Memorandum

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Copy	
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Office	Palmerston North
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Subject	Rātana WWTP - Technical assessments for irrigation design

1 Introduction

Rangitikei District Council (RDC) are upgrading the Rātana Wastewater Treatment Plant (WWTP) and moving to a system where discharge to land will occur. Part of the upgrade work includes irrigating treated wastewater to land.

The purpose of this document is to:

- Set out the base design criteria required to complete the detailed design of a deficit irrigation system.
- Identify risks where deficit irrigation cannot be achieved and whether these can be mitigated or not.

The following key assumptions have been made when considering the irrigation design:

- Irrigation would generally not occur during late autumn and winter (April – August) (unless deficit irrigation could be undertaken). Storage will be provided to hold treated wastewater volumes over these periods.
- Volume of storage to be provided is based on deficit irrigation during a median year. Options to allow for current wastewater flows and future wastewater flows are calculated. In either scenario during a wet year a greater proportion of non-deficit irrigation would occur.
- Setback distances of 20 m have been included around wetland areas and around neighbouring property boundaries. No irrigation would occur within the 20m of the wetlands. The boundary buffer area are designed to be controlled under separate irrigation management zones from the main irrigable area.
- Irrigation to dunelands is allowed for sparingly, but as such it is not accounted for in nitrogen loading calculations. It is understood a trial area in the dunelands is to be established, but at this stage a conservative approach is taken to nitrogen loading calculations.

This document should be read in conjunction with the following reports:

- Schedule F Assessment for Ratana Wastewater Discharge (August 2021)
- Preliminary Water Balance (August 2021) *(the 1-in-5 wet year Water Balance is added to this report as an Appendix)*
- Effluent irrigation and groundwater review (October 2021)
- Wetland delineation report (December 2021)
- Process Review (February 2022)
- Planning Assessment (January 2022)
- Groundwater Site Investigation (March 2022)

2 Site description

Rangitikei District Council have recently purchased an area of land totaling 21.81 ha off Whangaehu Beach Road, to potentially dispose of treated wastewater from the Rātana WWTP to land (Figure 3.1). The subject site is currently managed pasture used for grazing cattle and a pine plantation which has recently been cleared and replanted.

2.1 Key onsite factors influencing irrigation design

- Ecological assessments undertaken by WSP to date have identified Schedule F areas of duneland habitat and two small wetlands. (refer to reports “Schedule F Assessment for Ratana Wastewater Discharge” and “Wetland delineation report”). Vegetation present on the dunelands currently is of low value ecologically, the habitat value is due predominantly to the shape of the dunes. Restoration of the vegetation would be undertaken over time.
- The soil types present on site are Sandy Brown and Sandy Recent soils which have low water holding capacity and moderate to high leaching potential. There are also areas of exposed Bedrock which has very low or no water holding capacity, reduced infiltration, and therefore surface runoff risk. The sandy soils were verified from site observations of test pits.
- The topography at the site is variable ranging from undulating to moderately steep, with elevation ranging from 1-23 m. Steeper topography is a risk of surface run off, if application volumes or rates are too high.
- Infiltration testing in February 2022 showed that lower lying areas at the site had very low infiltration rates (0-12 mm/hr), and higher areas had greater infiltration rates (43-64 mm/hr). The groundwater level was observed to be variable across the site, ranging from 8.93 m (RL) to 12.05 m (RL) with indications that topography is influencing flow direction. These tests and observations were untaken within 3 weeks of two large rainfall events in the area, and therefore soils were likely to be more saturated than is typical for this time of the year.

