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Wastewater Proposal for Pohutukawa Drive Subdivision: Preliminary Data

Freeman Cook & Associates Pty Ltd

FREEMAN COOK
ASSOCIATES /
PTY LTD

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Freeman J Cook

Report

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For further information please contact:

Email: freeman@freemancook.com.au

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Website: www.freemancook.com.au

I. Cover Photograph: Form Upsplash

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EXECUTIVE SUMMARY

This report is a preliminary report which presents *in situ* soil measurements made to assess the suitability and design of wastewater from a communal wastewater treatment plant for a housing development at Pohutukawa Drive, Whirinaki, Hawke's Bay. This refines an earlier studied based on site characteristics and soil descriptions and draws on this for the area selected for the measurements.

The results show that the soil has rapid to moderately rapid hydraulic conductivity and is very suitable for land treatment of wastewater. The spacing and depth of subsurface drippers was calculated using the WetUp software and found to be 0.6 and 0.2 m respectively. The return period for irrigation was calculated as 8 days which means that 8 irrigation zones will be required of 0.225 ha each giving a total irrigated area of 1.80 ha. The depth of application per irrigation was calculated to be 47 mm for a wastewater containing less than 20 mg/L of nitrogen and less than 3 mg/L of phosphorus.

1. BACKGROUND

A development of 83 households (81 three- to four-bedroom houses and 2 two-bedroom flats) and ancillary commercial floorspace is proposed at Pohutukawa Drive, Whirinaki, Hawke Bay. As the site is not serviced by Council's reticulated wastewater network, wastewater treatment for the development will need to be developed with onsite disposal. The number and size of the residential lots means that this will be best achieved through a community wastewater treatment system and reticulation of the wastewater from individual lots to the community system. The final stage will require a polishing of the treated discharge through the receiving soil.

The development of an onsite community wastewater treatment plant and land treatment system for the wastewater is split into distinct steps:

1. Land treatment investigations and design requirements for subsurface drip irrigation of the wastewater (Freeman Cook & Associates Pty Ltd)
2. Subsurface drip irrigation (SDI) design of delivery system (NexGen Water)
3. Reticulation system from individual houses to treatment plant (Development Nous Ltd and NexGen Water)
4. Treatment plant design (Apex Water)
5. Commissioning of SDI system and delivery of operating manual (NexGen Water)
6. Commissioning of wastewater treatment plant and delivery of operating manual (Apex Water)

This report provides soil measurements and modelling to allow a preliminary wastewater land treatment system to be designed and to inform the development of subsurface drip irrigation (SDI) land treatment and the requirements in terms of water quality from the wastewater treatment plant.

A soil survey, climate analysis and estimates of land area required for an SDI land treatment system have already been performed (Cook and Gearing, 2021). This report builds on this information.

2. SOIL HYDRAULIC MEASUREMENTS

Site selection

From the report of Cook and Gearing (2021) the most suitable soils for onsite discharge of treated wastewater were near soil pits 1 and 6 of that report. As the soil near pit 6 was beyond the logical and coherent residential development area, this site was chosen for the location of the wastewater treatment plant and SDI land treatment. Four sites within this selected area were chosen for soil measurements and these are shown in figure 1.

Figure 1. Site locations for the soil measurements.

Hydraulic conductivity and sorptivity measurements

The SDI drippers are likely to be situated at a depth between 0.15 and 0.2 m depth, so hydraulic conductivity measurements were made at depths of 0.1 and 0.3 m. The *Ks* and sorptivity (*S*) of the soil was measured using a variation on the Twin Ring Method (Scotter et al. 1982; Cook, 2002). This method applied a series of different constant rate point sources (drippers) (Table 1) and measured the quasi steady-state saturated radius that formed. Initial water content (θ_I) was measured using a theta probe (https://delta-t.co.uk/product/ml3/) and cores were taken to measure the bulk density and also to give further estimates of the initial water content. The final water content (θ_F) was measured by taking a shallow soil sample under the saturated pond just as the surface water dissipated.

The results of the measurements are shown in Table 1. There is statistical difference in the measured values between the depths except for bulk density which is higher at the 0.1 to 0.15 m depth with the difference significant at the 5% level.

Table 1. Soil physical properties: Ks, S, θ_I, θ_F, and bulk density. Data is shown as mean ± standard error (SE) where appropriate. For site 3 at a depth of 0.3 – 0.35 m the Ks could not be determine (ND).

