the integrity of the capping and remediation works to check for defects or issues with the installed system. For the first 12 months after completion, any issues will be addressed by way of a defects correction arrangement with the appointed capping and remediation contractor.

Thereafter, any issues arising with the capping and/or remediation will be dealt with as part of DC's post remediation landfill management plan. In particular, DC will be vigilant in monitoring the completed surface for signs of scour and erosion caused by surface water run-off; with the aim of addressing the issue before this reaches the bottom layer or engineering barrier. Where other issues (such as signs of vegetation stress) are encountered, these will be dealt with by DC's engineering team or third party contractor, typically within [1 month] of them being identified.

Formal inspection of the capping and remediation system will be undertaken monthly by DC until the restoration vegetation is established, and thereafter quarterly; with the findings of the inspections, and any actions planned or undertaken, being included in the ISWMS contract Monthly Report to CIG. DC will further undertake an annual inspection of the capping and remediation system with CIG - with the findings of this, and any actions planned or undertaken, being included in the ISWMS contract Annual Report to CIG.

South Mound

Responsibility for monitoring and maintaining the condition of the South Mound surface will be the responsibility of CIG.

9.3 Operation and maintenance of landfill gas control system

North Mound

As set out in Section 7, DC will install an active landfill gas control system over the North Mound, supplying the collected gas to a temporary landfill gas flare until the ERF becomes operational and thereafter to the ERF for energy recovery.

Immediately following installation, DC will undertake weekly balancing of the gas field until flow rates and gas qualities stabilise. Thereafter, gas field balancing will be reduced to monthly and then quarterly or as required based on the record of total gas flow and quality; as part of the routine environmental monitoring of the site.

The integrity of the gas field will be visually checked during each site visit, with the aim of maintaining good control of the gas field. Where issues (such as broken well heads, failed wells or compromised pipework) are encountered, these will be dealt with by DC's engineering team or third party contractor, typically within [1 week] of them being identified.

The landfill gas flare will be serviced and tested in accordance with the manufacturer's recommendations, during both duty and standby phases of use.

The results of the balancing, inspection and servicing activities, and any actions planned or undertaken, will be included in the ISWMS contract Monthly Report to CIG. DC will further undertake an annual inspection of the landfill gas control system with CIG - with the findings of this, and any actions planned or undertaken, being included in the ISWMS contract Annual Report to CIG.

South Mound

Again as set out in Section 6.4, a passive landfill gas control system will be provided for over the South Mound, being limited to the installation of passive vents as required.

The efficacy of the passive control system will be checked as part of the routine monitoring visits, with the aim of avoiding nuisance and loss of amenity to the surrounding community (including the proposed after use for the GTLF). Where issues are encountered, CIG will consider the source of the issue and submit its proposals to remedy the situation. Such remedies can include: increasing the venting capacity; employing activated carbon filters to point source emissions; or upgrading to an active gas collection system.

Responsibility for monitoring the condition of the South Mound landfill gas control system will be the responsibility of CIG.

9.4 Maintenance of leachate management system

Please refer to Section 6.4 for details of DC's proposed approach to leachate management.

9.5 Surface water management system maintenance

Profiling, capping and restoring the GTLF will develop additional quantities of clean surface water requiring management and disposal.

Pending confirmation at detailed design stage, the intercepted surface water will be controlled and directed on site via a series of perimeter collection ditches, feeding to a balancing pond before being discharged to vertical drain, with any overflow during storm events being directed off-site to the surrounding canals.

Immediately following installation, the performance of the surface water management system will be monitored to check that the collection and control measures are working correctly, and that the discharge system is adequate for the quantity of surface water being collected (noting the expected temporal reduction in run-off intensity as the restoration vegetation becomes more established).

Thereafter, the performance of the surface water management system will be reviewed as part of the routine site inspections; checking for issues such as scour erosion, ponding water, leachate contamination and/or reduction in the performance of the vertical drains.

The results of the inspection activities, and any actions planned or undertaken, will be included in the ISWMS contract Monthly Report to CIG. DC will further undertake an annual inspection of the surface water management system with CIG - with the findings of this, and any actions planned or undertaken, being included in the ISWMS contract Annual Report to CIG.

