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Project Kea

Surface and Groundwater Assessment

for: South Island Resource Recovery Limited

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Cover photo: Project KEA's official logo, retrieved from https://www.projectkea.co.nz/

EXECUTIVE SUMMARY

South Island Resource Recovery Limited proposes to build and operate an Energy from Waste ("EfW") facility (known as Project Kea) at South Canterbury. The location is bordered by a natural surface water stream and irrigation channels, with groundwater levels reaching above 2 metres below ground level (mbgl) during irrigation season.

Part of the construction includes the excavation of an approx. 8m deep bunker at the centre of the Site to accommodate a "waste bunker". The excavation will likely go through groundwater and require dewatering during construction.

During operation of the facility, municipal solid waste (MSW) will be received and stored in the underground bunker. Moisture in the MSW can form a leachate that is collected at the base of the bunker for onsite disposal in the furnace. Stormwater, which may include deposited material from the air discharge, will be discharged to ground and infiltrate to groundwater. Domestic wastewater will be treated and disposed to a discharge field.

The proposed construction methodology, including the dewatering of the bunker excavation and discharge to ground at the location, are not likely to have significant effects to surface and groundwater quantity or quality.

The proposed operation of the facility includes the leachate collection at the base of the bunker below seasonal low groundwater levels. Due to the pressure differential, if there is any loss of integrity to the bunker seal, groundwater is likely to seep into the bunker instead of leachate seeping out of it.

The proposed stormwater system and the domestic wastewater system are designed in accordance with the relevant guidelines, standards, and best practices, providing appropriate treatment and discharge.

Therefore, the operation of the facility, including the underground waste storage bunker, stormwater system, and domestic wastewater system, is unlikely to have any significant effects to surface and groundwater quality.

As additional precaution, groundwater monitoring is recommended to enable samples to be taken both up and down gradient of the bunker.

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1 BACKGROUND

Babbage Consultants Limited (“Babbage”) has been engaged by South Island Resource Recovery Limited (“SIRRL”) to prepare a resource consenting application for the establishment of an Energy from Waste (“EfW”) facility (known as Project Kea) at Morven-Glenavy Road in Glenavy, Waimate District, Canterbury (the “Site”).

Part of the construction of the facility will include the excavation of an 8m deep trench at the centre of the Site to accommodate a “waste bunker”. The excavation will likely go through groundwater levels and require dewatering during construction.

During operation of the facility, municipal solid waste (MSW) will be received and stored in the underground bunker. Moisture in the MSW can form a leachate that is collected at the base of the bunker for onsite disposal in the furnace.

We were requested to provide a high-level assessment on the potential effects of the construction dewatering, and the operation of the storage bunker, on local groundwater and surface water around the Site.

2 SITE DETAILS

2.1 Site Location

The Site is located between Carrolls Road and Morven Glenavy Road in Waimate, South Canterbury. As shown in Figure 1, the site is bounded by the Morven Glenavy Road to the east, an irrigation race (from Morven Glenavy Ikawai Irrigation Company Limited) and the South Island Main Trunk railway (SIMT) line to the west, Carrolls Road to the south, and by Whitney's Creek to the north. The surrounding land use, including the Site, is pastoral farming, predominately dairy.

Other significant locations in the area are the State Highway 1 approximately 1.5 km to the west, the Oceania Dairy Limited dairy processing plant 1.5 km to the northwest, the township of Glenavy 2 km to the south, the Waitaki River approximately 3 km to the south, and the Pacific Ocean 4 km to the east.

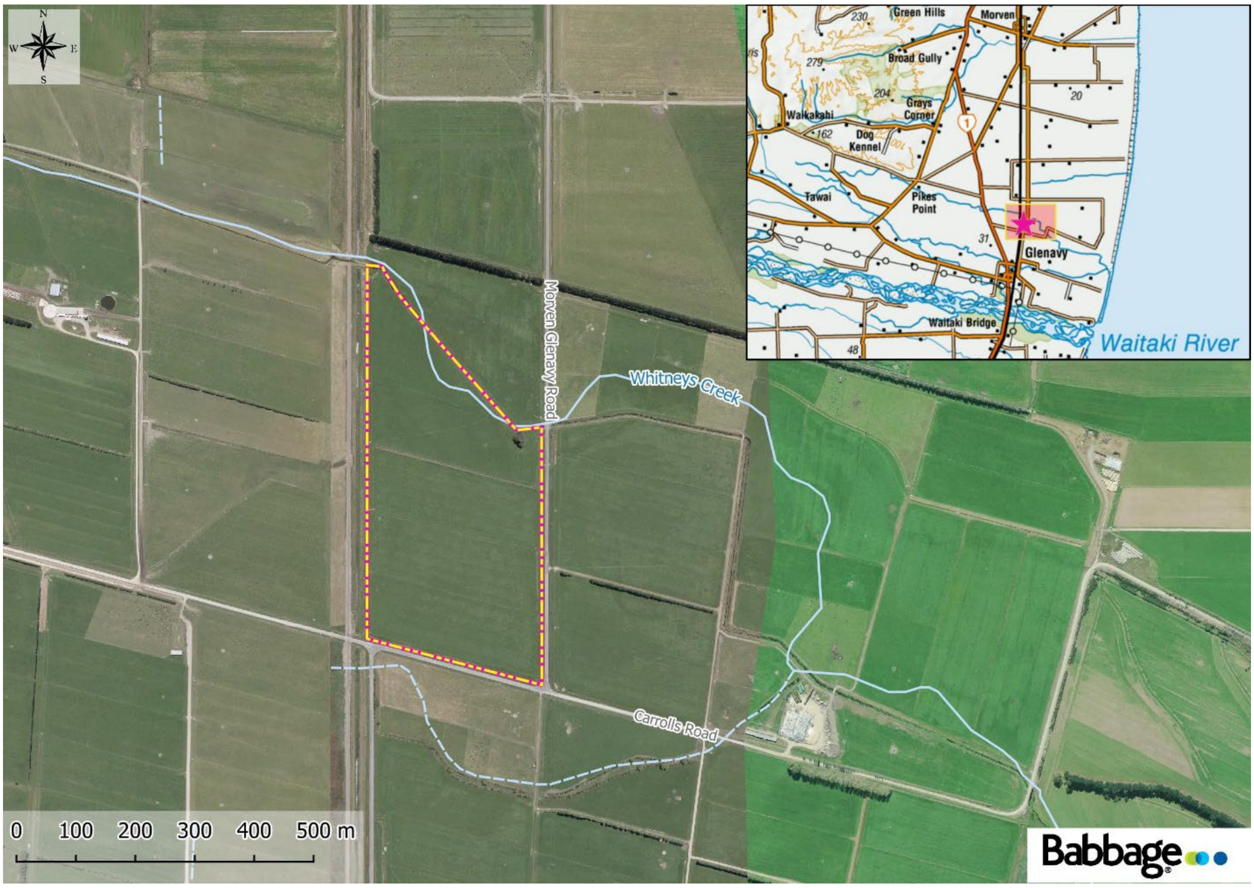


Figure 1: Site Location (Whitneys Creek prior to being channelized)

2.2 Property Details

The legal description of the site is Rural Section 22268, Title reference CB27B/314 with the owner being Murphy Farms Limited. The total area of the site is 14.85 hectares (ha).

3 EXISTING ENVIRONMENT

3.1 Topography and Land Use

The existing ground surface on the site generally slopes down from west to east with a very minimal gradient of approximately 0.3 % (1 v to 300 h). The railway line elevation varies between approximately RL 29.0 m and RL 27.4 m (northern site boundary and southern site boundary respectively), while the site is generally between RL 27.0 m and RL 26.0 m (western and eastern boundary respectively). The railway line is also elevated above the land to the east. The existing ground surface on the site is generally 1.5-2 m below the top of the railway line.

The Site is presently used as pastoral farming with improved pasture used for livestock grazing. Some trees and shrubs are present at the margins of Whitneys Creek at the northern boundary and at some paddock divisions.

3.2 Surface Water

The Site is bordered by an irrigation race on the west boundary, running north to south along the rail line, and by Whitneys Creek, which abuts the northern boundary of the site flowing west to east, as shown in Figure 2.

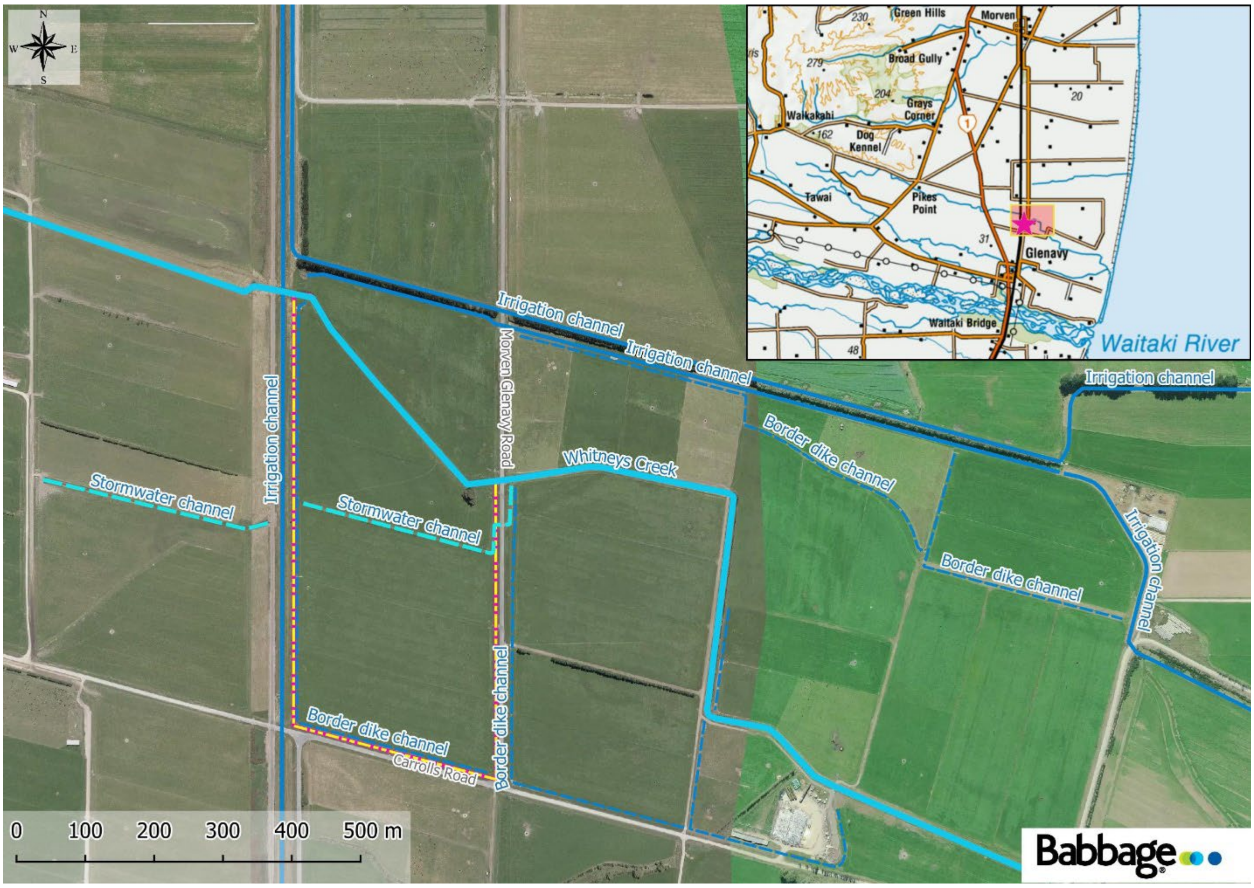


Figure 2: Surface water bodies and irrigation channels

The irrigation race, from the Morven Glenavy Ikawai Irrigation Company Limited (MGI), is an open channel with flowing water for most of the year, usually from September to April each year (irrigation season), with a few exceptions when channels are "flushed" in off-season. The main races are below ground level, but mounded earth up to 0.5 m high protects the main races from overland flows in most areas near the Site.

Further to the main irrigation race, the Site contains a series of border dike irrigation channels along the west and south boundaries, and along the eastern boundary across the Morven Glenavy Road, as shown in Figure 2. The border dike channels are used to irrigate the Site, and nearby paddocks, by flooding the channels and allowing water to infiltrate to the paddocks. A stormwater channel, draining the opposite side of the railway also crosses the Site and discharges to Whitneys Creek on the opposite side of Morven Glenavy Road.

The Whitneys Creek is a small local stream that runs from the hills at Pikes Point, over 12 km northwest of the Site, through an agricultural catchment dominated by dairy farming, to the Waitaki River mouth and the Pacific Ocean approximately 6 km to the southeast of the Site.

The creek is approximately 2.5 m wide and 0.25 m deep at the point where it crosses State Highway 1, upstream from the Site. Photos of Whitneys Creek upstream, as it crosses a neighbouring property near State Highway 1, and at the Site are shown in Figure 3.

a) **b)**

Figure 3. Whitneys Creek at a) a neighbouring property upstream near SH1; and b) at the Site.

The creek's flow path has been modified with sections straightened and/or realigned to suit paddock layouts and farm boundaries, as is the case for the Site. The creek has very limited riparian vegetation, and it is likely stock have access to the creek in some locations. It is likely the habitat within the creek is highly degraded with the biotic community limited to invertebrate and fish communities tolerant of high sediment loads, warm temperatures degraded water quality.

Environment Canterbury (ECAN) monitors the water quality in Whitneys Creek at two locations of interest, upstream of the Site at State Highway 1 (Site ID SQ21288), and at downstream of the Site at Carrols Road (Site ID SQ21289). A summary of the available water quality data is shown in Table 1.

Table 1. Summary of water quality for Whitneys Creek.

Measurement		Upstream at SH 1[1]			Downstream at Carrols Road[2]		
		Max	Average	Min	Max	Average	Min
Ammoniacal Nitrogen	mg/L	0.17	0.0	0.009	0.74	0.1	0.01
Dissolved Oxygen	mg/L	18.6	12.7	5.33	16.74	9.0	2.1
Dissolved Oxygen Saturation	%	170	116.3	63.1	152	80.2	14.1
Dissolved Reactive Phosphorus	mg/L	1.2	0.1	0.004	1.5	0.2	0.001
E. coli	MPN/100mL	-	-	-	2,420	500.7	2
Faecal Coliforms	Cfu/100mL	17,000	1,608.2	8	-	-	-
Nitrate-N Nitrite-N	g/m^3	2.1	0.4	0.01	4.5	1.5	0.003
pH		9.1	8.3	7.1	9	7.6	6.6
Total Nitrogen	g/m^3	3	1.1	0.37	5.2	2.2	0.43
Total Phosphorus	g/m^3	1.4	0.2	0.015	1.9	0.2	0.018
Total Suspended Solids	mg/L	205	18.3	0.8	220	8.8	0.4
Turbidity	NTU	120	7.3	0.7	150	4.6	0.2
Water Temperature (Field)	C	21.3	12.7	5.6	19.1	11.5	1.6

Note: Data from ECAN website accessed on 16/11/2022, as per footnote 1 and 2.

The wider catchment within which the Site is located is known to contain the *Threatened – Nationally Critical* Canterbury mudfish (Neochanna burrowsius). There have been several records of this species in various waterways including Whitneys Creek, approximately 4 km upstream from the Site. There are no records of mudfish east (downstream) of SH1 in the New Zealand Freshwater Fish Database, however it is possible they are present given the right conditions (slow flowing/still waterway/pond, with macrophyte coverage).

