TECHNICAL MEMORANDUM

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TO State Resource Development Manager, Alkina Holdings Pty Ltd

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GREAT SOUTHERN LANDFILL DESKTOP GEOCHEMICAL RISK CHARACTERISATION

1.0 INTRODUCTION

1.1 Background

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 geochemical risk characterisation of waste material as outlined in Section 3 Item 29c of the Environmental Scoping Document (ESD) issued by the Environmental Protection Authority (EPA) on 29 August of 2019. The work was conducted in accordance with Proposal 1777197-047-L-RevB dated 31 July 2019.

2.0 DESKTOP REVIEW

2.1 Characteristics of landfill leachate chemistry

According to DWER (2018), the waste types permitted for disposal at Class II or III landfill include clean fill, inert waste type 1, uncontaminated fill, neutralised acid sulfate soil, putrescible wastes, contaminated solid waste meeting waste acceptance criteria specified for Class II or III landfills (where authorised under an Environmental Protection Act licence), inert Waste Type 2 (where authorised under an Environmental Protection Act licence), Special Wastes Type 1, Type 2 and Type 3 (where authorised under an Environmental Protection Act licence). As a result of a series of chemical and microbiological processes, the common contaminants released from the landfill waste material include but not limited to: polychlorinated biphenyls, Alkanes, sulfides, metals, asbestos, organic acids, nutrients (e.g. nitrogen, phosphorus), petroleum hydrocarbons, polycyclic aromatic hydrocarbons, ammonia, landfill gases (e.g. methane), total dissolved solids (TDS), monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene & xylenes), phenols, etc (DER, 2014).

Golder Associates Pty Ltd (Golder) was provided with access to some monitoring results of landfill leachate chemistry from two operating landfill sites in WA (GHD, 2011,2014,2015,2016 and lab testing reports). These two operating landfill sites provide “expected landfill leachate” for the proposed Great Southern landfill development since the two operating landfill sites have received and are receiving waste materials with the same or similar classification (see details in Table 1).

Table 1: Selection of landfill sites in WA for leachate water quality analysis

Landfill Site	Status	Operation Start Year	Waste Classification
Cardup (Shale road)	in operation	1999	Class II and III (currently Class II) (putrescible)
Opalvale (Salt Valley Road)	in operation	2019	Class II (putrescible)
Great Southern (Allawuna farm)	proposed	n/a	Class II or III (putrescible)

Table 2 presents the maximum concentrations of landfill leachate monitoring results from Cardup landfill site during November 2011 to April 2016 and from Opalvale landfill site during August in 2019 to September 2019. As Cardup landfill has been in operation since 1999, the leachate at Cardup landfill is more “mature” and therefore regarded more representative and informative for the Great Southern landfill development. Whilst Opalvale landfill leachate is relatively “benign” in terms of concentrations of contaminants due to limited operation period (Table 2).

The main characteristics of Cardup landfill leachate chemistry are summarised below:

- Neutral or slightly alkaline leachate pH ranging from 7.4 to 8.4,
- Elevated salinity and TDS (up to 13700 mg/L) associated with elevated concentrations of major ions (e.g., sodium up to 2300 mg/L, potassium up to 1300 mg/L and chloride up to 4590 mg/L),
- Moderate to elevated concentrations of heavy metal(loid)s (e.g., arsenic, chromium, copper, total/dissolved iron, lead, manganese, nickel and zinc) that are mostly in exceedance of freshwater/drinking water guidelines (ANZECC, 2000; ADWG, 2011),
- Elevated nutrients concentrations (e.g., ammonia, total nitrogen) exceeding freshwater guideline (ANZECC, 2000),
- Elevated concentration of methane (up to 7150 µg/L) and chemical oxygen demand (up to 6500 mg/L),
- The BTEX group (Benzene, Toluene, Ethylbenzene, Xylene) has been detected and generally in exceedance of freshwater and/or drinking water guidelines,
- Organochlorine pesticides (Dieldrin) has been detected above LOR,
- Some other volatile organic compounds that have been identified above LOR include 1,2,4-trimethylbenzene, isopropylbenzene, styrene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2-butanone (MEK), acetone, chlorobenzene, cis-1,2-dichloroethene, dichloromethane, hexachlorobutadiene, n-propylbenzene, and p-isopropyltoluene, etc.