9.6 Environmental monitoring/surveys and reporting

On completion of the works employed to mitigate any risks identified by the technical closure option risk assessment, on-going verification monitoring will be required to validate that the mitigation measures or treatment systems have been successfully implemented. It is envisaged that the monitoring programme will comprise of air/odour, ground gas, surface gas, leachate, groundwater and surface water quality.

The intention of the air/odour monitoring is to demonstrate that the encapsulation of the landfilled wastes has reduced or eliminated odour nuisance from the site; noting that odour originating from the nearby WWTP may still affect the site and surrounding area. The odour monitoring will target points within the site and around the site boundary, and aim to assess odours during various atmospheric conditions. It is anticipated that monthly monitoring over three to six months will be sufficient. However, in the event that odour concentrations originating from the site are found to be unacceptable, further assessment will be required.

The ground gas, groundwater and surface water monitoring will require the installation of monitoring wells around the perimeter of the site, between the deposited wastes and neighbouring properties/sensitive receptors. Typically, ground gas, surface gas, groundwater and surface monitoring will be carried out monthly for the initial six months, reducing in frequency to bimonthly, quarterly and then every six months depending on the magnitude of the concentrations detected over time. The frequency and duration of the monitoring programme will also depend on the type of mitigation measures implemented and whether monitored natural attenuation has been selected. The ground and surface gas monitoring will be required to check for gases leaving the site towards neighbouring properties, as lateral gas migration may be increased by installation of a capping system and any dewatering i.e. removal of leachate.

9.7 Settlement monitoring

DC will undertake regular drone surveys to record the evolving topography and monitor the settlement of the GTLF. For the first two years this will be carried out on a six monthly basis and then annually thereafter depending on the magnitude of the change in settlement over time. The results of the surveys will be included in the ISWMS contract Monthly and Annual Reports to CIG. Settlement plates may also be used to assist in measuring settlement over time.

9.8 Site security

The requisite level of site security will be determined based on the final configuration of the agreed after use for the GTLF, noting the intention to adopt a phased approach regarding pubic access to recreational open space purposes. Site fencing is anticipated to be a fundamental security measure to be included, together with further protection of the provided environmental control infrastructure (e.g. gas wells and flare) as required.

9.9 Abnormal/emergency controls and procedures

DC will develop a comprehensive emergency plan for the GTLF, identifying potential impacts that could occur to people or the environment, either on or off site, as a result of an emergency and/or abnormal incident at the site. Impacts deemed as significant will be detailed within the emergency plan, with associated control procedures. Impacts deemed to be significant would at least include those which may require the assistance of off-site emergency services such as the fire brigade, ambulance and/or police. As a minimum, the following events will be included in the abnormal and emergency controls and procedures emergency plan:

- Fire/explosion
- Major injury requiring the assistance of the emergency services
- Significant release of gas/liquid to the environment
- Flood resulting in partial or complete site closure

The emergency plan will include the following sections:

- Incident controller information and abnormal/emergency controls and procedures (incident controller procedure)
- Appropriate maps/plan of the site
- Emergency services information
- Out of hours call out procedure

An appropriate number of DC members of staff will be identified and trained to act as Incident Controllers and Fire Wardens, including cover for holidays and sickness. All nominated staff will be inducted on the Site Emergency Plan, and all employees will receive induction on emergency procedures and on fire precautions and provision. Employees expected to use fire extinguishers or other such equipment will be trained to do so by a competent person (typically an external provider). Training exercises (fire/site emergency plan drills) will take place involving all employees to test emergency preparedness on at least an annual basis.

10. Risk assessment of proposed technical closure and remediation solution

10.1 Risk assessment goals

The goal of the technical closure and remediation of the GTLF is to gradually reduce the current impact of the site on the surrounding environment.