3.3 Groundwater

The Site is within the Whitney's Creek Groundwater Allocation Zone, shown in Figure 4.

The Site is underlain by the unconfined Waitaki Gravel Aquifer, which extends from approximately 2 metres below ground level (mbgl) to between 30-60 mbgl. The variation in depth is due mostly to the geological deposition (by braided river fans) and the formation of paleo-channels. Although considered

[1] https://www.ecan.govt.nz/data/water-quality-data/wqdetails/?SiteID=SQ21288
[2] https://www.ecan.govt.nz/data/water-quality-data/wqdetails/?SiteID=SQ21289

an unconfined aquifer, due to the varying layers of silty gravels and clay-bound gravels, the Waitaki Gravel Aquifer can present locally confined or semi-confined (leaky) layers, with varying degrees of connection to direct surface recharge.

Underlaying the Waitaki Gravel Aquifer is the Cannington Terrestrial Aquifer, which extends from between 40-60 mbgl to basement rock and is semi-confined under the Site.

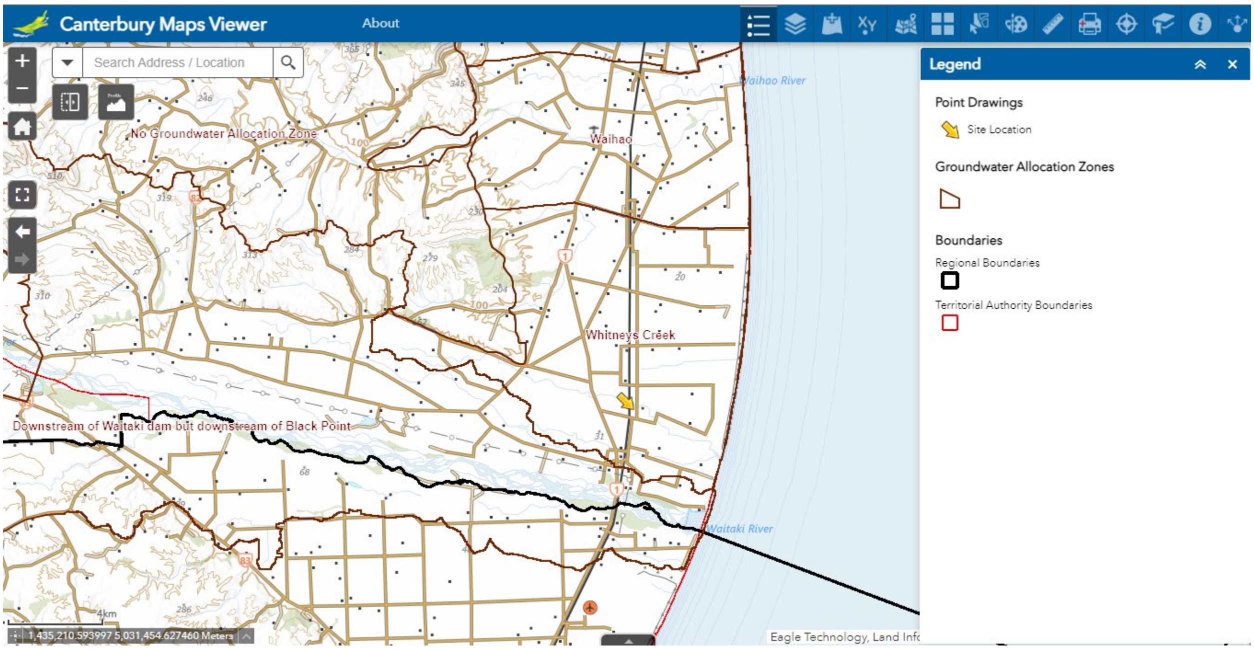


Figure 4: Groundwater Allocation Zones

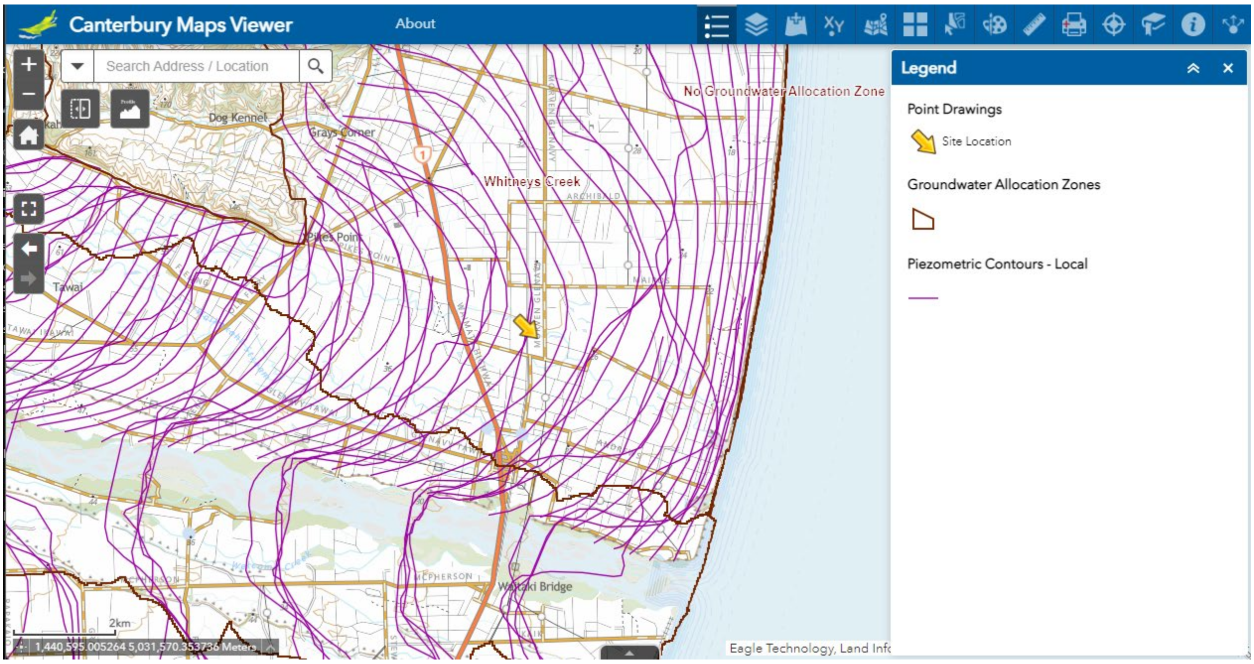


Figure 5: Piezometric contours for the area.

The Waitaki Gravel Aquifer receives recharge from the Waitaki River Catchment, as can be inferred by the local piezometric contours shown in Figure 5. Furthermore, groundwater levels in the aquifer are influenced by the MGI irrigation scheme, through soil drainage from irrigated fields and leakage from channels. Environment Canterbury Regional Council (ECan) identified that "*losses from irrigation races in the [...] region amounts to about 26 % of the total groundwater recharge in that area*".

Data from monitoring wells (graph presented in Figure 6, locations in Figure 7), installed about 1.5 km northwest of the Site, show that irrigation directly influences groundwater levels, with a groundwater seasonal high during the peak of irrigation season and a seasonal low just before the irrigation restarts. Despite being from monitoring bores 1.5 km away from the Site, the monitoring location, like the Site, is in the vicinity of MGI irrigation races, with the bores closer to the races (PZ08 – CB19/5043) showing the higher groundwater fluctuations (approximately 6 m).

As the Site is located further southeast from the monitoring location (shown in Figure 7), based on the local piezometric contours (shown in Figure 5), groundwater levels (in m RL) are likely 2 to 3 m lower (in m RL) at the Site than near Cooneys Road. Available piezometric contours from ECan (Figure 5) show that groundwater levels at the Site are around 26-24 m RL in September.

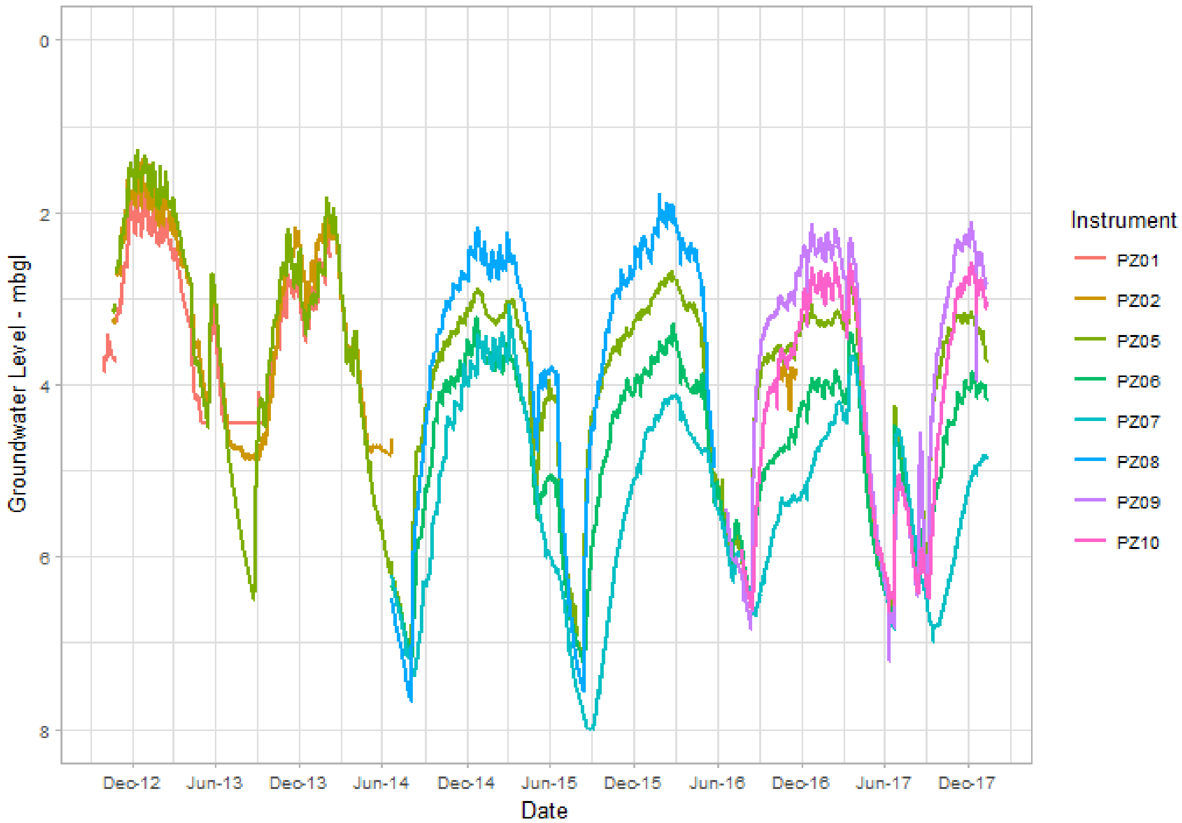


Figure 6: Groundwater monitoring data for Cooneys Road, 1.5 km northwest of the Site.

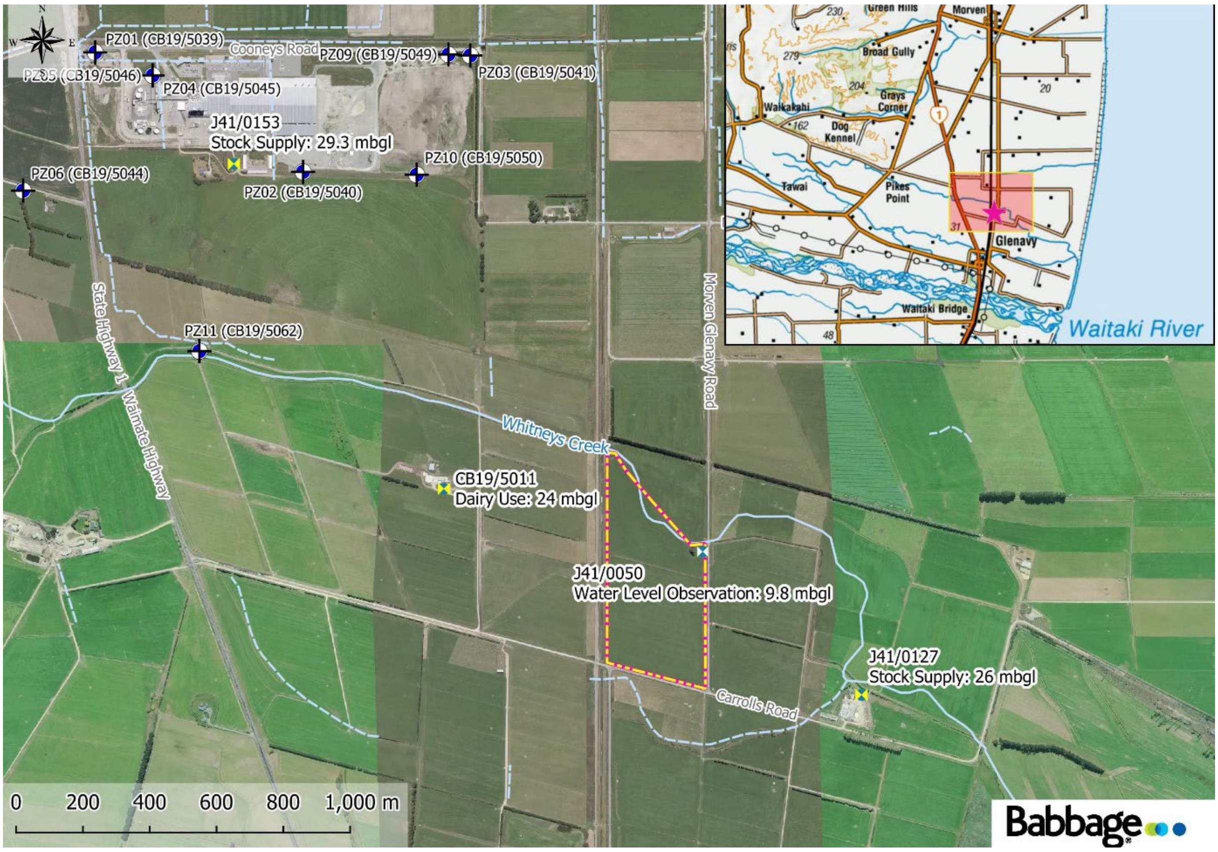


Figure 7: Nearby groundwater abstraction bores (and uses) and monitoring bores.

Further groundwater monitoring data, from a double piezometer (PZ11/PZ12 - CB19/5062) at the edge of Whitneys Creek (location shown in Figure 7) 1.5 km upstream from the Site, shows groundwater levels raising from 5 mbgl to 2 mbgl from October to November, as shown in Figure 6.

Furthermore, the data from the double piezometer near Whitneys Creek (shown in Figure 8) demonstrates that, locally, there is some degree of separation between the aquifer layers through clay-bound gravels between 10 and 15 metres below ground level. The piezometers (CB19/5062), screened at 7 to 10 mbgl (PZ11), and at 17 to 20 mbgl (PZ12), both show similar levels of recharge through the monitoring period, while effects of a pump test carried out at Cooneys Road on a bore over 40 m deep, were only observed on the bore screened in the deeper aquifer layer (PZ12).

