TECHNICAL MEMORANDUM

DATE 1 November 2019 **Reference No.** 1777197-050-M-Rev0

TO State Resource Development Manager, Akina Holdings Pty Ltd

CC Alan Kietzmann

FROM Edward Clerk **EMAIL** eclerk@golder.com.au

GREAT SOUTHERN LANDFILL GREENHOUSE GAS ASSESSMENT

1.0 INTRODUCTION

Alkina Holdings Pty Ltd proposes to construct and operate the Great Southern Landfill, located on Allawuna Farm lots 4869, 5931, 9926 and 26934 Great Southern Highway, St Ronans (approximately 80 km east of Perth). It is anticipated the landfill will receive 150,000 to 250,000 tonnes per annum of Class II or III waste, with a lifetime capacity of approximately 5.6 million cubic metres. The cells for the landfill will be developed in stages, with the construction of up to seven cells.

This Technical Memorandum addresses the greenhouse gas requirements as outlined in Section 4 Item 1 of the Draft Environmental Scoping Document (ESD) issued by the Environmental Protection Authority (EPA). The work was conducted in accordance with Proposal 1777197-047-L-RevB dated 31 July 2019.

2.0 TERMINOLOGY

2.1 Greenhouse gases

Greenhouse gas emissions contribute to the changing climate by absorbing infrared radiation and enhancing the Earth's greenhouse effect. The effects of the changing climate are predicted to be significant in Western Australia, with a drying climate in the south-west, more frequent and severe storms in the north-west, and a rising sea level along the entire coastline. The Environmental Protection Agency (EPA) encourages proposal design, technology and operation that ensure emissions are minimised (EPA, 2016)[1].

2.2 Landfill gas

Landfills generate methane (CH_4), a potent greenhouse gas, when organic waste decay in anaerobic conditions. Other gases, mostly carbon dioxide, are also produced and the mix of emitted gases is known as landfill gas. As the landfill gas rises to the surface of the landfill, some oxidation of CH_4 (to CO_2) occurs near the soil surface, where aerobic degraders persist. In landfills with active gas collection systems, the gas is collected (prior to reaching this aerobic soil layer), along with some infiltration air (nitrogen and oxygen). CH_4 typically makes up around half of landfill gas[2].

[1] Environmental Protection Agency (2016) Environmental Factor Guideline: Air Quality. Western Australia. December 2016. Available at: http://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/Guideline-Air-Quality-131216_3.pdf

[2] Intergovernmental Panel on Climate Change (2000). Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Gas emissions from landfills can vary greatly based on a range of factors including:

- The amount of waste deposited
- The type of waste deposited, and
- The location of, and climatic conditions at, the landfill.

2.3 Global Warming Potential and carbon dioxide equivalents

The Global Warming Potential (GWP) is an index used to convert relevant non-carbon dioxide gases to a carbon dioxide equivalent (CO_2-e) by multiplying the quantity of the gas (in tons) by its GWP. The GWP was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The time period used for GWPs is typically 100 years.

The Department of Environment and Energy (2019) suggest using a 100-year GWP of 25 for methane. This is in line with the IPCC Fourth Assessment Report, 2007 (AR4)[3]. It should be noted that in the IPCC Fifth Assessment Report, 2015 (AR5)[4], the GWP for methane was increased to 28.

Western Australia reported solid waste disposal greenhouse gas contributions as 1 286 000 tCO_2-e in 2017 (Department of the Environment and Energy (2019b)).

3.0 REGULATORY CONTEXT

The following documents were consulted in determining the regulatory context of this assessment:

- Clean Energy Regulator (2019) National Greenhouse and Energy Reporting. Guideline: Estimating Emissions and Energy from Solid Waste and Landfill Biogas Management.
- Department of the Environment and Energy (2019a) Australian National Greenhouse Accounts. National Greenhouse Accounts Factors.
- Department of the Environment and Energy (2017) National Greenhouse and Energy Reporting Scheme Measurement. Technical Guidelines for the Estimation of Emissions by Facilities in Australia.
- Department of the Environment and Energy (2019b) Australian National Greenhouse Accounts. State and Territory Greenhouse Gas Inventories (2017).
- Environmental Protection Agency (EPA) Western Australia (2016) Environmental Factor Guideline: Air Quality.
- Environmental Protection Agency (EPA) Western Australia (2019) Environmental Factor Guideline: Greenhouse Gases.