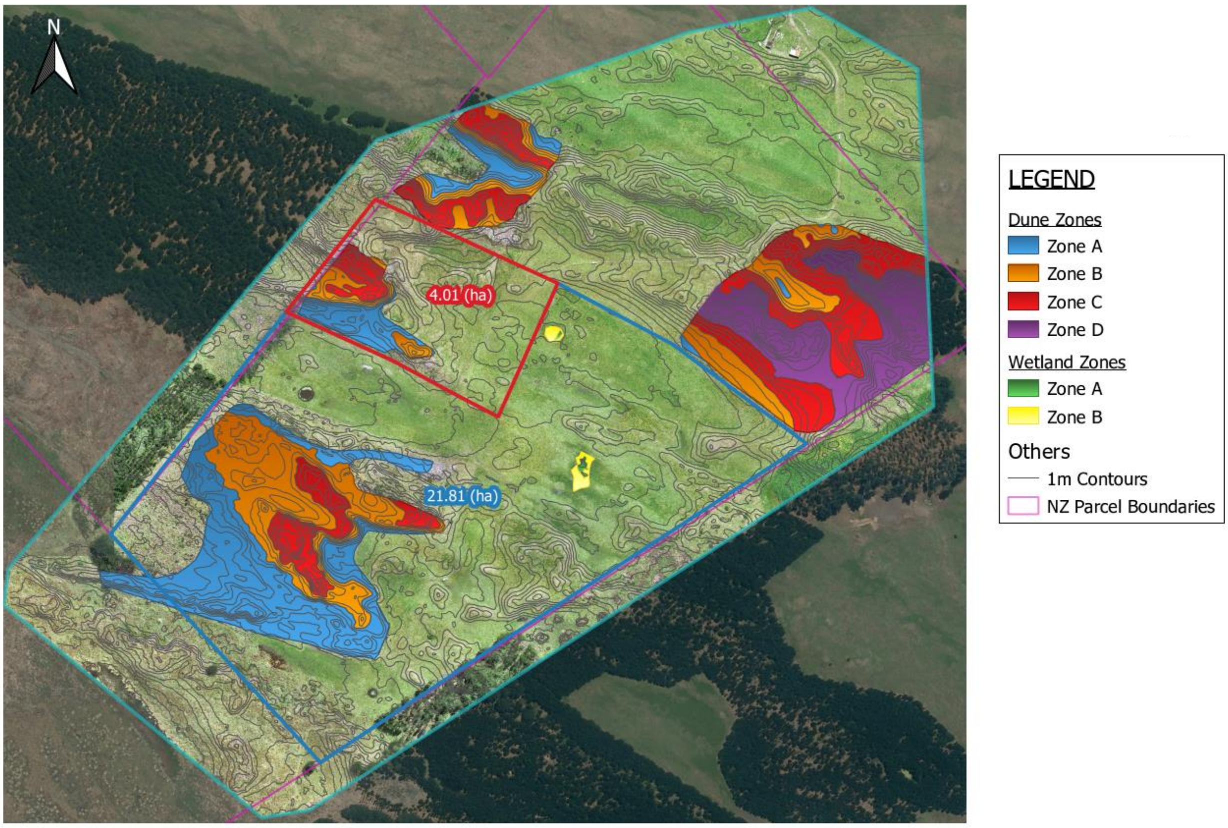

Figure 2-1: Location of the proposed disposal area for the Rātana wastewater treatment plant, showing dune and wetland zones. The area outlined in blue has been purchased by RDC; the area outlined in red has not yet been purchased by RDC.

3 Key design parameters

The key parameters that have been considered for the irrigation design are outlined below.

3.1 Wastewater flows and nutrient loading

Wastewater flows are the primary source of hydraulic and nutrient loading. To understand how much land area and buffer storage are required to achieve deficit irrigation, the average amount of wastewater inflows and the concentration of nutrients in these inflows is required. These have been quantified in the "Ratana WWTP Process Review" report and numbers for inflows and total nitrogen are summarised here in Table 3-1.

Table 3-1: Current and estimated future wastewater flows and estimated total nitrogen discharged from the Rātana WWTP.

	Nitrogen (kg N/yr)	Area available (ha)	Nitrogen loading (kg N/ha/yr)	Area available (ha)	Nitrogen loading (kg N/ha/yr)
Current flows	839	15	56	20	42
Future flows	1549	15	103	20	77

As nitrate nitrogen is only at very low concentrations, total nitrogen is assumed to be the same as TKN

3.2 Water balance

For deficit irrigation of wastewater to be achievable, there needs to be more evapotranspiration than rainfall. The net monthly water balance between rainfall and evapotranspiration over a period of a year is needed to determine the required land area and buffer storage.