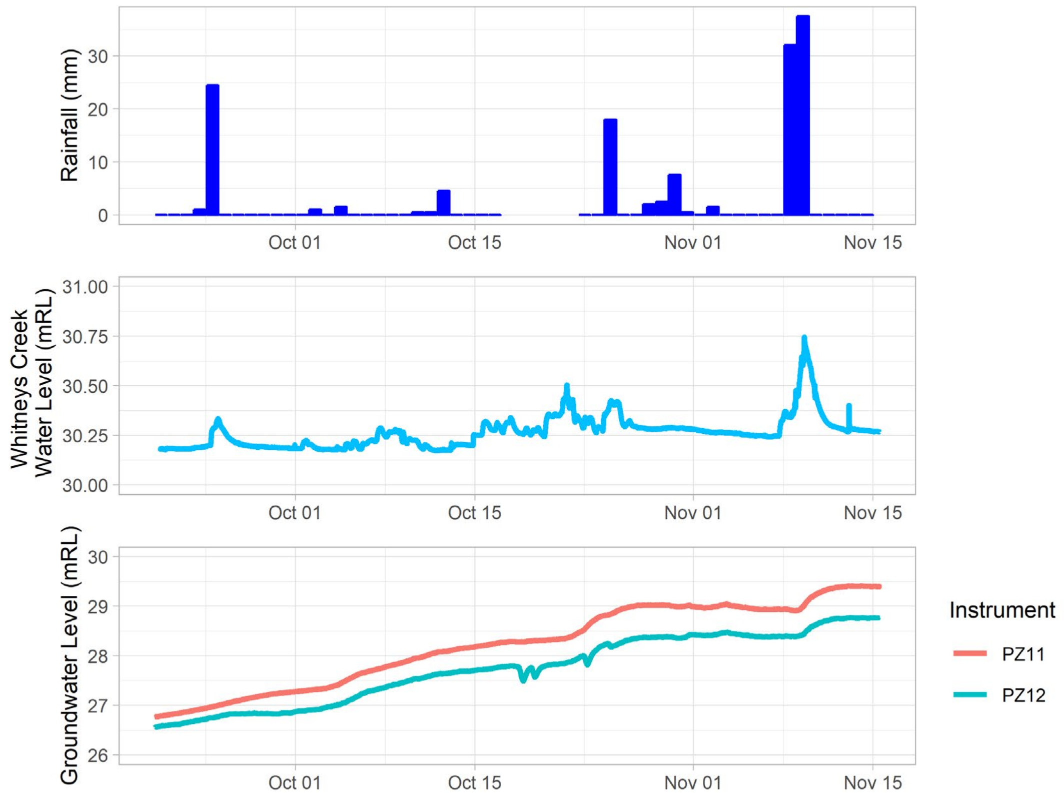


Figure 8. Recorded rainfall, stream levels and groundwater levels at the Whitneys Creek.

A single "water observation bore" is registered at the Site (J41/0050, location shown in Figure 7). The bore was not found at site visits, and the last record from it (on ECAN database) is from 05 July 1999. The bore information on ECAN database mentions the bore is located under a windmill. No windmill is present at the Site, and the bore was potentially destroyed when such windmill was removed.

Although no bore log is included in the bore information page[3] (ECAN Well Search), the available information shows that the bore, installed at 26.50 m RL and 9.80 m deep, was used for water level observations from 1951 to 1999, with recorded water levels varying between 0.32 m to 8.51 m. The large variation in water level measurements in bore J41/0050 is consistent with the observations of monitoring bores near Cooneys Road (Figure 6), where groundwater levels in the upper layer of the aquifer is quickly recharged by irrigation channels (races and border dike irrigation), and quickly falls at the end of each irrigation season.

ECAN has groundwater quality data from two bores in the vicinity of the Site, J41/0036[4] upgradient, and J41/0035[5] downgradient. There are no available bore logs for these bores in the ECAN database, and depths are not recorded. The summary of the available data is provided in Table 2.

[3] https://www.ecan.govt.nz/data/well-search/welldetails/?WellNo=J41/0050
[4] https://www.ecan.govt.nz/data/well-search/welldetails/?WellNo=J41/0035
[5] https://www.ecan.govt.nz/data/well-search/welldetails/?WellNo=J41/0036

Table 2. Summary of groundwater quality for nearest bores.

Measurement		J41/0036 (upgradient)		J41/0035 (downgradient)	
		14/02/1996	06/05/1996	23/02/1996	23/05/1996
Alkalinity, Total	g/m^3 as CaCO3	106	113	179	69
Ammoniacal Nitrogen	mg/L	0.042	0.027	<0.005	0.005
Calcium	mg/L	33	31	19	20
Chloride	mg/L	11	16	10	3
Conductivity	mS/m	30.1	29.7	20.8	21.5
Difference in Ion Balance	%	7.7	2.1	28.5	9.8
Faecal Coliforms	cfu/100mL	>400	80	<1	<1
Free Carbon Dioxide	g/m^3 at 25°C	28	47	47	28
Hardness, Total	g/m^3 as $CaCO_3$	43	100	66	68
Iron, Total	mg/L	0.4	0.05	<0.120	<0.050
Magnesium, Dissolved	mg/L	5.7	6.1	4.4	4.4
Manganese, Total	mg/L	0.16	0.13	<0.04000	<0.01000
Nitrate Nitrogen	mg/L	0.97	2.6	3.1	3.2
Nitrite Nitrogen	mg/L	0.028	0.027	<0.006	<0.004
pH		6.8	6.6	6.8	6.6
Potassium, Dissolved	mg/L	2.3	2.6	1.4	1.5
Sodium, Dissolved	mg/L	18	19	17	17
Sulphate	mg/L	20	16	15	15
Sum of anions	meq/L	2.53	2.82	3.75	1.76
Sum of cations	meq/L	2.96	2.94	2.09	2.14
Total Coliforms	cfu/100mL	>400	150	20	17
Total Phosphorus	g/m^3	0.075	0.079	<0.008	<0.008
Total Dissolved Solids	mg/L	180	-	140	-
Total BOD	g $O2/m^3$	3	-	<2.000	-

Note: <[value]: below detection limit.

Based on the ECAN Well Database and local piezometric contours (Figure 5), there are 16 active (on use) water take bores either within a 2 km radius of the Site or directly downgradient. A summary of these bores is provided in Table 3.

Table 3. Summary active groundwater abstraction bores within 2 km of the Site or downstream.

Bore number	Depth (m)	Distance to Site (m)	Up/Downgradient	Use
CB19/5011	24	500	Upgradient	Dairy Use
CB19/5017	56	1,150	Upgradient	Industrial
CB19/5018	70	1,250	Upgradient	Industrial
J41/0153	30	1,400	Upgradient	Stock Supply
CB19/5051	44	1,500	Upgradient	Industrial
CB19/5016	70	1,800	Upgradient	Industrial
J41/0016	3	2,000	Upgradient	Domestic
J41/0005	20	1,100	-	Dairy Use
J41/0035	n/a	1,100	-	Stock Supply
J41/0246	24	1,500	-	Stock Supply
J41/0127	26	700	Downgradient	Stock Supply
J41/0043	9	1,700	Downgradient	Stock Supply
J41/0014	9	1,900	Downgradient	Domestic
J41/0042	15	2,200	Downgradient	Stock Supply
J41/0108	23	2,400	Downgradient	Dairy Use
CB19/5014	41	3,300	Downgradient	Dairy Use

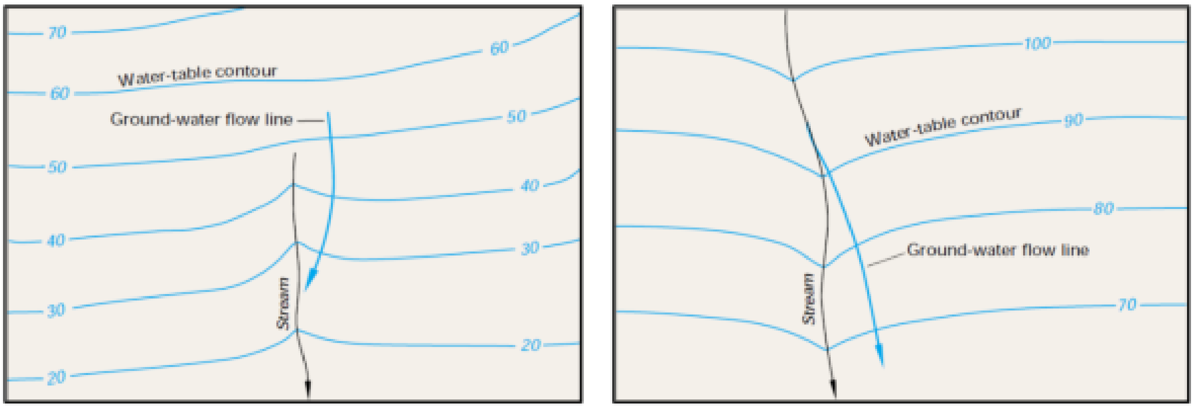
Note: n/a: Not available; -: Not upgradient, not downgradient, in a lateral position based on piezometric contours.

3.4 Groundwater-surface Water Interaction

According to Zarour (2016)[6], the Waitaki River is a regional groundwater sink in the area. Meanwhile, not enough information is available on the Whitneys Creek connection to groundwater, and although it is expected that it is primarily sourced by groundwater, it may lose water into the aquifer in some places and at sometimes.

The surface-groundwater relationship can be inferred from piezometric contours, as shown in Figure 9. Local piezometric contours (shown in Figure 5), indicates that Whitneys Creek does not seem to receive groundwater at or near the Site. That is, the available piezometric contours point in the downstream direction where they cross the stream. Although seasonal high groundwater levels could lead to groundwater contributing to the stream temporary, this would only occur over a limited period in the dry season. Such contributions, at the Site and in the region in general, could be significantly reduced with ongoing changes in irrigation infrastructure (piping of irrigation races) and practices (conversion of border dike to pivots).

[6] Zarour H. 2016, *Lower Waitaki Hydrogeology*. Report No. R15/54. Environment Canterbury. April 2016



(a) Gaining stream

Gaining streams (e.g. Figure 5-10a) can be identified from water table contour maps because the contour lines point in the upstream direction where they cross the stream.

(b) Losing stream

Losing streams (e.g. Figure 5-10b) can be identified from water table contour maps because the contour lines point in the downstream direction where they cross the stream.

Figure 9. Method for determining stream-groundwater relationship using groundwater level contour maps (from Zarour H. 2016[6])

4 PROPOSED ACTIVITY

The proposed activity consists of construction and operation of an energy from waste plant with buildings and associated roading and carparking covering most of the Site.

The proposed earthworks for construction of the facilities are described in the Earthworks Report[7]. In summary, earthworks will be required over almost the entire site to achieve desirable finished surface levels to enable the construction of the proposed building platforms, road subgrades, construction of the waste bunker and installation of infrastructure, including stormwater management devices. The bulk earthworks will generally comprise of cut to fill and importing and placement of clean fill to form the building platforms and road subgrades. The excavations are generally limited to form stormwater infiltration basins and the waste bunker, as shown in Figure 10.

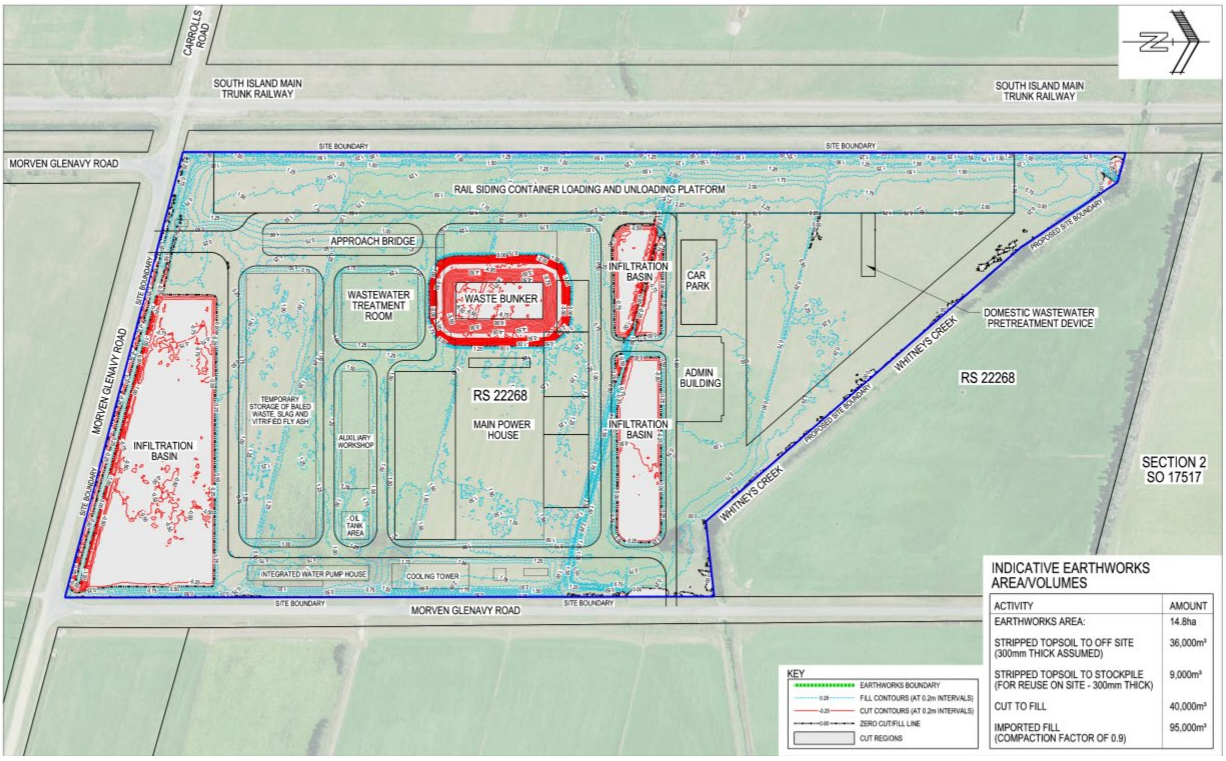


Figure 10. Proposed earthworks cut and fill plan (extract from Earthworks Report[6] drawing C02)

Excavation of the waste bunker will likely be below the natural ground water level and hence dewatering will be necessary during part of the activities. The groundwater within the bunker excavation is to be pumped from the excavation to discharge to the ground surface north of the bunker excavation to recharge to underlying aquifer. During times that topsoil is saturated (rain season - winter), water can be discharged to the border dike channels to infiltrate to the wider area and neighbouring paddocks.

[7] Babbage 2022. *Rural Section 22268, Title reference CB27B/314, Owner Murphy Farms Limited Earthworks Report*. A report prepared for South Island Resource Recovery Limited by Babbage Consultants Limited. September 2022.

The proposed facility operation is described in the Operational and Technical Overview Report[8]. In summary, municipal solid waste (MSW) is brought into the facility and temporary stored in a bunker to be processed as shown in Figure 11. The volume of the bunker allows for the storage of around 7 days capacity. Moisture in the MSW can form a leachate and this is collected at a sump at the base of the bunker (shown in Figure 12) for onsite disposal into the furnace.