[3] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[4] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- Environmental Protection Agency (EPA) Western Australia (2019) Technical Guidance: Mitigating Greenhouse Gases.
- National Pollutant Inventory (2010) Emissions Estimation Technique Manual for Municipal Solid Waste Landfills. Version 2.0.

3.1 National Greenhouse and Energy Reporting Act

Landfill operators and landfill biogas managers have reporting obligations under the National Greenhouse and Energy Reporting Act 2007 (NGER Act), the National Greenhouse and Energy Reporting Regulations 2008 (NGER Regulations) and the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (NGER Determination) (Clean Energy Regulator, 2019).

Landfill operators and landfill biogas managers required to report under NGER must keep records of the activities across its group to allow it to produce accurate reports prepared in accordance with the NGER Act. Records must be kept for five years and must enable the Clean Energy Regulator to ascertain whether the registered corporation or liable entity has complied with the obligations under the NGER Act.

According to the NGER Regulations, it is necessary to report the amount of waste entering (disposed at) the landfill and the amount of waste received at the landfill for treatment (either on site or off site) or use (waste diverted) when submitting an NGER Report. It is therefore necessary to report both of these values using the NGER Solid Waste Calculator (SWC). Once the emissions from the landfill have been calculated in the SWC, these can then be compared to the relevant reporting threshold. Emissions from the landfill do not need to be reported if they are less than 10,000 tCO_2-e for the reporting year.

Note: Section 8.10 of the NGER Determination states that the aggregated uncertainty level for solid waste disposal on land is 35 per cent. Using this percentage, an emission estimate of 100 kt CO_2-e +/- 35% at the 95% confidence interval means that the true value lies between 65 kt CO_2-e and 135 kt CO_2-e with a probability of 95%. A 95% confidence level does not mean that the estimate needs to be within 5 per cent of the true value.

Emissions from landfill biogas combustion only have to be reported if methane in landfill biogas is above the threshold of 1,000 m^3.

Emissions of CO_2 generated from waste management are considered to be biomass sources and therefore do not need to be estimated. Where methane from waste biomass is recovered and flared or combusted for energy, the CO_2 emitted is not counted as an emission but regarded as part of the natural carbon cycle. The total amount of CH_4 recovered is therefore regarded as saved (not emitted) so long as it does not enter the atmosphere as CH_4 (Department of Environment and Energy, 2017).

The Australian Government's principal mitigation initiative is currently the Emissions Reduction Fund (ERF) and the associated safeguard mechanism. The safeguard mechanism applies to facilities with direct emissions (scope 1) in excess of 100 000 tCO_2-e per annum and requires liable entities to keep emissions at or below a predetermined (historical or calculated) emissions baseline (EPA, 2019).

3.2 EPA Greenhouse Gas Guidance

The Western Australia EPA may decide to assess greenhouse gas emissions within the Environmental Impact Assessment (EIA) process if a proposal's expected total greenhouse gas emissions are deemed to be "significant", i.e. direct emissions of more than 100 000 tCO_2-e per annum (EPA, 2016). These projects with will be required to describe emissions associated with the proposal and to outline management measures for emissions consistent with the EPA's mitigation hierarchy (avoid, reduce, offset) to address all direct (scope 1)[5] emissions from the project. This comprises:

- Avoiding emissions through best practice design and benchmarking – comparing emissions and energy intensity performance metrics reasonably consistent with international industry best practice and ensuring emissions and energy intensity, including adoption of renewable/low emission technologies, are reduced at the design stage and/or a particular level of emissions intensity performance is attained
- Continuous improvement to reduce emissions over the project life – ensuring consideration of measures to improve performance or setting targets for emissions intensity improvement over time, and
- Offsetting emissions (carbon offsets) – requiring the implementation of a greenhouse gas emissions offset package to offset residual emissions.