In order to promote collective engagement between DC and CIG regarding the achievement of realistic levels of remediation, DC has applied the following protocol:

- Undertake risk assessment
- Agree extent of DC's technical closure responsibilities
- Agree target performance goals
- Agree monitoring approach
- Agree timeframe(s) for further investigation if goals not met
- Investigate cause of issue(s)
- If due to DC non-compliance with agreed activities, agree timeframe for DC to undertake corrective works and any additional monitoring during this period
- Otherwise prepare (priced) study into capping and remediation actions

10.2 Short listed options

The currently envisaged the after use for the GTLF comprised the following:

- Recreational open space (open space, recreational and other amenity uses)
- Additional non-landfill infrastructure (tbc)

The exact configuration and associated landscaping approach will be discussed and developed in conjunction with CIG as part of the detailed design submission, but will focus on creating and maintaining a diverse natural habitat encouraging naturally occurring flora and fauna.

The risk assessment is intended to assess the merits, viability and feasibility of DC's proposed technical closure solution, evaluating the acceptability of its performance - and satisfying stakeholder requirements - in terms of protecting human and environmental health and comparing this to the *status quo* (uncontrolled landfilling) arrangements.

10.3 Risk assessment approach

DC's approach to undertaking the risk assessment for the GTLF is summarised in Figure 9:

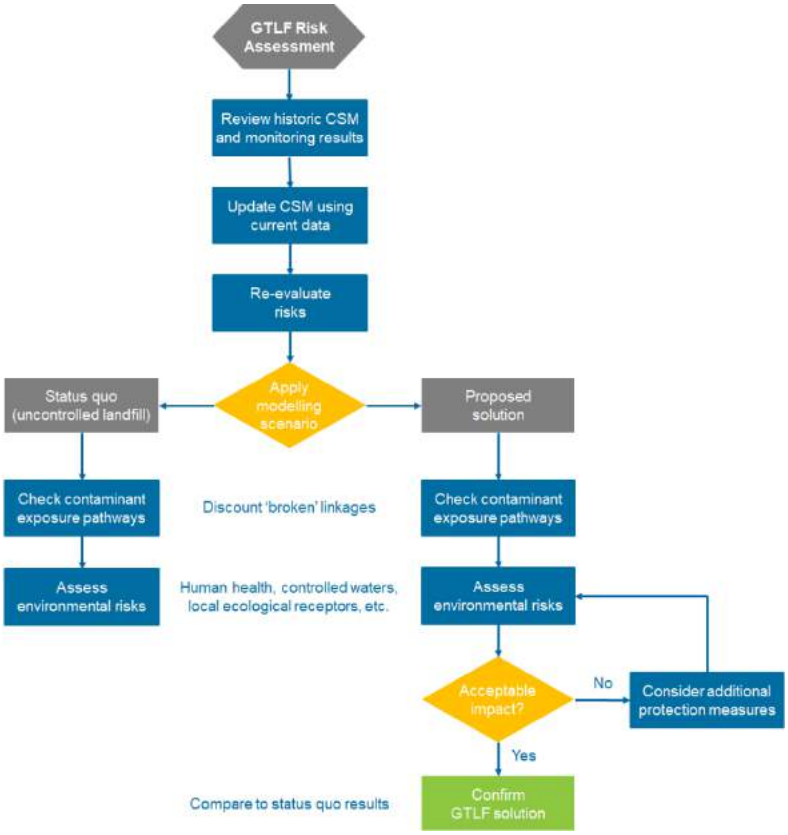

Figure 9 Risk assessment flow chart

10.4 Review of previous assessments

To provide context and background information to assist in developing targeted assessment objectives and work scopes, DC has reviewed various site reports and investigations prepared by and on behalf of CIG. These reports include various (limited) temporal groundwater, surface water, sediment and landfill gas data that were used to develop a Generic Quantitative Risk Assessment (GQRA) and CSM for the GTLF.