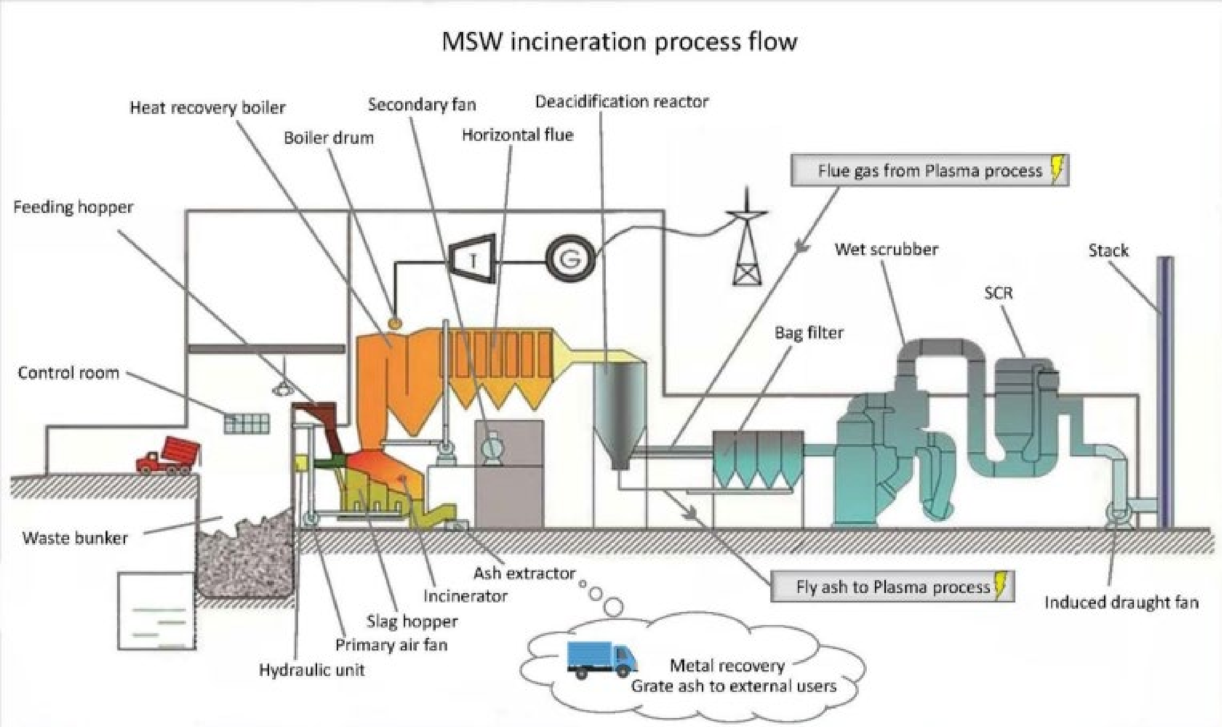


Figure 11. Proposed WfE process (extract from Operational and Technical Overview Report[7])

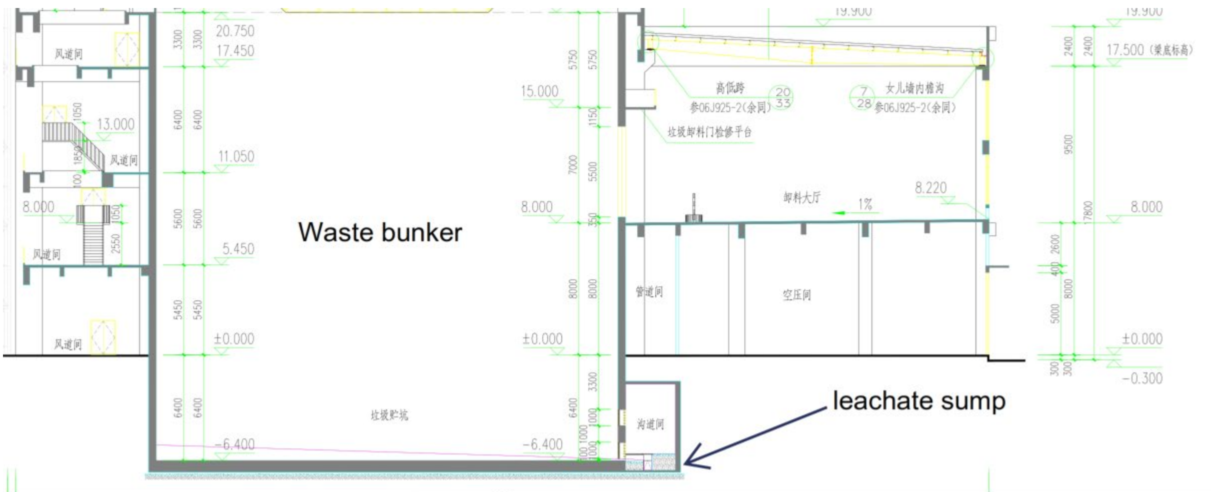


Figure 12. Waste bunker and leachate sump (extract from Main building construction drawing 9)

[8] Babbage 2022. *Project KEA Operational & Technical Overview Report*. A report prepared for South Island Resource Recovery Limited by Babbage Consultants Limited. September 2022.

5 ASSESSMENT OF EFFECTS

The proposed activity has the potential to effect surface and groundwater by:

- Dewatering of the bunker excavation and related discharge to land during earthworks.
- Discharge of contaminants from the waste bunker to surface and groundwater.
- Discharge of stormwater to surface and groundwater.
- Discharge of treated domestic wastewater to surface and groundwater.

5.1 Effects of Dewatering on Surface and Groundwater

The excavation of an 8 m deep bunker at the Site will likely interact with groundwater and require dewatering, particularly if caried out during the irrigation season or when the MGI irrigation races are flowing. The proposed excavation is limited to an area of approximately 90 m by 60 m in the central western of the Site, as shown in Figure 10. The exposure of groundwater during earthworks, and required dewatering have potential effects on surface and groundwater quantity (by pumping water out of the aquifer through the open excavation, and any resulting stream depletion) and quality (by discharge of water containing excavated material to surface or groundwater).

As the groundwater levels at the Site are estimated to vary seasonally from about 1 to 8 mbgl, the proposed dewatering is unlikely to significantly change groundwater levels for more than their current seasonal variation. That is, low groundwater levels and high groundwater mounding caused by the proposed dewatering activities are unlikely to be significantly different from seasonal groundwater levels at the Site.

During the dewatering activities, which are expected to occur to a maximum duration of one year, water is expected to be discharged to the paddocks at the northern portion of Site (indicated in Figure 13), between the excavated areas and Whitneys Creek. If soils at the paddocks are over saturated, water will be discharged to the border dike irrigation channels bordering the Site, from where it is expected to infiltrate to the wider area of the farm.

It must be noted that the region is relatively dry, and soils are only over saturated during the rainy season following or during extensive precipitation events. As high groundwater levels occur during summer and the dry season, it is expected that minimum dewatering will be required when soils are over saturated from rainfall. Furthermore, as border dike irrigation will cease at the Site during constructions, groundwater levels are expected to be relatively lower than the previous seasonal high levels.

As the aquifer is unconfined, particularly the shallow layers to 10-12 mbgl, and with high permeability, the discharge is expected to directly recharge the aquifer, and therefore any effects of the dewatering to groundwater levels are expected to be limited to the excavation location and direct surroundings. As water is expected to be fully returned to the aquifer (non-consumptive take), it is unlikely that there will be any significant effects to groundwater quantity in the aquifer or the region.

The dewatering of the excavation is unlikely to significantly change the quality of the water removed, except by the increase in suspended solids (fine sediments), by transportation of fine soil particles from the excavation. As the discharge of the water will be done to agricultural land, and at least 1 m of soil separate the discharge to the groundwater level, it is expected that any sediment particles will be retained by the filtration capacity of the soil profile. Therefore, effects to groundwater and surface water quality from the dewatering of the excavation and subsequent discharge, are unlikely to be significant.

Furthermore, dewatering will only be necessary during the earthworks, as the proposed bunker will be impervious and sealed from groundwater infiltration. Therefore, any effects of the dewatering to surface and groundwater are considered temporary, to a maximum of one year (maximum expected duration of the earthworks).

5.1.1 Effects on neighbouring bores – interference effects

To calculate the drawdown (and therefore interference) effects of the proposed dewatering, the hydraulic properties (transmissivity and storage coefficient) of the aquifer can be obtained from available records of nearby pump tests. For this assessment, we have used data from a pump test of production well CB19/5052 located 1.5 km northwest of the Site (shown in **Appendix A**).

Using the hydraulic properties from local pump test (bore CB19/5052) and a conservative groundwater drawdown (1 to 8 mbgl, which represents 7 m drawdown), the radius of influence of the waste bunker dewatering for an unconfined aquifer can be calculated by the Sichardt formula[9] below:

$$R_0 = r_e + 3000(H - h_w) \times \sqrt{K} \quad \text{(Eq. 1)}^{10}$$

Where the excavation/well radius (r_e) can be converted for a rectangular excavation area (A) based on equation 2:

$$R_e = \frac{\sqrt{A}}{\pi} \quad \text{(Eq. 2)}^{8}$$

The radius of influence (R_0) is the radial distance outward from the centre of the dewatered excavation to the point where no further lowering of water table is expected, that is, the aera of effect of the drawdown. The maximum radius of influence caused by a 7 m drawdown during dewatering in the irrigation period (high groundwater levels) is presented in Table 5. As the excavation has the potential to last for one year, calculations for three additional dewatering scenarios (for mean, low, and lowest groundwater levels across the year) are also included in Table 5.

---

[9] Yohannes Yihdego 2017. Engineering and enviro-management value of radius of influence estimate from mining excavation, Journal of Applied Water Engineering and Research. Retrieved from: http://dx.doi.org/10.1080/23249676.2017.1287022.

[10] R_0 is the radius of influence for unconfined aquifers (in meters), H is the total head of the water table aquifer (m, saturated thickness), K is the hydraulic conductivity (m/s) h_w is the total head of the dewatered aquifer (m) and r_e is radius of the excava-tion area/well.

The required pump rate for dewatering the excavation can be obtained by the radial flow from an unconfined aquifer into a circular open excavation using the Dupuit solution as described below[11] (calculations presented in **Appendix B**):

$$Q = -\pi K \frac{(H^2 - h_d^2)}{\ln\left\{\frac{R}{R_0}\right\}}$$ (Eq. 3) [12]

The estimated dewatering flow and main parameters used for the four groundwater levels scenarios are presented in Table 4.

Table 4 Excavation dewatering pump rates.

Parameters	A- High GW level	B- Mean GW Level	C- Low GW Level	D- Lowest GW Level
Hydraulic conductivity: K (m/d) *	7.6	7.6	7.6	7.6
Saturated thickness (m)**	7	3.5	2	1
Radius of excavation (m) by Eq 2***	41.5	41.5	41.5	41.5
Max. radius of influence (m) by Eq 1	238	140	98	70
Dewatering pump rate (L/s) by Eq 3	**7.7**	**2.8**	**1.3**	**0.5**

Note: * Appendix A - hydraulic conductivity average, ** Based on groundwater level shown in Figure 1 (red dashed lines), *** Equation 2 for A = 5400 m2 (90 X 60 m).

The water pumped out of the excavation will be discharged to the Site at the northern paddock, with an approximate area of 1.5 ha (indicated in Figure 13). Infiltration tests caried out at the Site (data provided in **Appendix C**) using double ring infiltrometer tests (saturated infiltration), showed infiltration rates of 1.4 to 1.8 mm/min. Therefore, an area of approximately 290 m^2 is required for infiltration of the maximum discharge rates from the excavation dewatering, and the 1.5 ha of the paddock are considered sufficient.

As the discharge to land occurs to the same aquifer and at the same rates, the effects to groundwater levels are the same but reversed. While the dewatering causes a cone of depression, the discharge causes a groundwater mound. As pump rates and aquifer properties are the same, the radius of both effects is the same but displaced by the distance of the dewatering to the discharge. Based on these assumptions and calculations, the effective radius of influence of the proposed dewatering will be reduced at the Site's northern portion, as shown in and Table 5 and indicated in Figure 13.

---

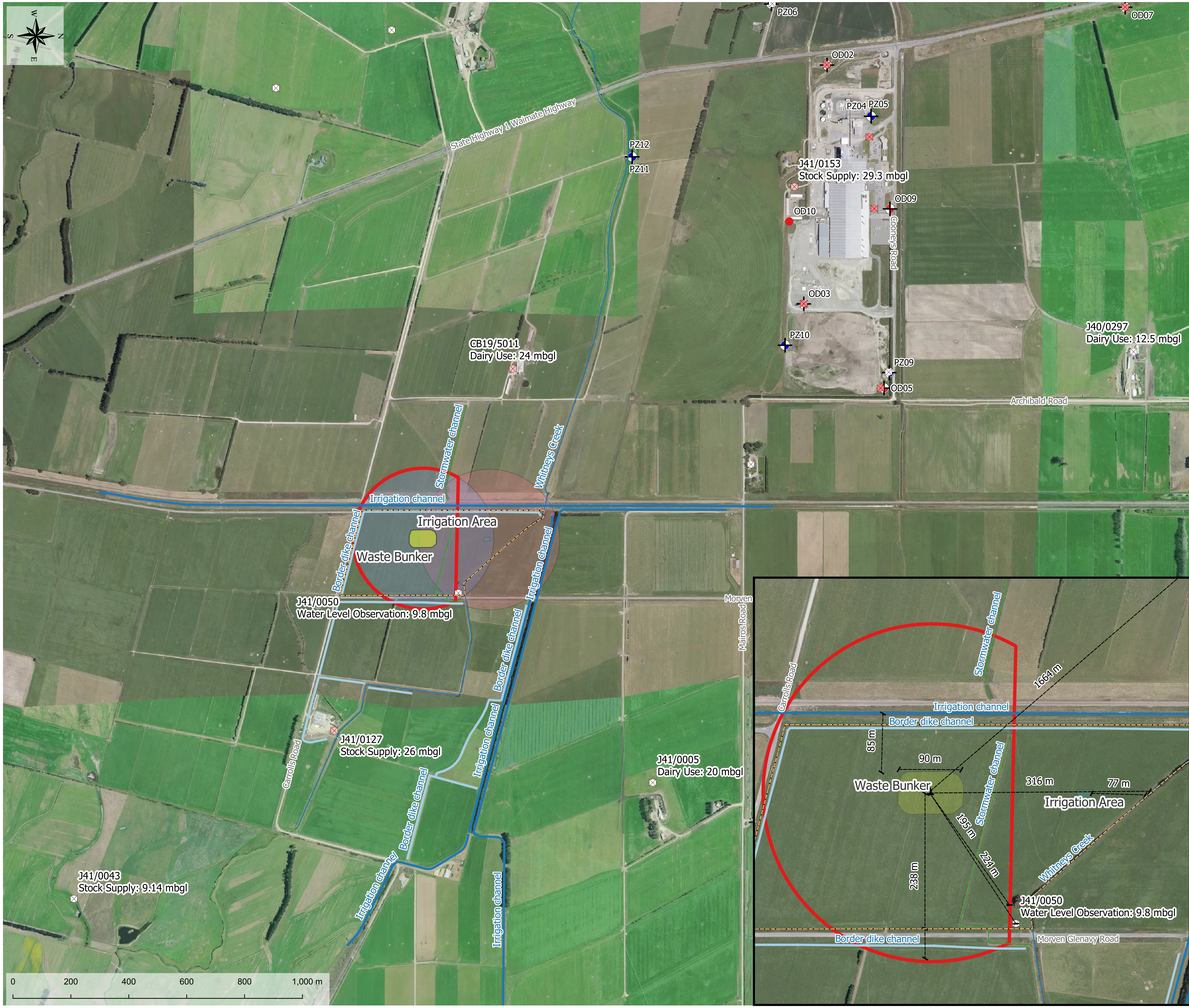
[11] Christopher J. Neville 2017. Analytical solutions for the preliminary estimation of long-term rates of groundwater inflow into excavations: Long excavations and circular excavations. Retrieved from: https://www.sspa.com/sites/default/files/images/sto-ries/software/Analytical%20solutions%20for%20flow%20into%20open%20excavations_1_Report_v02.pdf

[12] Where the heads H and hd are measured with respect to the base of the aquifer, Ro is the distance from centre to boundary of excavation (assumed to be the radius of excavation equal 41.5m calculated by eq. 2) and R is the distance from centre of excavation to constant-head boundary (assumed to be the radius of influence calculated by eq.1).