3.3 National Pollutant Inventory

It has become common at larger landfills for methane to be extracted by specialist companies as the methane can be used to generate electricity or to gain carbon credits (by burning the gas). These specialist companies are responsible for reporting emissions as the gas is a resource transferred for the beneficial use of energy recovery. Substances in the transferred gas may be voluntarily reported by the landfill facility as a transfer (NPI, 2010).

If landfill gas is burned by the landfill operator, they are responsible for reporting to the National Pollutant Inventory (NPI) the relevant set of Category 2a and 2b substances emitted (NPI, 2010).

The threshold quantities for burning landfill gas, as outlined in the NPI Guide, are:

- Category 2a: 367,000 m^3 in the reporting year
- Category 2b: 1,830,000 m^3 in the reporting year.

4.0 ASSESSMENT METHODOLOGY

The United States Environmental Protection Agency (USEPA) LandGEM model was used to estimate the anticipated methane (CH_4) and carbon dioxide (CO_2) emissions resulting from the waste decomposition at the proposed landfill. LandGEM is a screening-level model based on the first order decomposition rate equation for municipal solid waste (MSW) landfills. The model relies on typical factors based on empirical data from U.S. landfills.

LandGEM is one of three emissions estimation models recommended in the Australian National Pollutant Inventory (NPi) emissions estimation technique manual for MSW landfills (2010).

[5] Scope 1 emissions: The GHG emissions released to the atmosphere as a direct result of an activity, or series of activities at a facility level.

First-Order Decomposition Rate Equation used in the LandGEM model is:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}}$$

Where: Q_{CH4} = annual methane generation in the year of the calculation (m^3/year)
i = 1-year time increment
M_i = mass of waste accepted in the i^{th} year (t)
n = (year of the calculation) – (initial year of waste acceptance)
t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (decimal years, e.g., 3.2 years)
j = 0.1-year time increment
k = methane generation rate (year-1)
L_o = potential methane generation capacity (m^3/Mg)

5.0 INPUT PARAMETERS

The input parameters and waste acceptance rates used in the LandGEM model are given in Table 1 and Table 2 respectively. The Great Southern Landfill will have a lifespan of 28 years. For the purpose of this assessment it was assumed this would span 2021-2049. Default pollutant parameters were used.

Table 1: LandGEM input parameters

Parameter		Input
Landfill Characteristics	Landfill Open Year	2021
	Landfill Closure Year	2049
	Waste Design Capacity	7,000,000 t
Model parameters	Methane Generation Rate, k	0.050 $year^{-1}$
	Potential Methane Generation Capacity, L_o	170 m^3/t
	Nonmethane Organic Compound (NMOC) Concentration	4,000 ppmv as hexane
	Methane Content	50% by volume
Pollutants selected	Gas/Pollutant #1:	Total landfill gas
	Gas/Pollutant #2:	Methane
	Gas/Pollutant #3:	Carbon dioxide
	Gas/Pollutant #4:	NMOC

Table 2: Waste acceptance rates

Year	Waste Accepted (tpa)	Waste-In-Place (t)
2021	250,000	0
2022	250,000	250,000
2023	250,000	500,000
2024	250,000	750,000
2025	250,000	1,000,000
2026	250,000	1,250,000
2027	250,000	1,500,000
2028	250,000	1,750,000
2029	250,000	2,000,000
2030	250,000	2,250,000
2031	250,000	2,500,000