Under a median year climate scenario, the calculated water balance indicates that deficit irrigation is viable from October to March (refer to report “Ratana WWTP - Preliminary Water Balance”).

Under a 1-in-5 wet year scenario, where rainfall is higher and evapotranspiration is lower than a median year, deficit irrigation is generally not viable and non-deficit irrigation will likely need to be applied over November to March (refer to Appendix).

3.3 Target soil moisture

The purpose of deficit irrigation is to keep soil moisture within the plant root zone, between field capacity (the water remaining in the soil after gravitational water has drained) and stress point (the soil moisture content when plant growth starts to slow, typically 75% of field capacity). For plants to effectively abstract nutrients the soil moisture needs to be maintained between these two points. If the soil moisture is greater than field capacity, then nutrient can be flushed past the root zone of the plant into groundwater or if the soil gets saturated it can pond and result in surface run-off. If the soil moisture falls below stress point a plants ability to draw water and abstract nutrient can be restricted.

An effective irrigation system maintains a soil moisture between these points. To do this effectively, field calibrated real-time soil moisture monitoring is required.

It is important to determine the field capacity and stress point of the soils on site, as these values will determine and/or influence:

- how and when the irrigation system is operated,
- the type of irrigation system chosen, and
- the area of land and buffer storage required.

The target soil moisture will be a value less than the field capacity (but higher than the stress point). Actual field capacity and stress points for the soils at the proposed discharge site will need to be confirmed in the field.

3.4 Operational time per day

Theoretically a system can operate 24 hours per day. However, the ability to be able to undertake repairs and maintenance, operate outside rainfall events and operate at night (i.e., to allow for access the site during the day) mean that it is more practical to operate for less than 24 hours per day.

An operational period of 12 hours per day will give sufficient operational flexibility. The actual operational time per day can be determined during detail design.

3.5 Area available

As shown in Figure 2-1, the proposed discharge site has an area of 21.81 ha. In order to calculate the effective available area for irrigation, key areas are excluded as follows:

- The areas of duneland (one area is within the land yet to be purchased)
- The two wetland areas
- An area set aside for buffer storage

- Setback areas of 20 m around duneland, wetlands and neighbouring boundaries.

It is assumed the setback areas can be irrigated if conditions are suitable. Irrigation of these areas can be controlled separately from the remaining irrigable area if these are set up as separate irrigation management zones.

The calculated minimum effective irrigable land area for the proposed discharge site and additional area yet to be purchased is shown in Table 3-2.

If setback areas are able to be irrigated, this will allow for an additional 2.9 ha of irrigable land

Table 3-2: Irrigable land area calculations for the proposed disposal site.

	Purchased land
Gross Area (ha)	22
Area of Dune 1 (ha)	-5.0
Area of Wetland 1 and 2 (ha)	-0.1
Storage footprint (ha)	-1.5
Net Area including 20m setback area (ha)	15.4
Net Area not including 20m setback area (ha)	12.5

Allowing for the duneland areas to be irrigated to on a regular basis would result in an effective irrigable land of 20.4ha.

3.6 Buffer storage

Wastewater flows are more or less continuous throughout the year. Irrigation demand is seasonal and primarily occurs in summer. To achieve deficit irrigation buffer storage is required. However, an irrigation system solely designed to achieved deferred irrigation can require significant storage. Therefore, to reduce the storage area required, a mixture of deferred irrigation and not deferred has also been explored. These options are outlined in Section 4.1.

3.7 Boundary setback distances

There are key boundaries (wetlands and the neighbouring properties) where the wastewater irrigation cannot encroach on. These areas may require a boundary setback distance to ensure this does not happen.

A setback distance of 20 m has been assumed. This effectively reduces the irrigable area by 2.9 ha. This reduction in area represents a large percentage of the total available area. Therefore, it is recommended that some of these areas still able to be irrigated but under more stringent conditions. This would require these areas to operate independently of the main irrigation areas.