The conservative risks identified from the above are repeated below:

- Soil around landfill – risk of arsenic exposure to site workers and visitors through direct contact, inhalation of dust/vapour (to be addressed in separate arsenic contamination study)
- Waste oil storage area – risk of hydrocarbons exposure to surface water in canals through lateral migration in groundwater and runoff
- Groundwater – risk of ammonia, orthophosphate and metals exposure to groundwater, surface water, the North Sound marine waters and marine ecology through leachates from waste, lateral migration in groundwater, ingestion and bio accumulation. The risks to users of the local groundwater resources potentially impacted by landfill activities was also identified.
- Perimeter canal – risk of ammonia exposure to the North Sound marine waters and marine ecology through discharge from surface water canal, ingestion and bio accumulation
- Canal sediments – risk of hydrogen sulphide exposure to the North Sound marine waters and marine ecology through runoff from the canal, ingestion and bio accumulation
- Landfill – risk of landfill gas exposure to site workers, visitors and offsite receptors through the migration and inhalation of landfill gas and/or other vapours

10.5 Risk assessment objectives

Based on the above, DC has developed a site specific risk assessment for its proposed technical closure solution. The main objectives of this risk assessment were to:

- Develop a robust, up to date CSM for the GTLF
- Consider and proposed solution and *status quo* (uncontrolled landfilling) arrangements
- Assess the risks to human health, controlled waters (groundwater resources and surface waters) and local ecological receptors from source contaminants located at the landfill facilities
- Assess the exposure pathways identified by previous GQRA and conceptual risk models, to determine whether or not the linkages are valid (discounting 'broken' linkages from further assessment) or if further linkages should be included in the assessment
- Determine the acceptability of the residual contaminant concentrations at the GTLF (for DC's presumptive option) relative to the identified receptors
- Consider what additional protection measures or amendments to the proposed technical closure solution may be required
- Compare the impact of the proposed technical closure solution to the *status quo* arrangements to demonstrate the levels of additional protection to human and environmental health proved by the new solution.

10.6 Scope of work

Two tasks were required to assess the risks to the environment:

1. Completion of a risk assessment for the parameters in soil, sediment, groundwater, surface water and gas that exceeded the GQRAs
2. Assessment of the feasible risks identified by the risk assessment, if any, to determine the adequacy or otherwise of the presumptive technical closure option

Task 1 – Risk assessment

Following the site investigation and GQRA conducted in 2015/16, identified contaminants of concern were further assessed in the form of a risk assessment addressing risks to human health and controlled waters receptors.

Controlled waters risk assessment

The general approach adopted to conducting the risk assessment for the controlled waters is based on a staged method with each stage referred to as a 'Level'. At each assessment Level, the fate and transport of contaminants of concern are modelled with respect to a particular on- or off-site receptor. The various levels include:

- **Level 1** – constituent source assessment
- **Level 2** – unsaturated zone transport and aquifer dilution
- **Level 3** – saturated zone transport
- **Level 3A** – independent groundwater transport

As described below, the risk assessment was conducted in two parts; considering risks to human health and aquatic life through impacted soils and controlled waters (groundwater and surface water) and to on-site/off-site human health and property from landfill gases. The outcome of these assessments is that including a robust capping system for the North Mound effectively eliminates direct exposure pathways post technical closure.

The GQRA determined a low risk to human health with regard to contaminant concentrations within the ground of the GTLF. However, three water abstraction points are located within one mile of the site, these abstraction points are used for cooling water (0.7 miles south east of the landfill) and municipal water supply (1 mile south east of the landfill). The two water supply wells are operated by Water Authority Cayman who extract saline water and process for drinking water via its reverse osmosis plant at Red Gate Road Water Works. The source, pathway and receptor inputs as finalised in the risk assessment included those listed in Table 9.

Table 9 Human Health scope for risk assessment

Source	Pathway	Receptor
Contaminants within soils including; arsenic, iron and orthophosphate Contaminants within groundwater including ammonia, hydrocarbons and orthophosphates	Leaching of contaminants into groundwater and lateral migration	Groundwater abstraction for cooling water 0.7 miles south east of the GTLF (Progressive) Groundwater abstraction for cooling water 0.5 miles south east of the GTLF (CUC). (Note: process water is discharged to the North Sound). Groundwater abstraction for cooling water 1 mile south west of the GTLF (Government Admin Building). Groundwater abstraction for municipal water supply 1 mile south east of the GTLF Groundwater abstraction for municipal water supply 1 mile north west of GTLF (Britannia) Groundwater abstraction for private water supply 0.6 mile west of GTLF (Margaritaville)

For aquatic/marine life the source, the pathway and receptor inputs for this assessment included those listed in Table 10.