Site	Depth (m)	*Ks* (mm hr^{-1})	*S* (mm $hr^{-1/2}$)	θ_I (m^3 m^{-3})	θ_F (m^3 m^{-3})	Bulk density (Mg m^{-3})
1	0.1 – 0.15	79 ± 30	96 ± 17	0.282 ± 0.001	0.576	1.42
2	0.1 – 0.15	22 ± 8	53 ± 2	0.283 ± 0.001	0.554	1.54
3	0.1 – 0.15	33 ± 19	33 ± 3	0.304 ± 0.006	0.553	1.45
4	0.1 – 0.15	104 ± 60	84 ± 9	0.316 ± 0.002	0.622	1.45
Overall	0.1 – 0.15	60 ± 30	70 ± 10	0.295 ± 0.005	0.58 ± 0.02	1.47 ± 0.03
1	0.3 – 0.35	53 ± 13	65 ± 6	0.299 ± 0.001	0.616	1.34
2	0.3 – 0.35	ND	151 ± 21	0.22 ± 0.01	0.601	1.38
3	0.3 – 0.35	24 ± 20	33 ± 3	0.355 ± 0.006	0.494	1.32
4	0.3 – 0.35	154 ± 23	43 ± 8	0.35 ± 0.01	0.517	1.40
Overall	0.3 – 0.35	60 ± 20	70 ± 10	0.31 ± 0.02	0.54 ± 0.02	1.36 ± 0.02

The hydraulic conductivities are in the moderate to rapid class which means these soils will be very suitable for subsurface drip irrigation. The site was visited following 51.6 mm of

rainfall in the previous 10 days (as recorded at Napier Airport), so was at an initial water content that is likely to equate to field capacity. Given the difference in the initial and final water contents of 0.285 and 0.23 for depths of 0.1-0.15 and 0.3-0.35 m respectively this indicates that there is a relatively high air-filled porosity at field capacity. This means that aeration problems are highly unlikely in using this area for a subsurface drip irrigation area for the wastewater from the housing development.

Soil sampling

Duplicate soil cores were taken at both depths and sent to Manaaki Whenua (Landcare Research) for measurement of the soil moisture retention characteristics and bulk samples for soil chemistry measurements. These results will be reported in a future detailed design report.

3. SUBSURAFACE DRIP IRRIGATION (SDI) ESTIMATES

Wetting and solute fronts with time

The WetUp model (Cook et al. 2003; Cook 2017) was used to determine the wetting and solute distribution patterns with various flow rates. The results are shown for the mean *Ks* and for water, passive solutes such as chloride and nitrate and retarded solutes such as ammonium and phosphate. The results for the 0.1-0.15 m depth (figure 2) show that the after 10 hours the depth of wetting would be 0.39 m below the dripper and 0.21 m above the dripper.

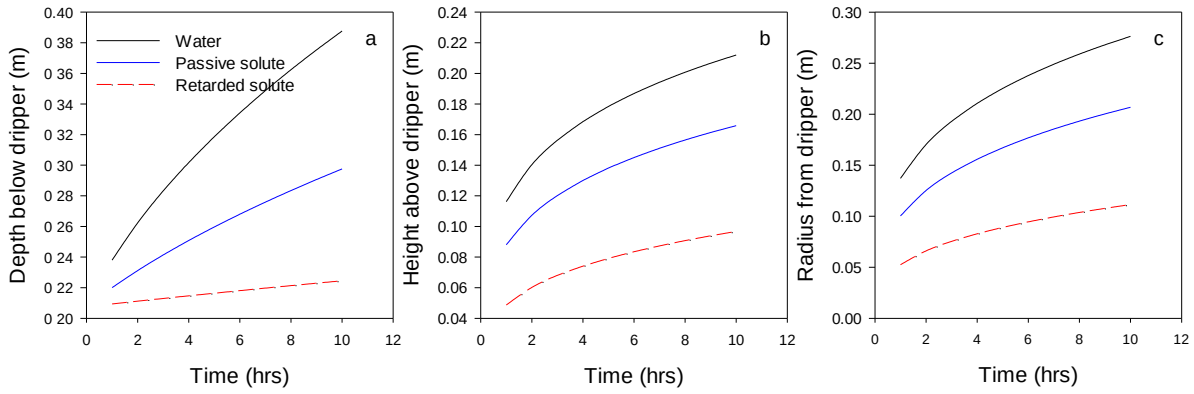

Figure 2. For depth 0.1-0.15 m distance of water, passive and retarded solute fronts: a) depth below the dripper, b) height above dripper and c) radius for a 2.1 L/hr dripper.