3.8 Distribution uniformity

Distribution uniformity is a measure of how even an irrigation system applies water to a ground area. Perfect uniformity is considered to be 100%. Generally, a distribution uniformity of greater than 80% is considered acceptable.

3.9 Appropriate Standards

The irrigation design will primarily follow the Irrigation New Zealand Design and Installation standards and code of practices (Irrigation New Zealand, 2007; 2013).

3.10 Key design parameters for range of deficit irrigation scenarios

Five scenarios have been quantified to illustrate the viability of deficit irrigation or mixed irrigation (deficit and non-deficit) under different rainfall and wastewater flow situations.

General Parameters		
Operational times per day	12	hrs
Field Capacity of Soil	62	mm
Target Soil Moisture	42	mm
Distribution uniformity (DU_{lq})	80	%
Net Area Available	15	ha
Boundary Buffer Zones	20	m

Scenario A: Future Flows with median rainfall and evapotranspiration extended irrigation period and dunelands		
Irrigation Philosophy	Mixed	
Rainfall-Evapotranspiration Data Period	Median year	
Irrigation area	20 ha	
WW water flow scenario	Based on Future maximum average flows	
Months of deficit Irrigation	5	November - March
Months of non deficit irrigation.	2	September, October
Months of no irrigation	5	April to August
Buffer Storage Required	28,500	m^3

Scenario B: Future Flows with 1:5 year maximum rainfall and minimum evapotranspiration.		
Irrigation Philosophy	Non-Deficit	
Rainfall-Evapotranspiration Data Period	1 in 5 wet year	
WW water flow scenario	Based on Future maximum average flows	
Months of deficit Irrigation	0	-
Months of non deficit irrigation.	7	September to March
Months of no irrigation	5	April to August
Buffer Storage Required	30.900	m^3

Scenario C: Future Flows with median rainfall and evapotranspiration extended irrigation period		
Irrigation Philosophy	Mixed	
Rainfall-Evapotranspiration Data Period	Median year	
WW water flow scenario	Based on Future maximum average flows	
Months of deficit Irrigation	4	December - March
Months of non deficit irrigation.	3	September, October and November
Months of no irrigation	5	April to August
Buffer Storage Required	28,500	m^3

Scenario D: Existing Flows with median rainfall and evapotranspiration		
Irrigation Philosophy	Mixed	
Rainfall-Evapotranspiration Data Period	Median year	
WW water flow scenario	Based on Average flows over last 5 years	
Months of deficit Irrigation	5	November to March
Months of non deficit irrigation	2	September and October
Months of no irrigation	5	April to October
Buffer Storage Required	21,200	m^3

Scenario E: Existing Flows with median rainfall and evapotranspiration		
Irrigation Philosophy	Deficit	
Rainfall-Evapotranspiration Data Period	Median year	
WW water flow scenario	Based on Average flows over last 5 years	
Months of deficit Irrigation	5	November to March
Months of non deficit irrigation	0	-
Months of no irrigation	7	April to October
Buffer Storage Required	30,000	m^3

4 Nutrient loading

4.1 Introduction

Potential nutrient loadings have been calculated. Using the current nitrogen concentration of the wastewater the total annual load is calculated to be 839 kg N/yr. Applying this to an area of 15ha equates to a nitrogen load of 56 kg N/ha/yr (Table 4-1).

Using estimated future flow rates, it has been estimated that the total annual nitrogen in the wastewater would be approximately 1,549 kg N/yr. This would result in a nitrogen load of 103 kg N/ha/yr when applied to 15 ha (Table 4-1). Putting these nitrogen loads into perspective, in an agriculture sense a nitrogen loading of up to 150 kg N/ha/yr is deemed reasonable.

Table 4-1: Summary of nitrogen loading

Nitrogen concentration (kg N/yr)	Area available (ha)	Nitrogen loading (kg N/ha/yr)	Area available (ha)	Nitrogen loading (kg N/ha/yr)
Current flows				
839	15	56	20	42
Future flows				
1549	15	103	20	77

4.2 Nitrate leaching

Nitrogen is present is several different forms. Organic forms of nitrogen are not freely available for loss and inorganic forms are freely available for removal and or losses. Figure 4-1 is a simple version of the nitrogen cycle. Nitrogen is added to the soil profile through a range of pathways.