Table 5 Influence radius of proposed excavation dewatering.

Parameters	A-High GW level	B- Mean GW Level	C- Low GW Level	D- lowest GW Level
Hydraulic conductivity: K (m/d) *	7.6	7.6	7.6	7.6
Saturated thickness : H – hw (m) **	7	3.5	2	1
Radius of excavation (m) by Eq 2 ***	41.5	41.5	41.5	41.5
Max. radius of influence (m) by Eq 1	**238**	**140**	**98**	**70**
Effective radius of influence range (m) at the north portion of the site considering infiltration mounding effects	**110 - 238**	**65 - 140**	**45 - 98**	**Null - 70**

Note: * Appendix A - hydraulic conductivity average, ** Based on groundwater level shown in Figure 6, ***Equation 2 for A = 5400 m2 (90 X 60 m).



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CLIENT / PROJECT

South Island Resource Recovery Ltd

Project KEA

MAP TITLE

Figure 1 - Proposed Waste Bunker Dewatering Assessment

MAP REVISIONS

16/11/2022 Initial version by TT.

Legend

- Site Boundaries
- Irrigation Area
- Waste Bunker

Radius Influence

- Drawdown radius
- Infiltrtation radius
- Effective Influence radius

Neighbouring wells

- 0 - 20
- 20 - 50
- 50 - 80
- 80 - 100
- 100 - 500

Existing wells

- Existing Monitoring
- Existing Production
- Inactive Monitoring
- Inactive Production
- Proposed Production

SOURCES

Aerial Image: LINZ Data Services

Wells: Environment Canterbury Regional Council

DISCLAIMER:
This map/plan is not an engineering draft.
This map/plan is illustrative only and all information should be independently verified on site before taking any action.

SCALE

1:12,000 @ A3

MAP NO.

63408#BEE - 01

As shown in Table 3, the nearest active abstraction well to the Site is 500 m upgradient, outside of the expected extent of the maximum drawdown radius of the proposed dewatering. The closest well (J41/0050) is located 224 m from the bunker, within the Site but outside and the estimated effective radius of influence of the proposed dewatering. Furthermore, as mentioned in Section 3.3, bore J41/0050 was not found at the Site and has no evidence of being used for recording water levels since 1999.

Therefore, the proposed dewatering (and related discharge to land) are not expected to cause significant interference effects to any neighbouring bores.

5.1.2 Effects to Whitneys Creek – stream depletion

Using the dewatering rates of Table 4, and the average of hydraulic properties presented in Appendix A, the stream depletion was calculated using the Theis model (ECAN's Spreadsheet **Appendix D**) for each abstraction rate. As detailed in Section 5.1.1, the effects of the abstraction at the excavation and the discharge at the northern paddock are expected to counter each other. Therefore, any stream depletion effects caused by the lowering of groundwater levels from the dewatering will have a corresponding, but reverse effect caused by the discharge. This occurs particularly at the northern boundary of the Site, near Whitneys Creek, as illustrated in Figure 13.

The calculated stream depletion effects for the proposed dewatering at different groundwater levels across the year are shown Table 6, along with main parameters used in the calculations.

Table 6 Stream depletion.

Parameters	**A-High GW level**	**B- Mean GW Level**	**C- Low GW Level**	**D- Lowest GW Level**
Hydraulic conductivity: K (m/d) *	7.6	7.6	7.6	7.6
Saturated thickness (m)**	7	3.5	2	1
Transmissivity: T (m2/d)	53	26	15	8
Dewatering rates (L/s)***	7.7	2.8	1.3	0.5
Whitneys Creek Distance (m)	316	316	316	316
Stream depletions - Whitneys Creek (L/s (% of abstraction/discharge))				
7 days abstraction	3.2 (41)	0.7 (24)	0.2 (12)	0.0 (03)
150 days abstraction	6.6 (86)	2.2 (80)	1.0 (74)	0.3 (65)
7 days discharge	-3.2 (41)	-0.7 (24)	-0.2 (12)	0.0 (03)
150 days discharge	-6.6 (86)	-2.2 (80)	-1.0 (74)	-0.3 (65)
Combined effects of abstraction and discharge	**Null**	**Null**	**Null**	**Null**

Note: * Appendix A - hydraulic conductivity average, ** Based on groundwater level shown in Figure 6, *** Equation 2 for A = 5400 m2 (90 X 60 m). *** Based on Eq. 3 calculations.

5.2 Effects of the plant operation on surface and groundwater

5.2.1 Leaching of contaminants from the waste bunker operation

The waste bunker is constructed below ground level and is used to store MSW. The MSW in the bunker can form a leachate liquid which free drains to the base of the bunker where it is collected in a sump and extracted for disposal through the main combustion process. The leachate composition is not described in the available reports (as it may vary depending on the MSW composition), but it is considered a potential contaminant to the environment. The operation of the underground bunker for MSW storage and leachate collection have potential effects on groundwater quality if leachate is released from the facility.

The bunker construction, as described in the Operational and Technical Overview Report[7] and shown in Figure 12, includes a reinforced concrete structure with impermeable membranes, to seal the bunker against contact with groundwater. A pathway for contamination to groundwater is only likely if there is a crack in the concrete structure and a loss of integrity of the impermeable membrane.

The bunker is built underground, to a depth of up to 8 mbgl, and leachate is constantly drained to the sump and removed for treatment. The bottom of the sump is proposed to be below the lowest seasonal groundwater levels, likely down to 8-10 mbgl. Therefore, in the case of any crack forming, it is expected that the pressure differential between the bunker void and the surrounding groundwater will result in groundwater leaching into the bunker, where it will be captured at the sump by the wastewater system.

Potential for contaminants to leak from the bunker into groundwater only exists in the situation where a crack is present in the walls of the bunker, there is a loss of integrity to the impermeable membranes and the ground water level is below the base of the bunker sump.

Therefore, it is extremely unlikely that potential for contaminants will enter groundwater as a result of the proposed use and operation of the waste bunker. As the main pathway for contaminants from the waste bunker to reach surface water is through groundwater contributions to surface water, it is also extremely unlikely that potential contaminants will enter surface water as a result of the proposed use and operation of the waste bunker.

5.2.2 Effects of the stormwater discharge to surface and groundwater

The proposed operation of the facility will discharge stormwater to infiltration basins at the Site. The proposed system is described in detail on the Stormwater Report[13] (Babbage, 2022). In summary, stormwater at the Site will be captured by the stormwater system, treated by Enviropods and infiltration basins, and discharged to ground through the infiltration basins.

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[13] Babbage 2022. *Rural Section 22268, Title reference CB27B/314, Owner Murphy Farms Limited Stormwater Report*. Prepared for South Island Resource Recovery Limited by Babbage Consultants Limited. September 2022.

The proposed operation of the facility also causes the discharge of potential contaminants to air, some of which are expected to deposit at the Site and be discharged to surface and groundwater through stormwater. The discharge to air and deposition of potential contaminants to land by the proposed activity are described and assessed on the Air Quality Emissions Assessment[14] (PDP 2022).

Therefore, the proposed operation of the facility has the potential to discharge contaminants (from roofs, vehicle pavements, walkways, and dust deposition from the air discharge) to groundwater. As the discharge to groundwater occurs in relative proximity to Whitneys Creek, there is potential that the discharge occurs also, indirectly, to surface water.

Although, it is important to note that stormwater discharge will occur mainly during the rainy season, when groundwater levels are at the lowest. Therefore, when stormwater discharges to ground and groundwater are occurring, the contributions of groundwater to Whitneys Creek are expected to be minimal to none.

The proposed systems, as assessed by Babbage (2022)[13] and PDP (2022)[14], are designed in accordance with all relevant guidelines and best practices, and therefore expected to provide sufficient treatment for any potential contaminants from the Site.

Furthermore, Babbage (2022)[13] caried out an assessment of expected concentrations of potential contaminants in the stormwater discharge based on the deposition modelling done by PDP (2022)[14] and the expected stormwater volumes and contaminants. A summary of average and worst-case scenario concentrations is provided in Table 7 along with relevant guideline limits.

All expected concentrations of potential contaminants (both for average stormwater discharges and for the worst-case scenario: rainfall following 3 months of dry deposition) are below the limits for a level of protection of 95% of species from Table S5B from Schedule 5 of the Canterbury Land and Water Regional Plan, except for Chlorine concentration, which for the average discharge is still lower than the defined limit for a level of protection of 90% of species of the Australian and New Zealand Guidelines for Fresh & Marine Water Quality, and for worst-case is still lower than the maximum acceptable values (MAVs) and guideline values (GVs) stipulated by the Drinking-water Standards for New Zealand (DWSNZ).

Furthermore, all expected concentrations of potential contaminants (both average and worst-case scenario) are orders of magnitude lower than the relevant MAVs and GVs stipulated by the DWSNZ, and therefore the discharge is unlikely to cause the receiving freshwater bodies (surface or groundwater) to exceed the limits stipulated in Schedule 8 (Region-wide Water Quality Limits) of the Canterbury Land and Water Regional Plan.

[14] PDP 2022, *South Island Resource Recovery Limited – Air Quality Emissions Assessment – Project Kea.* Prepared for South Island Resource Recovery Limited by Pattle Delamore Partners Limited. September 2022.

Table 7. Summary of potential contaminant concentrations in stormwater discharge.

Potential Contaminant	Average[1] (g/m³)	Event[2] (g/m³)	Tox LOSP 99[3]	Tox LOSP 95[4]	Tox LOSP 90[5]	Tox LOSP 80[6]	DWSNZ MAV[7]	DWSNZ GV[8]
Calcium	0.010120366	0.071950115	-	-	-	-	-	200 *
Chlorine	0.004989707	0.035474012	0.0004	0.003	0.006	0.013	5	0.6
Silicon	0.001212189	0.008617980	-	-	-	-	-	-
Potassium	0.001014856	0.007215053	-	-	-	-	-	-
Sulphur	0.000704761	0.005010454	-	-	-	-	-	250 #
Iron	0.000704761	0.005010454	-	-	-	-	-	0.2
Sodium	0.000676570	0.004810036	-	-	-	-	-	200
Carbon	0.000422856	0.003006272	-	-	-	-	-	-
Aluminium	0.000310095	0.002204600	0.027	0.055	0.08	0.15	-	0.1
Magnesium	0.000310095	0.002204600	-	-	-	-	-	200 *
Zinc	0.000140952	0.001002091	0.0024	0.008	0.015	0.031	-	1.5
Titanium	0.000112762	0.000801673	-	-	-	-	-	-
Lead	0.002453737	0.000400836	0.001	0.0034	0.0056	0.0094	0.01	-
Phosphorous	0.000056381	0.000400836	-	-	-	-	-	-
Bromide	0.000056381	0.000400836	-	-	-	-	-	-
Chromium	0.000028190	0.000200418	0.00001 VI	0.001 VI	0.006 VI	0.04 VI	0.05	
Manganese	0.000028190	0.000200418	1.2	1.9	2.5	3.6	0.4	0.04
Strontium	0.000028190	0.000200418	-	-	-	-	-	-
Copper	0.000477603	0.000200418	0.001	0.0014	0.0018	0.0025	2	1
Barium	0.000028190	0.000200418	-	-	-	-	0.7	-
Cadmium	0.000000000	0.000080167	0.00006	0.0002	0.0004	0.0008	0.004	-
Nickel	0.000000000	0.000020042	0.008	0.011	0.013	0.017	0.08	-
TPH	0.000234733	0.000234733	-	-	-	-	-	-

Note: 1: Average concentrations based on total annual dust deposition and stormwater discharge; 2: Event concentrations based on 3 months dry deposition followed by precipitation; Tox LOSP: Toxicant default guideline values (DGVs) for freshwater from the Australian and New Zealand Guidelines for Fresh & Marine Water Quality (including values incorporated from the ANZECC & ARMCANZ 2000 guidelines), also used in Table S5B of Schedule 5 of the Canterbury Land and Water Regional Plan; 3: Level of protection 99 % of species; 4: Level of protection 95 % of species; 5: Level of protection 90 % of species; 6: Level of protection 80 % of species; 7: Drinking Water Standards for New Zealand (DWSNZ) Maximum Acceptable Values (MAVs); 8: Drinking Water Standards for New Zealand (DWSNZ) Guideline Values (GVs); *: As hardness (total) (Ca+Mg); #: As Sulphate; VI: as Chromium (CrVI), TPH: Total Polycyclic Hydrocarbons.

For total polycyclic hydrocarbons (TPHs), the expected concentrations in the proposed stormwater discharge are orders of magnitude lower than the highest acceptance criteria for protection of groundwater quality for sand and sandy silt soils, as described in the relevant guidelines[15].

5.2.3 Effects of the discharge of threated domestic wastewater

The domestic wastewater treatment and discharge system, along with the effects of the system to surface and groundwater, is detailed in the Domestic Wastewater Report[16] (Babbage 2022). In summary the Site will treat domestic effluent from up to 90 people (staff and guests) through a primary and secondary system (including biological treatment and UV disinfection), and discharge the treated effluent to land over a 2,000 m^2 vegetated drip field.

The proposed discharge, as detailed in Babbage (2022)[16], when done in accordance with the system suppliers operational and maintenance instructions, is not expected to have significant effects to surface and groundwater. The potential contaminants concentrations will be in accordance with Schedule 5 of the Canterbury Land and Water Regional Plan, in particular to relevant receiving water standards Table S5A and S5C. In addition, the potential discharge is unlikely to result in non-compliance of the receiving freshwater environments with the relevant values of Schedule 8 – Region Wide Water Quality Limits.

5.3 Monitoring and Remediation of Groundwater

Section 14.3 of Operational and Technical Overview Report[7], describes further processes and measures to ensure no groundwater contamination occurs during the plant operation. These include installing at least 4 monitoring bores, 2 upgradient and 2 downgradient of the Site, as shown in Figure 14, and process to detect and remediate any issues in the MSW bunker structure. All monitoring bores are expected to be 10 to 12 m deep, fully penetrating and screened in the upper layer of the aquifer.

[15] Ministry for the Environment 1999. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand.
[16] Babbage 2022. Project KEA Domestic Wastewater Discharge to Land - Assessment of Effects. A report prepared for South Island Resource Recovery Ltd by Babbage Consultants Limited. November 2022.