The depth and radius of wetting are greater when the soil data from 0.3-0.35 m are used in WetUp (figure 3).

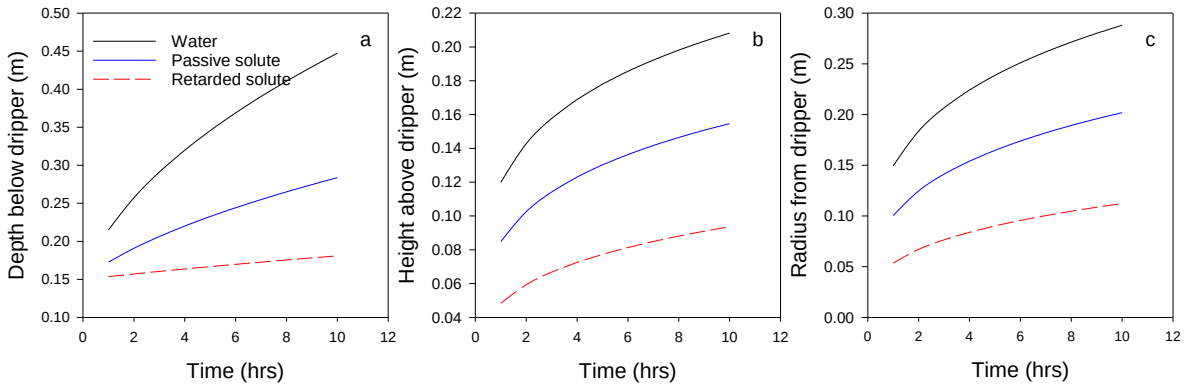

Figure 3. For depth 0.3-0.35 m distance of water, passive and retarded solute fronts: a) depth below the dripper, b) height above dripper and c) radius for a 2.1 L/hr dripper.

What these results suggest is that the drippers should placed at a depth of approximately 0.2 m below the soil surface with a spacing of 0.6 m between the drippers both on the dripline and between the driplines.

Application time and volume

Assuming a rooting depth for grass of 0.6 m we would want the depth of the wetting front to be 0.4 m below the drippers. This would occur at approximately 10 hours using the 0.1-0.15 m soil data and 8 hours for the 0.3-0.35 m soil data. The volume of water applied into a 0.6 m square area would then be 21 and 16.8 L for 10 and 8 hours respectively, which would be equivalent to a depth of application of 58 and 47 mm respectively for 0.1-0.15 m soil data and 0.3-0.35 m soil data. As the dripper will be sited at a depth of 0.2 m the results for the 0.3-0.35 m depth would be more appropriate in the preliminary design. Thus, an application of 47 mm over a period of 8 hours is recommended.

Return period and wastewater SDI area

The wastewater disposal site will be fully irrigated so based on an annual evapotranspiration rate of 1078 mm and the pasture production estimated by Mills et al. (2021) of 16.9 kg/mm/yr, the annual pasture dry matter will be 18,200 kg_DM/yr. With a nitrogen (N) content of 2.5% this results in an annual nitrogen uptake of 455 kg_N/ha/yr. The phosphorus concentration in grass dry matter ranges from 0.3 to 0.5%. Taking a value of 0.4 % the uptake of phosphorus (P) by the pasture will be 72 kg_P/ha/yr.

Using these values of N and P we can estimate the return period between irrigations so that the grass will have taken up the nutrients. The N and P annual uptake rates can be converted to average daily uptake rates. These daily average rates will underestimate the uptake in summer and overestimate in winter but can give a good estimate for preliminary design of the wastewater SDI system. The return period was calculated for a range of wastewater nitrogen and phosphorus concentrations (figure 4). A return period of 8 days would be suitable if the application is 47 mm based on the 0.3-0.35 m depth wetting patterns. The nitrogen concentration of the wastewater would need to be < 20 g/m^3 and the phosphorus concentration < 3 g/m^3 to meet the daily average plant uptake rate.