Table 2: Table Statistic summary of leachate water quality based on lab testing results from two other landfill sites

ChemGroup	ChemName	Unit	Limit of Reporting (LOR)	ANZECC (2000) Fresh Waters	ADWG (2011) Drinking Water Health Value	DoH (2014) Non-Portable Groundwater Use	Cardup (Shale Road)	Opalvale (Salt Valley Road)
Inorganics	Chemical Oxygen Demand	mg/L	10				6500	39
	Dissolved Oxygen	mg/L	0.1				1	
	pH (Lab)	pH unit	0.01	6.5-8.5			8.4	
	Total Dissolved Solids	mg/L	10				13700	380
Major ions	Calcium (Filtered)	mg/L	0.2				76	----
	Magnesium (Filtered)	mg/L	0.1				97	----
	Sodium (Filtered)	mg/L	0.5				2300	----
	Potassium (Filtered)	mg/L	0.1				1300	13
	Chloride	mg/L	1			250	4590	86
	Sulfate (Filtered)	mg/L	1		500	1000	58	140
Metals	Arsenic (Filtered)	mg/L	0.001	0.037	0.01	0.1	0.474	0.001
	Cadmium (Filtered)	mg/L	0.0001	0.0002	0.002	0.02	0.0005	< 0.0002
	Chromium (III+VI) (Filtered)	mg/L	0.001				0.795	< 0.001
	Copper (Filtered)	mg/L	0.001	0.0014	2	20	0.62	0.008
	Iron	mg/L	0.05	0.3		0.3	19	1.4
	Lead (Filtered)	mg/L	0.001	0.0044	0.01	0.1	0.017	< 0.001
	Manganese (Filtered)	mg/L	0.001	1.9	0.5	5	0.6	0.12
	Nickel (Filtered)	mg/L	0.001	0.011	0.02	0.2	0.43	0.006
	Zinc (Filtered)	mg/L	0.005	0.008		3	0.612	0.012
Nutrients	Ammonia as N	mg/L	0.01	0.9		0.41	3400	0.58
	Nitrate (as N)	mg/L	0.01		11.3	112.9	0.24	0.36
	Nitrite (as N)	mg/L	0.01		0.9	9.1	0.025	0.04
	Nitrite + Nitrate as N	mg/L	0.01	2			0.2	0.4
	Nitrogen (Total)	mg/L	0.1	0.2			3400	4.06

ChemGroup	ChemName	Unit	Limit of Reporting (LOR)	ANZECC (2000) Fresh Waters	ADWG (2011) Drinking Water Health Value	DoH (2014) Non-Portable Groundwater Use	Cardup (Shale Road)	Opalvale (Salt Valley Road)
Organic	TRH C6 – C 9 Fraction	µg/L	40				930	<20
	Methane	ug/L	10				7150	<10
Organochlorine pesticides	Dieldrin	ug/L	0.002				0.7	<0.5
BTEX	Benzene	ug/L	1				10	<1
	Toluene	ug/L	1				210	<2
	Ethylbenzene	ug/L	1				130	<2
	Xylene (o)	ug/L	1				92	<2
	Xylene (m & p)	ug/L	1				350	<2
	TRH C6-C10 less BTEX	mg/L	0.05				1.3	< 0.02
	Naphthalene	ug/L	5				10	<1
Volatile Organic Compounds	1,1,1,2-tetrachloroethane	ug/L	1				<1	<1
	1,1,1-trichloroethane	ug/L	1				<1	<1
	1,1,2,2-tetrachloroethane	ug/L	1				<1	<1
	1,1,2-trichloroethane	ug/L	1				<1	<1
	1,1-dichloroethane	ug/L	1				<1	<1
	1,1-dichloroethene	ug/L	1				<1	<1
	1,1-dichloropropene	ug/L	1				<1	<1
	1,2,4-trimethylbenzene	ug/L	1				69	<1
	Isopropylbenzene	ug/L	1				4	----
	Styrene	ug/L	1				6	<1
	1,2,3-trichlorobenzene	ug/L	1				<1	----
	1,2,3-trichloropropane	ug/L	1				<1	<1
	1,2,4-trichlorobenzene	ug/L	1				<1	----
	1,2-dibromo-3-chloropropane	ug/L	1				<1	<1
	1,2-dibromoethane	ug/L	1				<1	<1
	1,2-dichlorobenzene	ug/L	1				<1	<1