Table 10 Controlled waters scope for risk assessment

Source	Pathway	Receptor
Ammonia, iron and orthophosphate within groundwater Ammonia, copper, lead and elevated nutrients within surface water Spills of hydrocarbon from waste storage area	Vertical and lateral migration of groundwater Surface water run off	Surface water in canals around the landfill Marine water in the North Sound Local groundwater abstractions

To assess risks to human health and aquatic/marine life associated with impacted controlled waters a Level 3A assessment was carried out using the UK Environment Agency (EA) approved ConSim and LandSim software. This software was selected as the preferred tool for this risk assessment as the probabilistic nature of the model and the calculation of contaminant distributions, rather than single values, provides results that can be presented to the Regulators with a higher degree of confidence.

The contaminant distributions calculated for each level of the assessment incorporate the natural variation in the physical characteristics of the subsurface and variation in chemical properties for each contaminant included in the model.

The source, pathway, receptor inputs for the GTLF were modelled. Where aquifer and soil properties were required but site specific data is not available from the 2015 investigation these were obtained from published literature based on comparable aquifers and geology.

The model outputs were being compared with published screening criteria contained within:

- Florida Administrative Code chapter 62-777 Contaminant Clean-up Target Levels from 2005, as consistent with the 2016 GQRA assessment
- Water Framework Directive standards for protection of water environment for nutrients
- US National oceanic & Atmospheric Administration screening criteria for some inorganic and organics where standards are not available in the above sources.

Screening criteria were chosen based on the proposed end land use options set out above. Where relevant criteria were not available in the above resources, GHD assigned other appropriate criteria from reputable sources.

Landfill gas assessment

A landfill gas assessment was being undertaken for the GTLF using the UK EA's GasSim assessment tool. This assessment looked at the following aspects of landfill gas generation at the landfill sites.

- The ongoing production of landfill gas at the Site over the next 150 years
- Landfill gas flux to the environment (for bulk and trace components)
- An assessment of the potential risk to on- and off-site human health and environmental receptors from bulk and trace landfill gas components

Task 2 - Technical closure option assessment

DC's proposed technical closure solution comprises a combination of options shown in Table 11. The final design will be developed to adequately manage the impacts of the pollutants on sensitive receptors as informed by the results of the risk assessment.

Table 11 Technical closure option combinations

Capping and remediation	Gas management	Leachate management
GCL	Passive venting Low density well coverage High density well coverage Landfill gas to flare (enclosed) Landfill gas to flare (elevated) Landfill gas to ERF	Monitoring only Monitoring and reactive management Monitoring and proactive management

The factors being assessed for each aspect of the technical closure option are shown in Table 12.

Table 12 Technical closure option assessment considerations

Capping and remediation	Gas management	Leachate management
Reduction of infiltration of rainwater Providing a barrier for potential harmful substances in soils to impact human health	Reduce the potential for hazardous gasses to concentrate in buildings at the Site Safely capture and utilise or vent hazardous gases away from human health receptors Prevent the lateral migration of hazardous gasses in to surrounding properties Reduce greenhouse gas emissions	Reduce the lateral and vertical migration of leachate in to surrounding groundwater or surface water receptors

10.7 Reporting and risk assessment schedule

GHD's original 'George Town Landfill Environmental Risk Based Assessment' was completed and submitted to CIG in January 2020. This was subsequently updated in August 2020 to consider the requirement or otherwise to provide a landfill cap for the older, less active South Mound.

The risk based assessment confirmed that a landfill cap with an active landfill gas management system is required to be provided over the North Mound to reduce its impact on the surrounding environment, but is not required for the older, less active South Mound.

10.8 Engineering considerations

In support of the above, DC will undertake a Stability Risk Assessment of the proposed finished landform (using SlopeW software) in order to assess its potential short- and long-term stability.