A small proportion of inorganic nitrogen is converted to organic nitrogen and joins the soil organic matter. The inorganic form ammonium can either be taken up by a plant or converted to another inorganic form nitrate. However, this conversion is temperature sensitive and optimal temperature range is between 25 and 35 degrees while the transformation stops at temperature below 5 degrees. Like ammonium, nitrate is readily available for plant uptake. However, it is also readily available to be lost through a process known as nitrate leaching.

Most nitrogen loss occurs through nitrate leaching which is a physical process where nitrate is carried through the soil profile by water as the water moves through. Leaching results when nitrate moves so far through the soil profile that it is not within the root zone anymore. Thus, removing plant uptake. A key reason that nitrate is leached is because it sits in the soil solution as a form of inorganic nitrogen that does not bind to soil particles due to its negative charge.

There are two key conditions required for leaching to result: a buildup of nitrate in the soil profile, and excess moisture in the soil. Any excess of moisture results in movement down or along the soil profile known as a drainage event. In most areas of New Zealand, leaching is at greatest risk of occurring during late autumn, winter, and early spring when there is an excess of rainfall over evapotranspiration and the soil is at or near field capacity. During this time of year plant growth rates are also low, therefore little nitrate is being removed from the soil via plant uptake allowing a buildup of nitrate in the soil profile over these months. Consequently, application of wastewater from mid-April until mid-October would present a greater risk of nitrate leaching. This is discussed further in section 4.5 and 4.6 below.