ChemGroup	ChemName	Unit	Limit of Reporting (LOR)	ANZECC (2000) Fresh Waters	ADWG (2011) Drinking Water Health Value	DoH (2014) Non-Portable Groundwater Use	Cardup (Shale Road)	Opalvale (Salt Valley Road)
	1,2-dichloroethane	ug/L	1				<1	<1
	1,2-dichloropropane	ug/L	1				<1	<1
	1,3,5-trimethylbenzene	ug/L	1				18	<1
	1,3-dichlorobenzene	ug/L	1				<1	<1
	1,3-dichloropropane	ug/L	1				<1	<1
	1,4-dichlorobenzene	ug/L	0.1				5.7	<1
	2,2-dichloropropane	ug/L	1				<1	----
	2-butanone (MEK)	ug/L	10				60	<2
	2-chlorotoluene	ug/L	1				<1	----
	2-hexanone (MBK)	ug/L	10				<10	----
	4-chlorotoluene	ug/L	1				<1	<1
	4-methyl-2-pentanone (MIBK)	ug/L	10				<10	2
	Acetone	ug/L	10				60	10
	Bromobenzene	ug/L	1				<1	<1
	Bromodichloromethane	ug/L	1				<1	<1
	Bromoform	ug/L	1				<1	<1
	Bromomethane	ug/L	10				<10	<1
	Carbon disulfide	ug/L	1				<1	<1
	Carbon tetrachloride	ug/L	1				<1	<1
	Chlorobenzene	ug/L	1				3	<1
	Chlorodibromomethane	ug/L	1				<1	----
	Chloroethane	ug/L	10				<10	<1
	Chloroform	ug/L	1				<1	<5
	Chloromethane	ug/L	10				<10	<1
	cis-1,2-dichloroethene	ug/L	1				3	<1
	cis-1,3-dichloropropene	ug/L	2				<2	<1
	cis-1,4-Dichloro-2-butene	ug/L	1				<1	<5

ChemGroup	ChemName	Unit	Limit of Reporting (LOR)	ANZECC (2000) Fresh Waters	ADWG (2011) Drinking Water Health Value	DoH (2014) Non-Portable Groundwater Use	Cardup (Shale Road)	Opalvale (Salt Valley Road)
	Dibromomethane	ug/L	1				<1	<1
	Dichlorodifluoromethane	ug/L	10				<10	<1
	Dichloromethane	ug/L	2				2.5	----
	Hexachlorobutadiene	ug/L	0.5				0.5	<1
	Iodomethane	ug/L	1				<1	<1
	n-butylbenzene	ug/L	1				<1	----
	n-propylbenzene	ug/L	1				6	----
	Pentachloroethane	ug/L	1				<1	<5
	p-isopropyltoluene	ug/L	1				111	----
	sec-butylbenzene	ug/L	1				<1	----
	tert-butylbenzene	ug/L	1				<1	----
	Tetrachloroethene	ug/L	1				<1	<1
	trans-1,2-dichloroethene	ug/L	1				<1	<1
	trans-1,3-dichloropropene	ug/L	2				<2	<1
	trans-1,4-Dichloro-2-butene	ug/L	1				<1	<5
	Trichlorofluoromethane	ug/L	10				<10	<1
	Vinyl acetate	ug/L	10				<10	----
	Vinyl chloride	ug/L	10				<10	<1

2.2 Characteristics of groundwater chemistry at Allawuna Farm

The groundwater monitoring results at Allawuna Farm (Golder, 2017 and references therein) provided a baseline groundwater quality dataset for the proposed landfill development. The key findings were follows:

- Groundwater pH, which was moderately to strongly acidic ranging from 3.2 to 6.0, didn't meet the ANZECC (2000) guideline for fresh and marine water quality.
- Groundwater Electrical Conductivity (EC) measurements were highly variable, ranging from brackish to saline (1.3 to 30.6 mS/cm), with a median EC of 18 mS/cm (brackish-saline, ~12000 mg/L) and the median chloride concentration of 6130 mg/L.
- Some heavy metals (e.g., iron, manganese, nickel) were identified above LOR and in exceedance of the ANZECC (2000) guideline for fresh and marine water quality.
- With the exception of total recoverable hydrocarbons, the datasets did not record the presence of potential contaminants including polycyclic aromatic hydrocarbons, monocyclic aromatic hydrocarbons, total recoverable hydrocarbons, organochlorine and organophosphorus pesticides, solvents, volatile organic compound and halogenated benzenes.

Overall, the acidic pH and high salinity characteristics of identified groundwater at the site precluded the use for portable (drinking) and non-portable domestic use (Golder, 2017).