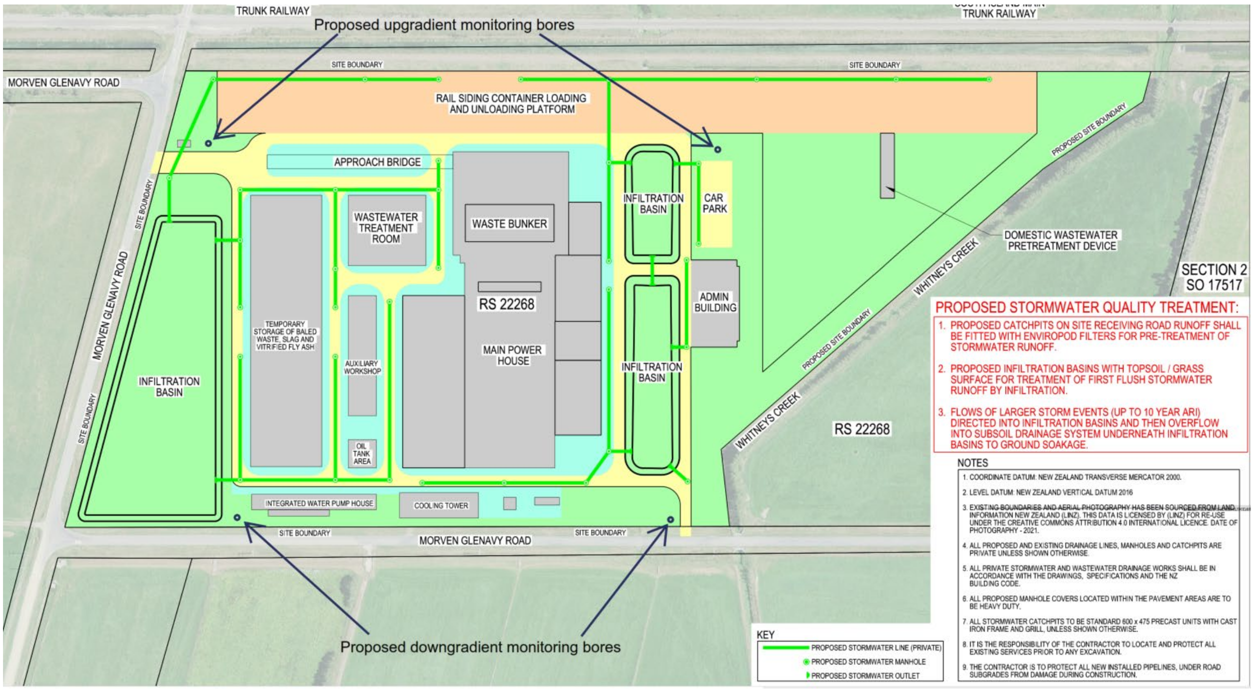


Figure 14. Proposed monitoring bore locations.

A detailed monitoring and remediation plan should be prepared as a condition of consent. In summary, groundwater levels should be monitored regularly to confirm they remain higher than the base of the bunker sump. In this case, the risk of groundwater contamination will be considered very low. If the groundwater levels drop below the leachate levels within the bunker sump, then regular groundwater quality monitoring should be caried out to detect any contamination.

6 CONCLUSION

The proposed construction and operation of an energy from waste plant at the Site will result in discharges to land and air that have the potential to impact groundwater. Furthermore, although no direct discharge to surface water is proposed, the discharge to groundwater could potentially result in effects in surface to water. The proposed construction methodology and operation are design to comply with relevant guidelines, standards, and best practices. Therefore, effects to surface and groundwater are not expected to be significant.

The proposed earthworks at the Site will include large excavations that will likely require dewatering during the earthworks. As the dewatering will discharge to the paddocks (or border dike irrigation channels) at the Site, the aquifer will be locally recharged. Therefore, effects of the earthworks to groundwater quantity and availability are not considered to be significant.

The dewatering at shallow groundwater level (1-2 mbgl) is the worst-case scenario, and it will require extraction of nearly 8 L/s from a period of 6 to 9 months to maintain the excavation without groundwater. Considering the water abstracted from the excavation will be discharged to land at the Site, the resulting infiltration effect the drawdown at the northern portion of the Site, and the maximum effective radius of influence of the activity will range between 110-238 m.

No active abstraction bores are within the maximum radius of influence of the proposed dewatering, and therefore there are no interference effects to neighbouring bores. The only bore near the expected interference area is J41/0050, a groundwater level observation bore at the Site not used since 1999 and likely no longer existing.

Stream depletion assessment indicated high degree of effect (150 days of steady continuous groundwater abstraction is greater than 60% of that abstraction rate). However, the discharge of extracted groundwater to land will have a similar, but opposite effect. Therefore, stream depletion effects caused by the combined dewatering and discharge to land are not considered significant.

As the main potential contaminant from the dewatering is particulate material (fine soil particles from the exposed excavation), topsoil filtration is considered to be sufficient to avoid any effects to groundwater quality. Therefore, effects to groundwater quality from the proposed excavation and dewatering are not likely to be significant.

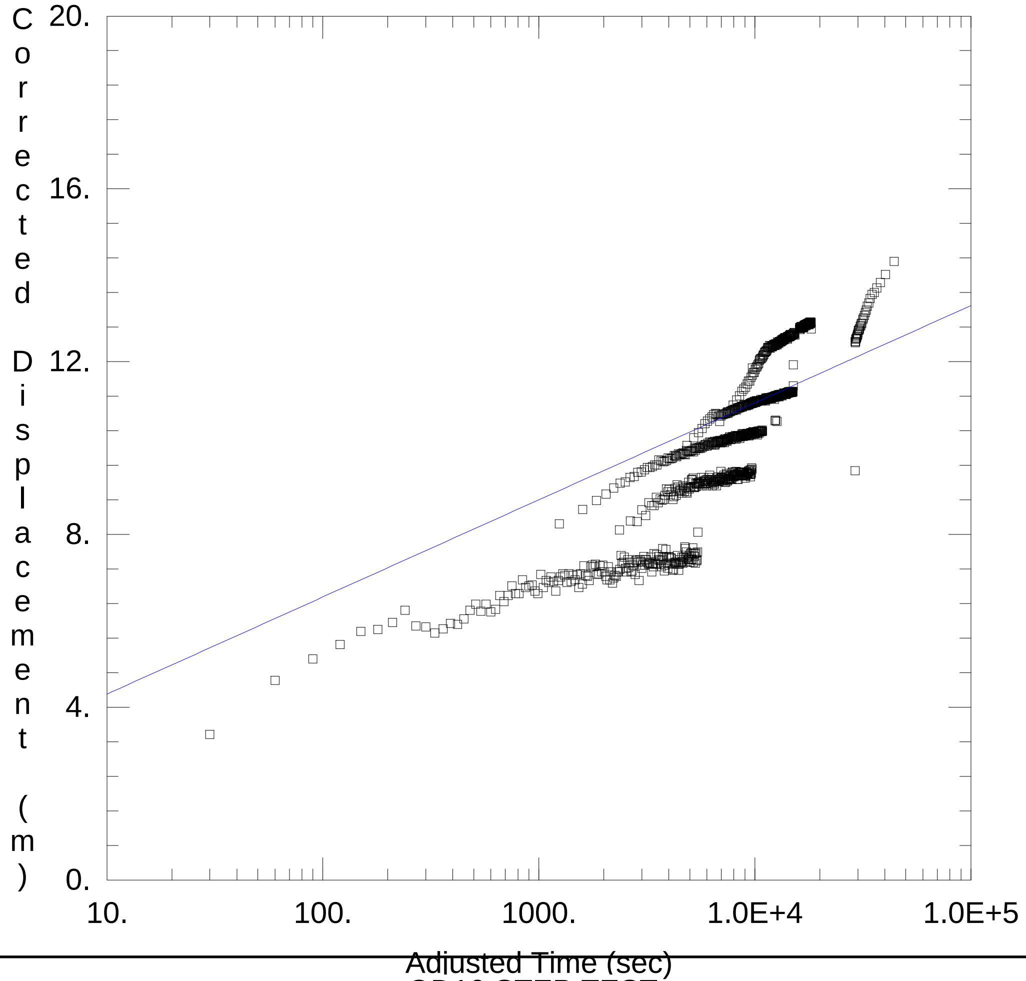
The proposed stormwater system for the Site will include treatment and discharge to land through infiltration basins. As all the systems are designed based on best practices and compliant with relevant codes and guidelines. Therefore, the proposed stormwater discharge to surface and groundwater at the Site are not expected to cause significant effects to any receiving environment.

Furthermore, expected concentrations of potential contaminants (both for average stormwater discharges and for the worst-case scenario: rainfall following 3 months of dry deposition) are orders of magnitude lower than the relevant maximum acceptable values (MAVs) and guideline values (GVs) stipulated by the Drinking-water Standards for New Zealand (DWSNZ).

The discharge is proposed to be to land and groundwater, and at times where groundwater levels are low and potential connection of groundwater to surface water limited or none. Nonetheless, expected concentrations of contaminants in the stormwater discharge are below the relevant discharge limits to surface water for a level of protection of 90% of species of the Australian and New Zealand Guidelines for Fresh & Marine Water Quality. Therefore, the proposed stormwater discharge is unlikely to cause significant effects to receiving surface and groundwater.

The proposed waste bunker design and operation provide a series of barriers (construction using impermeable layers) and measures (maintaining a pressure differential so that any failure results in groundwater entering the bunker instead of contaminants leaving it) to avoid contamination of groundwater during the facility operation. Furthermore, groundwater protection and monitoring are proposed, along with processes to ensure the bunker structural integrity. Therefore, effects to groundwater quality from the proposed operation of the MSW bunker are unlikely to be significant.

Appendix A Average of Hydraulic Properties



OD10 STEP TEST

Data Set: L:\...\OD010_Step.aqt
Date: 07/09/19
Time: 15:09:21

PROJECT INFORMATION

Company: Babbage
Client: Oceania
Project: 51444#EN1
Location: Glenavy
Test Well: OD10
Test Date: 13/12/2016

AQUIFER DATA

Saturated Thickness: 41. m
Anisotropy Ratio (Kz/Kr): 0.04

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
OD10	1	1

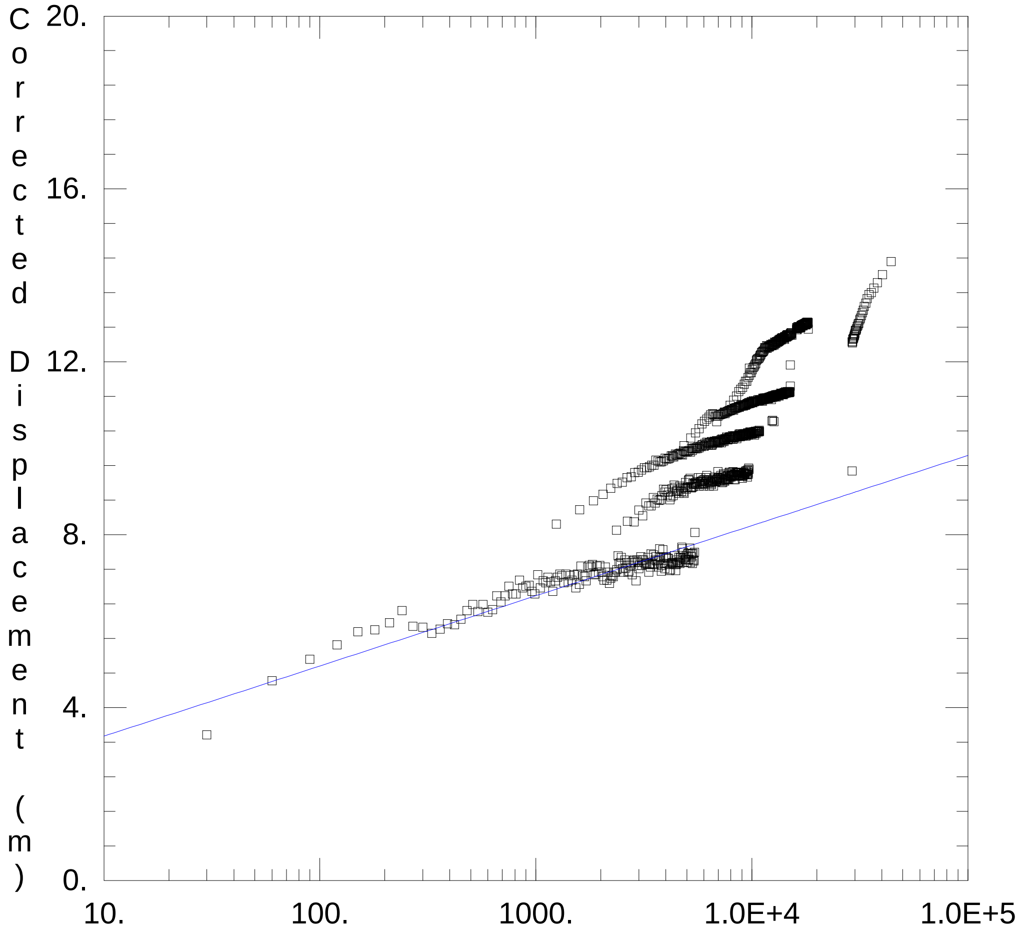
Observation Wells

Well Name	X (m)	Y (m)
□ OD10	1	1

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 260. m^2/day
S = 0.005



OD10 STEP TEST

Data Set: L:\...\OD010_Step.aqt
Date: 07/09/19 Time: 15:09:50

PROJECT INFORMATION

Company: Babbage
Client: Oceania
Project: 51444#EN1
Location: Glenavy
Test Well: OD10
Test Date: 13/12/2016

AQUIFER DATA

Saturated Thickness: 41. m
Anisotropy Ratio (Kz/Kr): 0.04

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
OD10	1	1

Observation Wells

Well Name	X (m)	Y (m)
□ OD10	1	1

SOLUTION

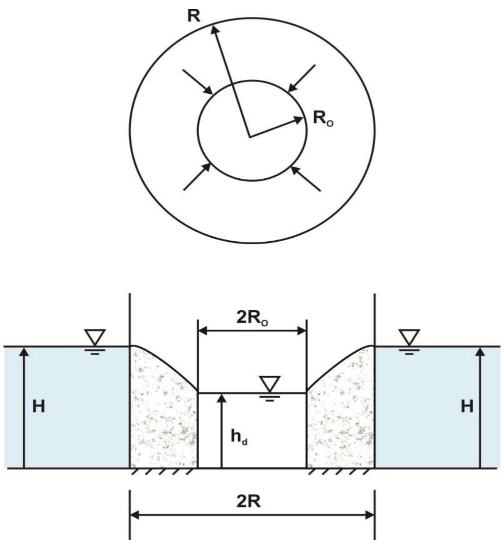
Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 360. m^2/day
S = 0.005

Appendix B Excavation Dewatering Pump Rates Calculation

Model 7

Radial unconfined flow into a circular excavation - A- High GW Level



The inflow into the excavation is:

$$Q = -\pi K \frac{(H^2 - h_d^2)}{\ln\left\{\frac{R}{R_0}\right\}}$$

Units are labels only; the user must specify consistent units

Parameter	Units	Value	User-specified units
Hydraulic conductivity, K	L/T	8.75E-05	m/s
Elevation of base of aquifer, z_{bot}	L	19.0	m
Thickness of aquifer where confined, D	L	0.0	m
Distance from centre of excavation to constant-head boundary, R	L	238.0	m
Distance from centre to boundary of excavation, R_0	L	41.5	m
Head at the constant-head boundary, H	L	26.0	m
Head in the excavation, h_d	L	19.0	m

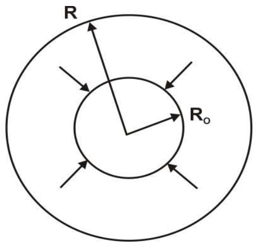
Result

Calculated inflow, Q	L^3/T	0.008	m^3/s	**7.712981**	L/s

Reference:

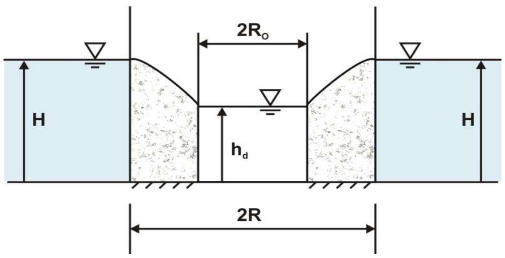
Christopher J. Neville 2017. Analytical solutions for the preliminary estimation of long-term rates of groundwater inflow into excavations: Long excavations and circular excavations. Retrieved from: https://www.sspa.com/sites/default/files
/images/stories/software/Analytical%20solutions%20for%20flow%20into%20open%20excavations_1_Report_v02.pdf

Model 7
Radial unconfined flow into a circular excavation - B Mean GW Level



The inflow into the excavation is:

$$Q = -\pi K \frac{(H^2 - h_d^2)}{\ln\left\{\frac{R}{R_0}\right\}}$$



Units are labels only; the user must specify consistent units

Parameter	Units	Value	User-specified units
Hydraulic conductivity, K	L/T	8.75E-05	m/s
Elevation of base of aquifer, z_{bot}	L	19.0	m
Thickness of aquifer where confined, D	L	0.0	m
Distance from centre of excavation to constant-head boundary, R	L	140.0	m
Distance from centre to boundary of excavation, R_0	L	41.5	m
Head at the constant-head boundary, H	L	22.5	m
Head in the excavation, h_d	L	19.0	m

Result

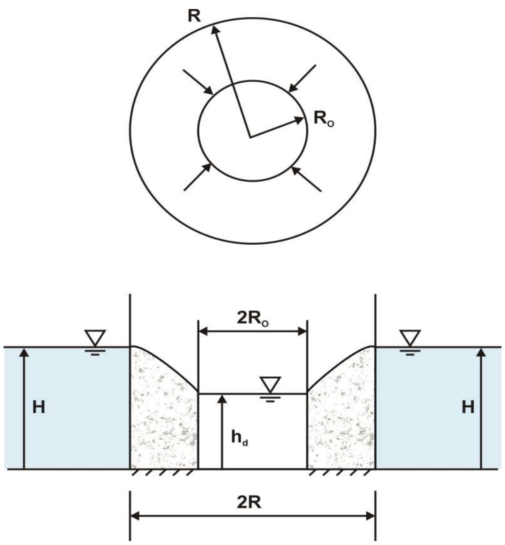
Calculated inflow, Q	L^3/T	0.003	m^3/s	**2.769713**	L/s

Reference:

Christopher J. Neville 2017. Analytical solutions for the preliminary estimation of long-term rates of groundwater inflow into excavations: Long excavations and circular excavations. Retrieved from: https://www.sspa.com/sites/default/files
/images/stories/software/Analytical%20solutions%20for%20flow%20into%20open%20excavations_1_Report_v02.pdf

Model 7

Radial unconfined flow into a circular excavation - C Low Low GW Level



The inflow into the excavation is:

$$Q = -\pi K \frac{(H^2 - h_d^2)}{\ln\left\{\frac{R}{R_0}\right\}}$$

Units are labels only; the user must specify consistent units

Parameter	Units	Value	User-specified units
Hydraulic conductivity, K	L/T	8.75E-05	m/s
Elevation of base of aquifer, z_{bot}	L	19.0	m
Thickness of aquifer where confined, D	L	0.0	m
Distance from centre of excavation to constant-head boundary, R	L	98.0	m
Distance from centre to boundary of excavation, R_0	L	41.5	m
Head at the constant-head boundary, H	L	21.0	m
Head in the excavation, h_d	L	19.0	m

Result

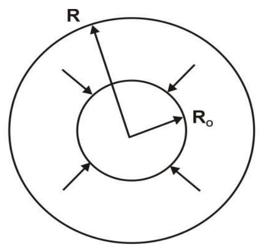
Calculated inflow, Q	L^3/T	0.001	m^3/s	**1.2798**	L/s

Reference:

Christopher J. Neville 2017. Analytical solutions for the preliminary estimation of long-term rates of groundwater inflow into excavations: Long excavations and circular excavations. Retrieved from: https://www.sspa.com/sites/default/files /images/stories/software/Analytical%20solutions%20for%20flow%20into%20open%20excavations_1_Report_v02.pdf

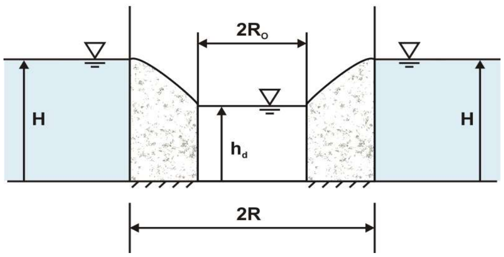
Model 7

Radial unconfined flow into a circular excavation - D- Low Low GW Level



The inflow into the excavation is:

$$Q = -\pi K \frac{(H^2 - h_d^2)}{\ln\left\{\frac{R}{R_0}\right\}}$$



Units are labels only; the user must specify consistent units

Parameter	**Units**	**Value**	**User-specified units**
Hydraulic conductivity, K	L/T	8.75E-05	m/s
Elevation of base of aquifer, z_{bot}	L	19.0	m
Thickness of aquifer where confined, D	L	0.0	m
Distance from centre of excavation to constant-head boundary, R	L	70.0	m
Distance from centre to boundary of excavation, R_0	L	41.5	m
Head at the constant-head boundary, H	L	20.0	m
Head in the excavation, h_d	L	19.0	m

Result

Calculated inflow, Q	L^3/T	0.001	m^3/s	**0.525868**	L/s

Reference:

Christopher J. Neville 2017. Analytical solutions for the preliminary estimation of long-term rates of groundwater inflow into excavations: Long excavations and circular excavations. Retrieved from: https://www.sspa.com/sites/default/files /images/stories/software/Analytical%20solutions%20for%20flow%20into%20open%20excavations_1_Report_v02.pdf

Appendix C Infiltration Tests Data

Site	Sample depth	Soil Texture	Soil Structure			Coarse fragments		Soil Colour	Mottles		LUC
	(cm)		Degree	Shape	Size	Size	Abundance	Primary / Secondary	Abundance	Colour(s)	Class
Auger 1	**10**	silt loam	moderate-strong	spheroidal	microfine - very fine		-	10YR2/1			Hard to work + mottling indicates imperfect drainage
	20	silt loam	moderate-strong	spheroidal	microfine - very fine		-	10YR2/1			
	30	silt loam	moderate	polyhedral	very fine		-	2.5Y5/3	y	7.5YR5/8	
	40	loamy silt	weak	blocky	very fine - fine		-	2.5YR5/4	y	7.5YR5/8	
	50	silt loam	structureless	cloddy	-		-	10YR7/2	y	7.5YR5/8	
	60	silt loam	structureless	cloddy	-		-	10YR7/2	y	7.5YR5/8	**2s**
Auger 2	**10**	silt loam	strong	spheroidal	microfine - very fine	fine to medium	slightly gravelly	10YR2/1	-		>10cm very gravelly
	15	silt loam	strong	spheroidal	microfine - fine	fine to medium	very gravelly	10YR2/1	-		
(ALSO INFILTRATION SITE)		couldn't get deeper									
											4s
Auger 3	**10**	silt loam	strong	spheroidal	microfine - very fine	fine	slightly gravelly	2.5Y4/3	-		>10cm very gravelly
	20	silt loam	strong	spheroidal	microfine - very fine	medium - coarse	very gravelly	2.5Y4/3	-		
		couldn't get deeper									
											4s
Auger 4	**10**	silt loam	strong	spheroidal	microfine - very fine	medium - coarse	very gravelly	2.5YR4/3	-		>5cm very gravelly
		couldn't get deeper									
											4s
Auger 5	**10**	loamy silt	moderate - strong	spheroidal	microfine - very fine	medium	slightly gravelly	2.5YR4/3	-		>30cm very gravelly
	20	loamy silt	moderate - strong	polyhedral	extremely fine - fine	medium	slightly gravelly	2.5YR4/3	-		
(ALSO INFILTRATION SITE)	**30**	loamy silt	moderate	polyhedral	extremely fine - fine	medium	slightly gravelly	2.5YR4/3	-		
		couldn't get deeper									
											3s
Auger 6	**10**	silt loam	moderate - strong	spheroidal	microfine - very fine	fine - medium	slightly gravelly	2.5YR4/3	-		>15cm very gravelly
	15	silt loam	moderate	spheroidal	microfine - very fine	fine - medium	very gravelly	2.5YR4/3	-		
		couldn't get deeper									
											4s

Site location	Time (minutes)	Water height (mm)	Infiltration rate (mm/5min)	Infiltration rate (mm/min)	SAT mm/min
Infiltration at Auger 2	0	200	-	-	1.4-1.6 mm/min
	5	188	12	2.4	
	10	178	10	2	
	15	170	8	1.6	
	20	160	10	2	
	25	155	5	1	
	Refill	200	-	-	
	30	196	4	0.8	
	35	188	8	1.6	
	40	180	8	1.6	
	45	174	6	1.2	
	50	168	6	1.2	
	55	163	5	1	
	Refill	200	-	-	
	60	195	5	1	
	65	187	8	1.6	
	70	180	7	1.4	
	75	172	8	1.6	
	80	164	8	1.6	
Infiltration at Auger 5	0	200	-	-	1.6-1.8 mm/min
	5	152	48	9.6	
	10	131	21	4.2	
	Refill	200	-	-	
	15	191	9	1.8	
	20	178	13	2.6	
	25	166	12	2.4	
	30	159	7	1.4	
	35	149	10	2	
	Refill	200	-	-	
	40	193	7	1.4	
	45	180	13	2.6	
	50	170	10	2	
	55	162	8	1.6	
	60	152	10	2	
	Refill	205	-	-	
	65	197	8	1.6	
	70	188	9	1.8	
	75	179	9	1.8	

Appendix D Theis Model (ECAN's Spreadsheet)

Stream depletion analysis - Theis (Jenkins) solution

Pumped aquifer

Transmissivity (T)	53	(m^2/d)
Storage coefficient (S)	0.005	-

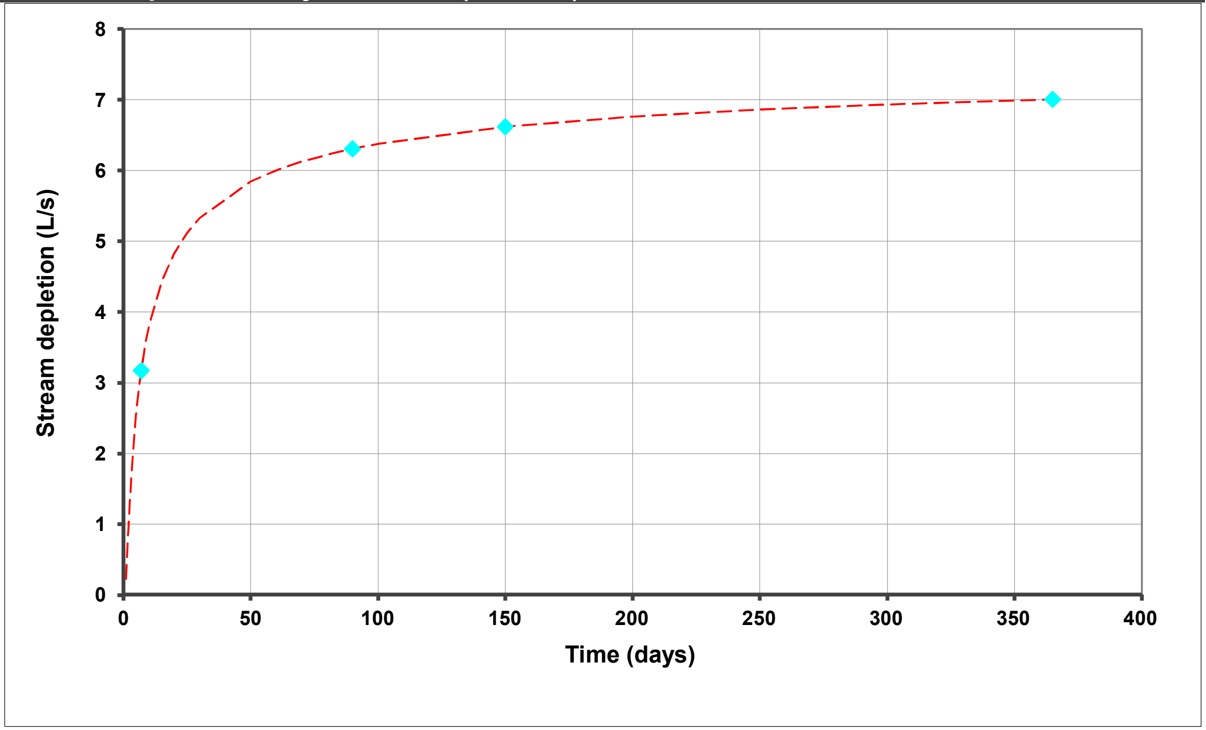
Well

Pumping rate (Q)	7.7	(L/s)
Separation distance (L)	316	(m)
Stream depletion factor (sdf)	9.42037736	(days)

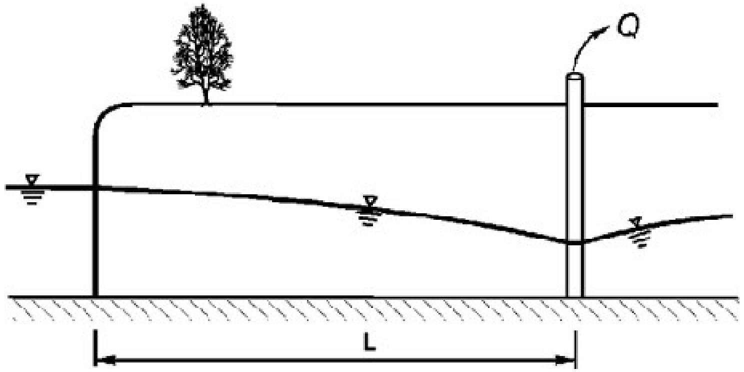
Stream depletion after

Time (days)	q (L/s)	%
7	3	**41%**
90	6	**82%**
150	7	**86%**
365	7	**91%**

Only the values in shaded cells can be updated - all other cells are dependent on those input values.