Year	Waste Accepted (tpa)	Waste-In-Place (t)
2032	250,000	2,750,000
2033	250,000	3,000,000
2034	250,000	3,250,000
2035	250,000	3,500,000
2036	250,000	3,750,000
2037	250,000	4,000,000
2038	250,000	4,250,000
2039	250,000	4,500,000
2040	250,000	4,750,000
2041	250,000	5,000,000
2042	250,000	5,250,000
2043	250,000	5,500,000
2044	250,000	5,750,000
2045	250,000	6,000,000
2046	250,000	6,250,000
2047	250,000	6,500,000
2048	250,000	6,750,000
2049	250,000	7,000,000
2050-2100	0	7,250,000

6.0 RESULTS

Predicted pollutant emissions rates are shown in Figure 1. Emissions are predicted to peak in the final year prior to capping and decrease exponentially thereafter.

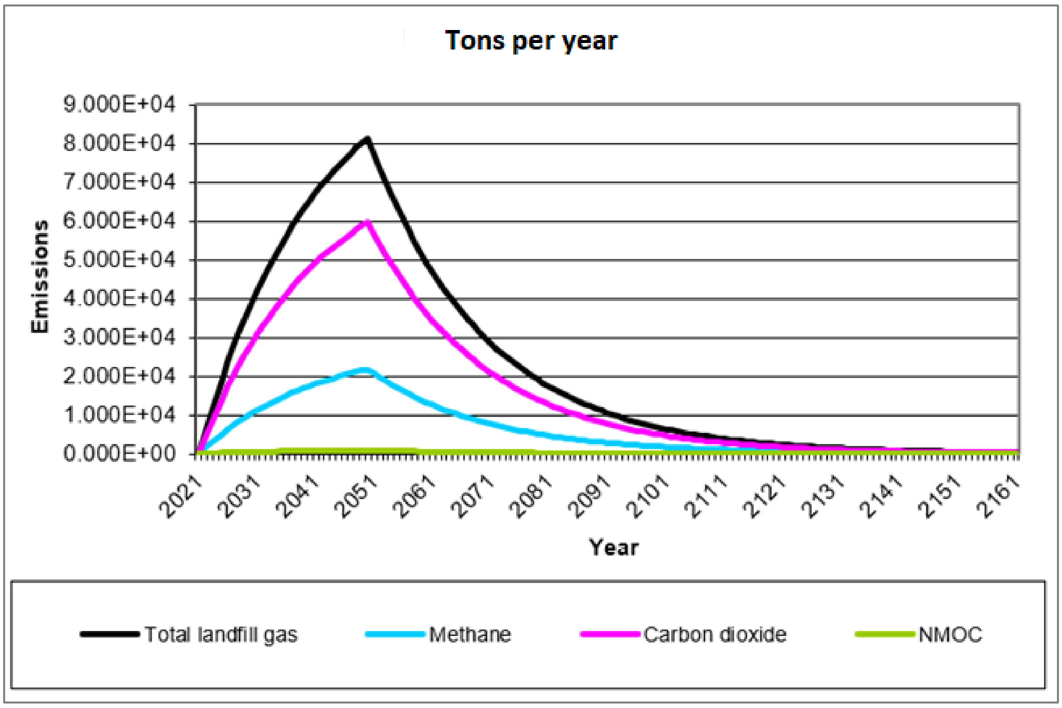

Figure 1: Predicted pollutant emissions rates (tpa)

Predicted emissions and calculated carbon dioxide equivalents (CO_2-e) for selected years are shown in Table 3. According to the LandGEM simulations, with no mitigation measures in place, the landfill would exceed the CO_2-e reporting threshold (>10 000 tCO_2-e) within the first year of opening. Emissions would be considered 'significant' (> 100000 tCO_2-e) within five years of opening. Emissions would peak in the final year (prior to capping) at 543 929 tCO_2-e.

According to the 'Landfill Gas Management Plan – Allawuna Farm Landfill' prepared by SITA in March 2015, landfill gas management measures would collect and treat 95% of this gas during the operational life of the landfill, and close to 100% following the final capping. Assuming a 95% control efficiency, the predicted mitigated tCO_2-e are shown in Table 3. With management measures in place, CO_2-e reporting threshold (>10 000 tCO_2-e) would be reached in year 8 and emissions would not be considered 'significant' (< 100000 tCO_2-e), even at their peak in the final year prior to capping.