3.0 GEOCHEMICAL RISK

The geochemical risk for the landfill waste material is associated with landfill leachate escaping the landfill cells and leachate pond and entering local soils and aquatic systems.

The likelihood of deterioration and contamination of groundwater quality caused by leakage and/or spilling of landfill leachate from landfill cells and leachate pond during operation is categorised “Unlikely” based on the following mitigation and control measures in place (Golder, 2015a):

- Designed liner system (composite liner) and underlying sub-drainage (clayey soil) layer (all constructed under a third-party quality assurance programme) will minimise seepage infiltration and to provide greater residence time before being mobilised in groundwater aquifer. Any leakage of leachate from the landfill will likely be intercepted before impacting receptors.
- Recycled leachate head on the landfill liner will be maintained at a maximum of 300 mm in accordance with the Vic-BPEM guidelines, industry practice and typical landfill licensing conditions.
- The collected recycled leachate will be pumped into the recycled leachate pond for storage and evaporation.
- The design of the leachate and surface water infrastructure (incl. leachate pond, stormwater dam, retention pond) have been designed for storm events.
- A site-specific water management plan will be developed for the site including the management of surface water, leachate and sub-soil drainage (Golder, 2015b).
- Surface and groundwater monitoring regimes will be implemented to detect any leachate contamination.

If leachate leakage/spilling were to occur, the following leachate-groundwater interactions could be expected:

- Neutralisation reaction between neutral to slightly alkaline leachate and acidic groundwater, resulting in decrease in leachate pH and increase in groundwater pH.

- Significant change of TDS is unlikely to occur in the groundwater aquifer due to similar EC/TDS values between Cardup landfill leachate (13700 mg/L) and groundwater at Allawuna farm (median TDS ~12000 mg/L).
- Contaminants in landfill leachate (e.g., heavy metal(loid)s, ammonia, organo-pesticides, BTEX and volatile organic compounds) are expected to be mobilised following the pathway of groundwater flow. Modelling of groundwater flow and un-retarded contaminant transport (Golder, 2019) indicated that contaminant plume would travel a distance of 360 m over a period of > 20 years to reach the creek line receptor, and that the centroid of the contaminant plume is likely to reach the creek after 45 years (>95% confidence).
- The soils and alluvial sediments underlying/near the landfill site are likely to provide some attenuation (e.g. sorption, degradation and amelioration) to the transport of contaminant plume in the groundwater system, thus limiting the impact on groundwater quality. Based on groundwater gradients, and underlying soils, there will be substantial residence time for solutes to be ameliorated prior to entering downstream environments.

These potential leachate-groundwater interactions have been identified according to the characteristics of local groundwater quality, expected landfill leachate water quality and the hydrogeological conceptualisation and contingency planning as part of the ESD requirement (Golder, 2019).

In determining the consequence of a risk event, the following is considered:

- The groundwater has limited use based on its quality.
- There are no groundwater users.
- The adjoining Helena catchment is not a receptor and there is no paleo-channel in the valley.
- The condition of the Thirteen Mile Brook vegetation is considered to be degraded.

The hydrogeological setting of the landfill site, condition of the receptors, together with the design of the containment infrastructure and proposed mitigation/management strategies presents limited pathways to receptors, suggesting that any off-site impacts at a local level would be minimal, and not detected at a wider scale (minor consequence rating, Table 3). Based on the setting and mitigation controls, the risk event will probably not occur in most circumstances (unlikely), resulting in a low risk profile (Table 3).

Table 3: Risk matrix

Likelihood		Consequence				
		Catastrophic	Major	Significant	Minor	Insignificant
		5	4	3	2	1
Almost certain	**5**	25 (VH)	20 (VH)	15 (H)	10 (M)	5 (L)
Likely	**4**	20 (VH)	16 (H)	12 (M)	8 (M)	4 (L)
Possible	**3**	15 (H)	12 (M)	9 (M)	6 (L)	3 (VL)
Unlikely	**2**	10 (M)	8 (M)	6 (L)	4 (L)	2 (VL)
Rare	**1**	5 (L)	4 (L)	3 (VL)	2 (VL)	1 (VL)

(VL) Very Low Risk	No additional controls necessary. Continue to monitor risk.
(L) Low Risk	Consider additional controls to further reduce risk.
(M) Moderate Risk	Controls must be implemented to reduce risk.
(H) High Risk	Risk unacceptable; do not proceed without controls, minimum of 'engineering controls'.
(VH) Very High Risk	Risk unacceptable; do not proceed without controls, elimination or substitution

4.0 REFERENCES

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