Time (days)	Depletion Rate (L/s)
1.0	0.2
2.0	1.0
3.0	1.6
4.0	2.1
5.0	2.6
6.0	2.9
7.0	3.2
8.0	3.4
9.0	3.6
10.0	3.8
15.0	4.4
20.0	4.8
25.0	5.1
30.0	5.3
50.0	5.8
60.0	6.0
70.0	6.1
84.0	6.3
90.0	6.3
100.0	6.4
150.0	6.6
200.0	6.8
250.0	6.9
300.0	6.9
365.0	7.0



Stream depletion analysis - Theis (Jenkins) solution

Pumped aquifer

Transmissivity (T)	26	(m^2/d)
Storage coefficient (S)	0.005	-

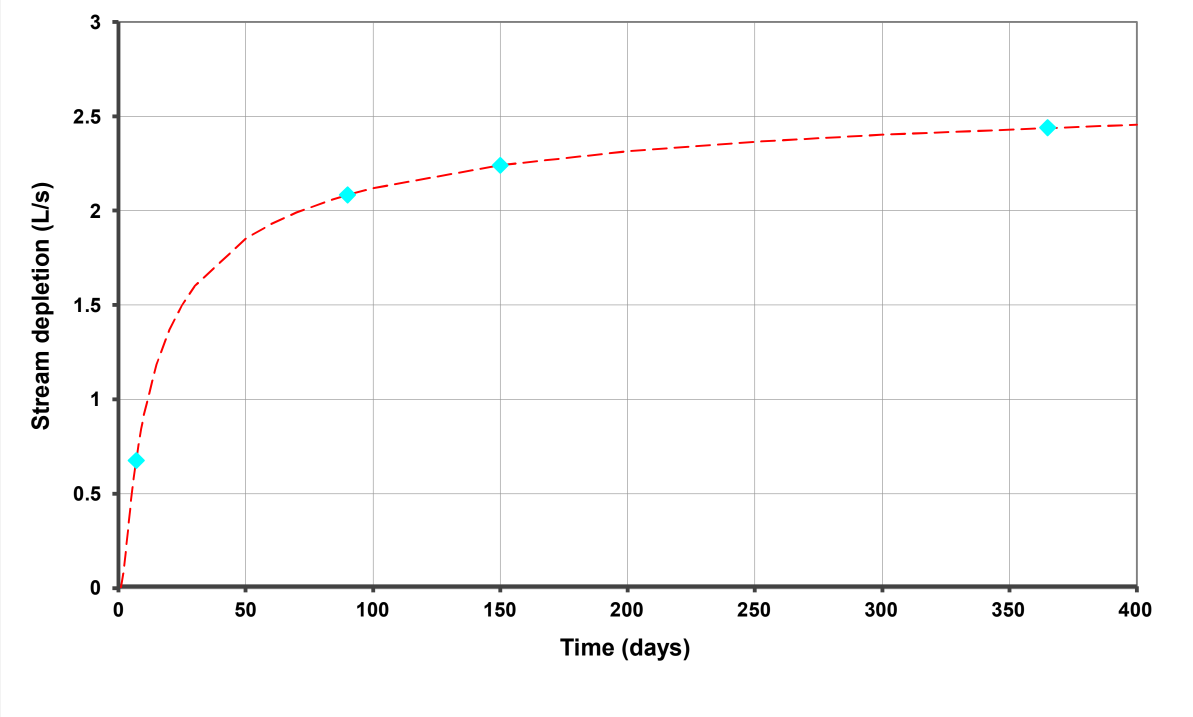
Well

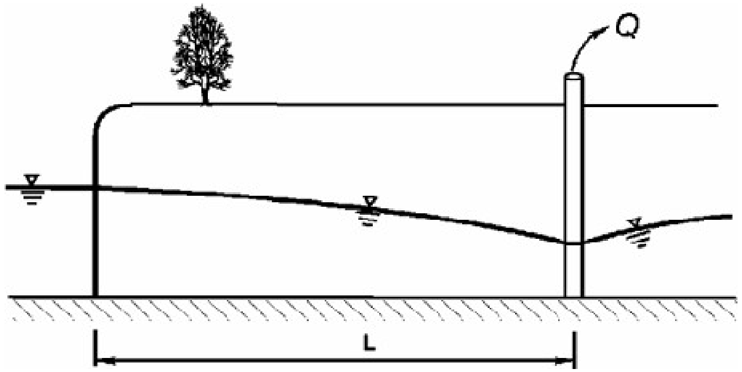
Pumping rate (Q)	2.8	(L/s)
Separation distance (L)	316	(m)
Stream depletion factor (sdf)	19.2030769	(days)

Stream depletion after

Time (days)	q (L/s)	%
7	1	**24%**
90	2	**74%**
150	2	**80%**
365	2	**87%**

Only the values in shaded cells can be updated - all other cells are dependent on those input values.





Time (days)	Depletion Rate (L/s)
1.0	0.0
2.0	0.1
3.0	0.2
4.0	0.3
5.0	0.5
6.0	0.6
7.0	0.7
8.0	0.8
9.0	0.8
10.0	0.9
15.0	1.2
20.0	1.4
25.0	1.5
30.0	1.6
50.0	1.9
60.0	1.9
70.0	2.0
84.0	2.1
90.0	2.1
100.0	2.1
150.0	2.2
200.0	2.3
250.0	2.4
300.0	2.4
400.0	2.5

Stream depletion analysis - Theis (Jenkins) solution

Pumped aquifer

Transmissivity (T)	15	(m^2/d)
Storage coefficient (S)	0.005	-

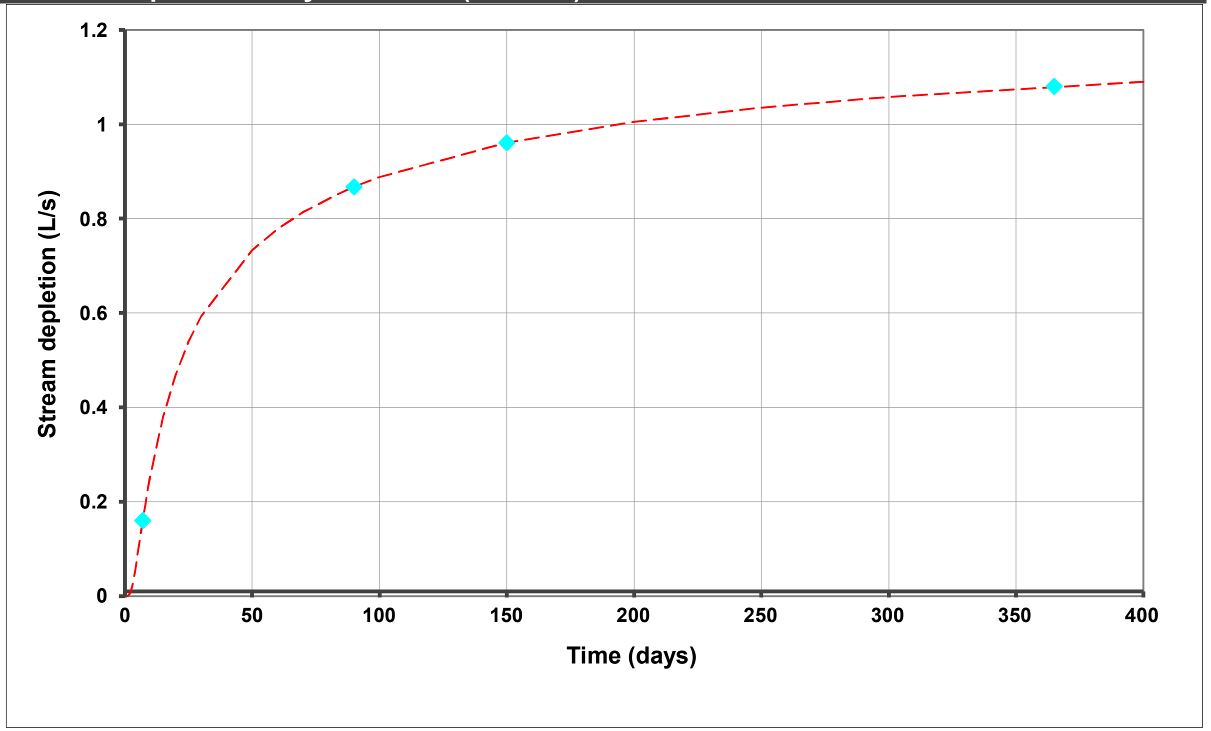
Well

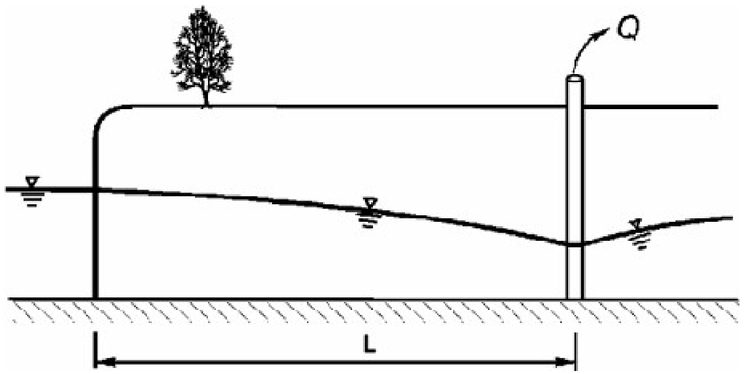
Pumping rate (Q)	1.3	(L/s)
Separation distance (L)	316	(m)
Stream depletion factor (sdf)	33.2853333	(days)

Stream depletion after

Time (days)	q (L/s)	%
7	0	**12%**
90	1	**67%**
150	1	**74%**
365	1	**83%**

Only the values in shaded cells can be updated - all other cells are dependent on those input values.





Time (days)	Depletion Rate (L/s)
1.0	0.0
2.0	0.0
3.0	0.0
4.0	0.1
5.0	0.1
6.0	0.1
7.0	0.2
8.0	0.2
9.0	0.2
10.0	0.3
15.0	0.4
20.0	0.5
25.0	0.5
30.0	0.6
50.0	0.7
60.0	0.8
70.0	0.8
84.0	0.9
90.0	0.9
100.0	0.9
150.0	1.0
200.0	1.0
250.0	1.0
300.0	1.1
400.0	1.1

Stream depletion analysis - Theis (Jenkins) solution

Pumped aquifer

Transmissivity (T)	8	(m^2/d)
Storage coefficient (S)	0.005	-

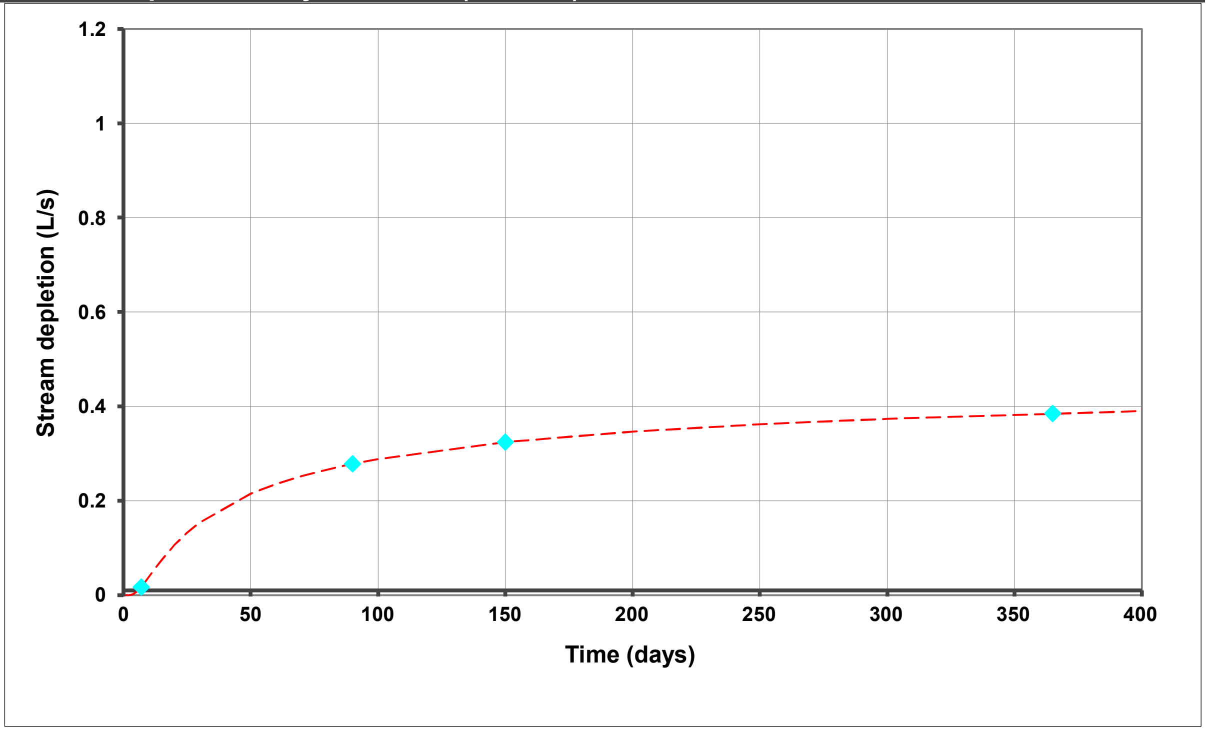
Well

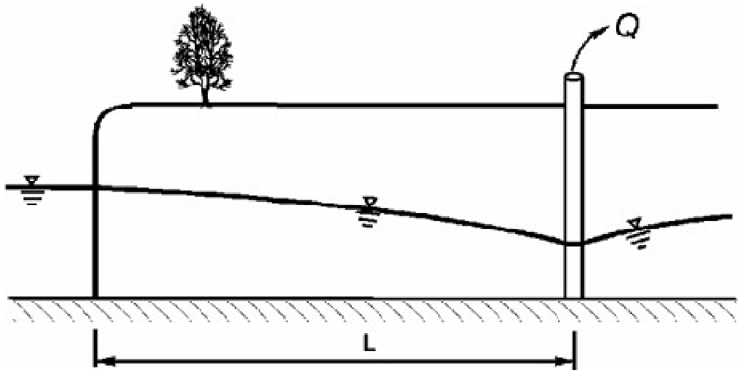
Pumping rate (Q)	0.5	(L/s)
Separation distance (L)	316	(m)
Stream depletion factor (sdf)	62.41	(days)

Stream depletion after

Time (days)	q (L/s)	%
7	0	**3%**
90	0	**56%**
150	0	**65%**
365	0	**77%**

Only the values in shaded cells can be updated - all other cells are dependent on those input values.





Time (days)	Depletion Rate (L/s)
1.0	0.0
2.0	0.0
3.0	0.0
4.0	0.0
5.0	0.0
6.0	0.0
7.0	0.0
8.0	0.0
9.0	0.0
10.0	0.0
15.0	0.1
20.0	0.1
25.0	0.1
30.0	0.2
50.0	0.2
60.0	0.2
70.0	0.3
84.0	0.3
90.0	0.3
100.0	0.3
150.0	0.3
200.0	0.3
250.0	0.4
300.0	0.4
400.0	0.4

APPLICABILITY AND LIMITATIONS

Restrictions of Intended Purpose

This report has been prepared solely for the benefit of South Island Resource Recovery Limited as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such party's sole risk.

Legal Interpretation

Opinions and judgements expressed herein are based on our understanding and interpretation of current regulatory standards, and should not be construed as legal opinions. Where opinions or judgements are to be relied on they should be independently verified with appropriate legal advice.

Maps and Images

All maps, plans, and figures included in this report are indicative only and are not to be used or interpreted as engineering drafts. Do not scale any of the maps, plans or figures in this report. Any information shown here on maps, plans and figures should be independently verified on site before taking any action. Sources for map and plan compositions include LINZ Data and Map Services and local council GIS services. For further details regarding any maps, plans or figures in this report, please contact Babbage Consultants Limited.

Reliability of Investigation

Babbage has performed the services for this project in accordance with the standard agreement for consulting services and current professional standards for environmental site assessment. No guarantees are either expressed or implied.

Recommendations and opinions in this report are based on discrete sampling data. The nature and continuity of matrix sampled away from the sampling points are inferred and it must be appreciated that actual conditions could vary from the assumed model.

There is no investigation that is thorough enough to preclude the presence of materials at the site that presently, or in the future, may be considered hazardous. Because regulatory evaluation criteria are constantly changing, concentrations of contaminants present and considered to be acceptable may in the future become subject to different regulatory standards, which cause them to become unacceptable and require further remediation for this site to be suitable for the existing or proposed land use activities.

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