Table 3: Peak predicted CO_2-e in 2050

Year	Gas/Pollutant	Unmitigated			Mitigated		
		Emissions rate (tpa)	GWP values for 100-year time horizon	tCO_2-e	Emissions rate (tpa)	GWP values for 100-year time horizon	tCO_2-e
1	Methane	1 386	25	**34 657**	69	25	**1 733**
	*Carbon dioxide**	*3 804*	*1*	*3 804*	*190*	*1*	*190*
5	Methane	5 153	25	**128 813**	258	25	**6 441**
	*Carbon dioxide**	*14 137*	*1*	*14 137*	*707*	*1*	*707*
7	Methane	7 367	25	**184 179**	368	25	**9 209**
	*Carbon dioxide**	*20 214*	*1*	*20 214*	*1011*	*1*	*1 011*
28 (final prior to capping)	Methane	21 757	25	**543 929**	1088	25	**27 196**
	*Carbon dioxide**	*59 697*	*1*	*59 697*	*2985*	*1*	*2 985*

*Notes: *Predicted carbon dioxide is shown here for reference. Emissions of CO_2 generated from waste management are considered to be biomass sources and therefore do not need to be estimated. Where methane from waste biomass is recovered and flared or combusted for energy, the CO_2 emitted is not counted as an emission but regarded as part of the natural carbon cycle (Department of Environment and Energy, 2017).*

7.0 RECOMMENDATIONS FOR MITIGATION AND MANAGEMENT

The following best practice landfill gas management measures reported in the Golder 2017 Works Approval Supplementary Information for the Great Southern Landfill remain valid and are considered appropriate to avoid and reduce greenhouse gas emissions. The implementation of an appropriate landfill gas management system, as described below, is considered critical in ensuring greenhouse gas emissions are avoided and reduced as far as practically feasible.

Proposed Design and Construction Controls

- Design and install an efficient landfill gas extraction and flare system to minimise landfill gas emissions to the environment.
- Engage a specialist landfill gas contractor to design, install, manage and operate the extraction system.
- Lateral and vertical wells will be progressively installed in the waste mass as the height increases. These will start being installed once the waste height has reached a minimum of 10 m above the base liner. These wells will continue to be installed at minimum 10 m height intervals.
- The leachate drainage layer installation will extend 2 m (vertical) up the slope of the landfill as measured from the base of the landfill.

- The remainder of the slope will be covered with a soil protection layer. This will be to prevent a preferred flow path for gas to escape the landfill.
- As the final waste profile is progressively achieved, deep vertical wells (up to 20 m) will be installed on the surface. These wells will be installed at a spacing of 40 m to 50 m to allow for comprehensive coverage of the waste mass. In some areas this spacing will likely be reduced to improve extraction ability. The gas extraction wells will be piped to the gas management system (likely a flare) in the allocated landfill gas infrastructure location. There will be a condensate return pipe from the gas management infrastructure back into the landfill and connected into the leachate collection aggregate layer and/or adjacent waste mass. The gas extraction wells, connecting pipes and condensate return pipes will all be installed before the lined capping layer has been constructed so that there will be minimal penetrations through the capping layer. Where required, penetrations will all be located as close to the edge of the landfill as is reasonably possible.
- A perimeter landfill gas manifold will be installed around the edge of the landfill to act as the main collector of gas running to the flare. All of the extraction wells will be connected to this manifold.
- To reduce the possibility of oxygen intake, there will be no gas extraction (drilled pipes) within 5 m of the sides of the waste mass or final waste profile. There will also be no gas well drilling closer than 5 m from the base and side slopes.