Should the outputs from this modelling present a lower than acceptable factor of safety (typically 1.25), then DC will engage with CIG to present these findings and agree an acceptable way forward.

Potential options are considered to include *inter alia* the following:

- Further reprofiling of the GTLF landform, including additional excavation of materials and/or placement of additional toe support to vulnerable areas
- Drawing down of leachate levels within the GTLF
- Utilisation of additional stabilisation products (e.g. geogrid) within the capping and remediation design

10.9 Mitigation measures

The primary means of mitigating the GTLF's impact on the surrounding environment will be the provision of the new engineered cap and accompanying gas, leachate and surface water management systems. The combined mitigative effects of these actions include the following:

- Capping the previously placed wastes to:
    - Break the current, uncontrolled, migration pathways
    - Remove the potential for direct contact with contaminant materials on-site
    - Remove the potential for airborne transmission of contaminant materials off-site
    - Reduce water infiltration into the waste mass

    - Reduce leachate generation and leachate levels within the waste mass
    - Reduce landfill gas emissions from the surface of the landfill
    - Improve landfill gas capture potential
    - Promote clean surface water run-off
    - Reduce odour from the landfill
- Providing a new gas management system to:
    - Create a negative pressure environment within the waste mass
    - Improve gas capture and collection
    - Valorise the captured gas and generating renewable energy by way of the DC's ERF
    - Provide secondary control by way of a standby flare
    - Reduce odour from the landfill gas
- Providing a new leachate management system to:
    - Monitor for - and react to - leachate outbreaks over the surface and around the perimeter of the landfill thereby minimizing the potential for standing leachate
    - Reduce odour from the landfill leachate
- Providing new environmental monitoring to:
    - Provide active monitoring of environmental conditions on site
    - Enable trending of emissions data
    - Provide early warning of potential environmental issues
    - Establish trigger levels for further action
    - Establish an escalation route in the event of trigger and / or control levels being breached

In the event that the above measures prove insufficient, potential additional mitigation measures that may be considered include:

- Enhanced environmental monitoring
- Extended environmental review
- Additional contaminant source management
- Enhanced barrier systems:
    - Enhanced/improved capping
    - Berms and bunds
    - Cut-off walls
- Enhanced capture and control systems:
    - Gas wells and extraction system
    - Leachate pipes and extraction system
    - Surface water swales
- Enhanced treatment systems:
    - Pump and treat (groundwater)

- Other *in situ* treatment (e.g. for hydrocarbons)
- Active leachate treatment
- Active surface water treatment (e.g. aeration and/or flocculation)

In the event that such additional measures are required, the extent of the studies/works, timescales and division of responsibility will be discussed and agreed with CIG in advance of such works being commenced.

10.10 Further monitoring or study requirements

Casual observation of the area around the GTLF suggests that the WWTP located immediately to the east of the site is a significant additional source of odour in the area, with the prevailing NE to SE winds carrying odours generated at the WWTP across and around the landfill and into the neighbouring communities - particularly along West Bay road between the intersection with Eastern Avenue North and the intersection with Lawrence Boulevard.

Previous stationary and mobile monitoring by DC for hydrogen sulphide (H_2S), methane (CH_4) and odour identified the GTLF to be the origin of odour arising from the emplaced waste, but also highlighted the WWTP as being a source of H_2S odour in the area - as well as generating odour within the WWTP ponds and headworks. Accordingly, this monitoring will be extended during and beyond the technical closure and remediation of the GTLF with a view to:

- Definitively identifying the split of H_2S malodourous emissions from the GTLF, WWTP and other sources
- Quantifying the reduction in odour originating from the GTLF as a result of the technical closure works
- Pinpointing the source of the remaining H_2S and malodours
- Agreeing an action plan to study and remedy the cause of these H_2S emissions and malodours in conjunction with CIG, as part of the overall enhancement of the remediated GTLF area

END

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	A Wilson	DC		A Wilson		20/1/2020
1	A Wilson	DC		A Wilson		21/8/2020
2	A Wilson	DC		A Wilson		25/05/2021

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