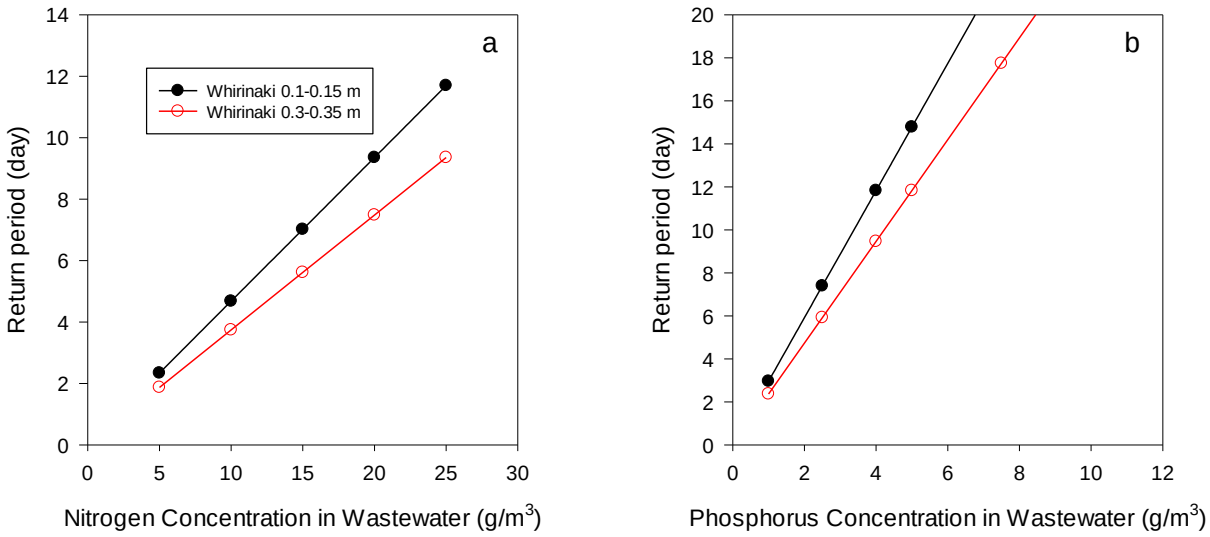

Figure 4. Return period for irrigation with wastewater based on grass uptake of: a) nitrogen and b) phosphorus.

This development will consist of 83 households (81 three- to four-bedroom houses and 2 two-bedroom flats above the commercial area) and a small commercial area of 1750 m^2. It is difficult to find exact wastewater estimates for the commercial area but from the design criteria in NZ4404-2010 a value of 0.4 L/s/ha is given for light industry. This would result in a daily wastewater volume of 6.048 m^3/day.

The occupancy rate in 2001 for regional council areas was 2.69 people per household and has consistent decreased with 2.78 and 2.77 in 1991 and 1996 respectively (https://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE2361), so this may now be lower than 2.69 people per household. For this development we have considered that the houses will have three to four bedrooms and have 6 people per household which is likely to be an overestimate. Taking a wastewater per person rate of 200 L/person/day this would result in 1200 L/day of wastewater per house lot. The proposed 81 house lots would result in 97.2 m^3/day of wastewater. Two two-bedroom flats are also proposed for this development, assuming two persons per bedroom and 200 L/day of wastewater per person gives 1.6 m^3/day of wastewater to be treated.

The total daily wastewater volume (from residential and commercial) is then 104.85 m^3/day. The reticulation system will be a sealed pressurised system, so no additions from ingress into the system are expected.

The area of land required for the wastewater irrigation field can then be estimated from the total daily volume of wastewater (104.85 m^3/day) and the depth of application of 47 mm to give a required daily area of 0.225 ha. There is a return period of 8 days so 1.80 ha of land is required for the wastewater irrigation.

4.SUMMARY

This preliminary analysis for the wastewater land treatment at the Pohutukawa Drive housing development indicates that:

1. The SDI discharge area required will be 1.80 ha
2. This area should be split into 8 irrigation zones of 0.225 ha in area, so that the return period between irrigations is 8 days

3. For the subsurface dripper irrigation, the spacing between the drippers and driplines should be 0.6 m and the depth of the drippers 0.2 m
4. The nitrogen concentration of the applied wastewater should be < 20 mg/L and the phosphorous concentration < 3 mg/L.

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FREEMAN COOK ASSOCIATES / PTY LTD

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E: freeman.j.cook@gmail.com
7 Virginia Heights, Otamatea, Whanganui, New Zealand