Proposed Operational Controls

- Controls:
  - Operate an efficient landfill gas extraction and flare system to minimise landfill gas emissions to the environment in accordance with Alkina (2017), the operating licence and Landfill Gas Management Plan.
  - Engage a specialist landfill gas contractor to manage and operate the extraction system.
- Monitoring:
  - The landfill gas contractor will undertake regular monitoring of the performance of the gas extraction and destruction system. The extent of monitoring will depend on the type of systems that the contractor installs. As a minimum, the following monitoring will be anticipated:
    - Flare operation
    - Gas flow rate
    - Oxygen content
    - Methane content
    - Moisture content
    - Temperature
    - The monitoring locations and frequency will be determined by the landfill gas contractor.
  - All monitoring of landfill gas emissions will occur on the landfill areas. The following minimum locations will be monitored for fugitive emissions:
    - Landfill surface final cap – random monitoring around the capped surface

- Around penetrations through the capped surface
- Landfill surface intermediate cover area – random monitoring around the covered surface
- Around penetrations through the covered surface
- At the landfill gas flare
- The monitoring frequency is as stipulated in the facility operating Licence.

▪ The regular monitoring of the landfill gas system provides insight into the system operations and analysis of the monitoring data would indicate that there is a potential problem with an element of the system. The following is a list of potential indicators:

- Lower combustion efficiency of the flare could indicate that there is a problem with the temperature of the flare burners
- Reduced gas flow rate would indicate a blocked gas pipe
- Elevated oxygen content would indicate problems with penetration seals or excessive vacuum in an area of the waste mass
- Decreased methane content would indicate decreased moisture content in the waste, or it is stabilising
- Elevated temperature would indicate a subterranean landfill fire, and
- Elevated fugitive gas emissions would indicate problems with cap penetrations, ruptures in the cap lining system or insufficient gas extraction below the landfill cap.

▪ If the regular landfill gas monitoring identifies potential problems with the landfill gas management system, a response plan is to be implemented. This response plan is to incorporate the following:

- Assess the monitoring data to try and identify the possible cause(s)
- Assess how best to confirm the suspected possible cause(s)
- Consider the impact of the problem(s)
- If possible, rectify the problem (e.g. increase gas vacuum pressure)
- If not possible to rectify the problem (e.g. blocked gas extraction pipe), assess the likely impact on future landfill operations and whether there are any contingency measures that could be implemented to minimise the impact (e.g. install additional extraction well), and
- Consider amending the standard operating procedures if the current procedures are ineffective (e.g. change specification of the gas pipe).

■ Contingencies

▪ The landfill gas action levels (EPA, 2014), beyond which the landfill gas contractor or the landfill operator will be required to undertake remedial action include:

- Landfill surface final cap = Methane ≥100 ppm
- Within 50 mm of penetrations through the final cap = Methane ≥100 ppm

- Landfill surface intermediate cover areas (no waste within next three months) = Methane ≥ 200 ppm
- Within 50 mm of penetrations through the intermediate cover = Methane ≥ 1,000 ppm, or
- Landfill gas flares = Methane and volatile organic compounds ≥ 98% destruction efficiency.

8.0 LIMITATIONS OF THE MODEL

LandGEM is a predictive, screening level tool and should not be relied upon for exact landfill gas generation values. In practice, landfill gas quantities generated by the site are likely to vary from those estimated by the model as site specific factors influence the rate of landfill gas generation. Refinement of the estimates using the Technical Guidelines for the Estimation of Emissions (Department of the Environment and Energy, 2017) is recommended as the landfill develops.

9.0 CLOSING REMARKS

We trust that this technical memorandum provides sufficient information regarding the anticipated greenhouse gas emissions associated with the proposed Great Southern Landfill. Please do not hesitate to contact us if you require any further elaboration or clarification.

GOLDER ASSOCIATES PTY LTD

Edward Clerk
Principal

CA/LC,EWC/ds

https://golderassociates.sharepoint.com/sites/101511/shared documents/06 deliverables/correspondence out/049-052 esd responses for env review doc/1777197-050-m-rev0 ghg.docx

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