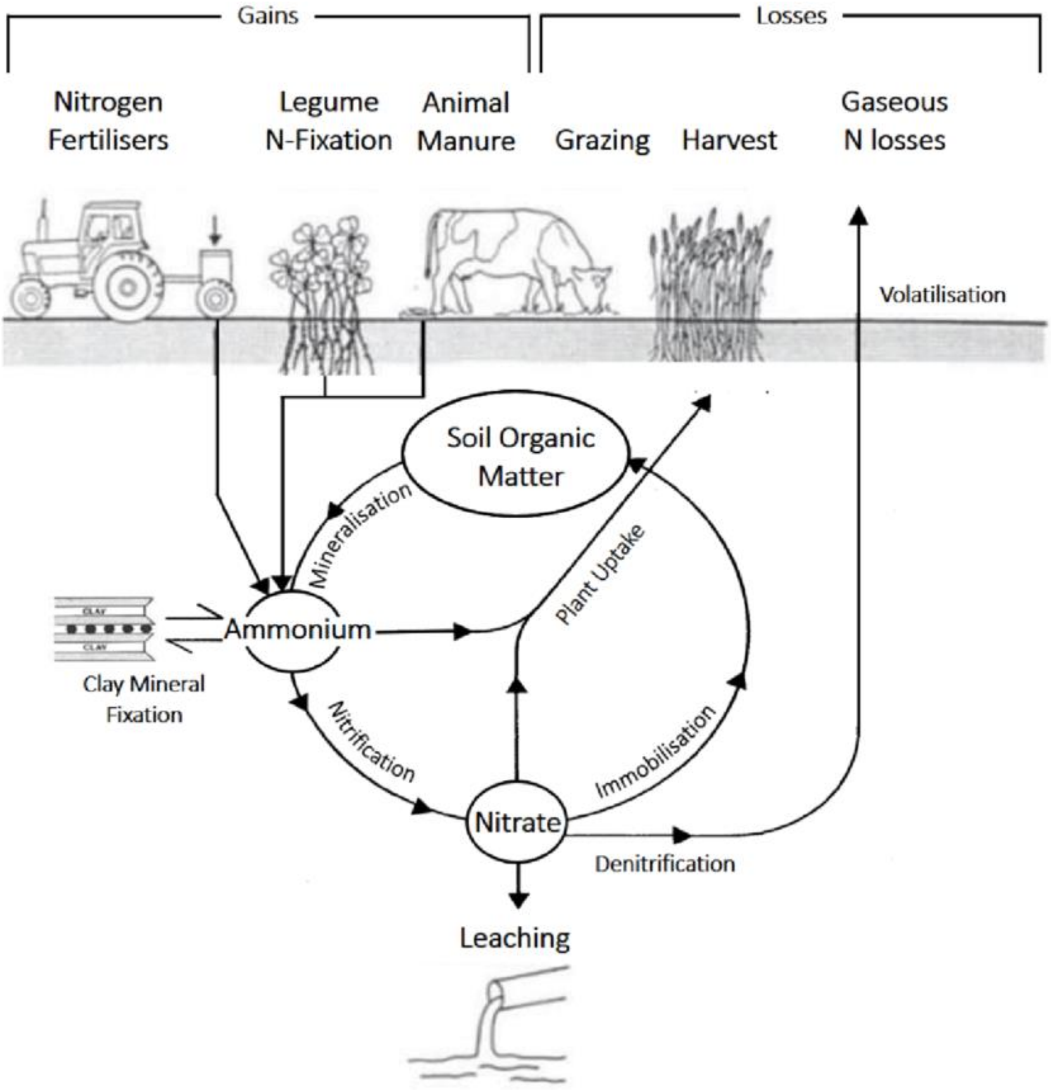

Figure 4-1: The nitrogen cycle (McLaren and Cameron 1996)

4.3 Soil type effect

Several soil characteristics influence the rate at which nitrate is leached through the soil profile. There are several soil types present on the land application site. These soil types range from recent soils to brown soils to gley soils, thus impact the nitrate leaching potential. S-Map Online does however highlight that the dominant soil is the well-drained recent soil while there are only small pockets of the poorly drained gley soils. The brown soil has an imperfect drainage status.

Infiltration testing showed two different infiltration rates across the irrigation area. The first is a very low rate of 0-12 mm/hr indicating gley soils. While with the second being a moderate rate of 43-64 mm/hr indicating either recent or brown soils. These difference in rates influences the application rate and depth at which irrigation water can be applied.

Key characteristics that need to be considered include:

Characteristic	Explanation
Soil texture	The proportion of small (clay), medium (silt), and large (sand) particles in a soil. Fine-textured soils (high clay) are generally less susceptible to nitrate movement than sandy-textured soils because water permeability is much lower. However, fine-textured soils are more prone to denitrification losses of nitrate.
Soil structure	The arrangement of soil particles into stable units (aggregates). Soil structure can range from loose and friable, to blocky, plate like, or massive (without structure). Water takes the easiest path through soil and primarily flows around aggregates, rather than through them.
Water holding capacity	The maximum amount of water that can be stored in the soil is important in estimating the potential for nitrate leaching. Sandy-textured soils cannot retain as much water as loam-textured soils.
Soil porosity	The space between soil particles that is occupied with ever-changing amounts of air and water. Porosity is determined by soil texture and soil structure. Compaction reduces the number and size of soil pores.
Soil permeability	This property is determined by the soil texture and the structure. The size and arrangement of the pores determines the rate of infiltration (movement of water into the soil) and the rate of percolation (movement of water through the soil). Permeability is a measure of water moving through the pores of a saturated soil (also called the saturated hydraulic conductivity).

https://smap.landcareresearch.co.nz/maps-and-tools/app/

4.3.1 *Ratana land application site*

The recent soil has a coarse sand texture that is weakly developed. The water holding capacity is classified as moderate to low. The soil has been determined to a rapid permeability thus a very low vulnerability to water logging. However, these characteristics increase the nitrate leaching risk.

The brown soil has a coarse sand texture that is weakly developed. The water holding capacity is classified as moderate. The soil has been determined to a rapid permeability thus a medium vulnerability to water logging. These characteristics increase the nitrate leaching risk but not as great as the recent soil.

Like the above two soils, the gley soil has a coarse sand texture that is weakly developed. The water holding capacity is classified as moderate. While this soil is classified as having rapid permeability it is poorly drained. This is due to gley soils being affected by the water table thus slowing down water movement causing long periods of waterlogged soil. Gley soil are deemed to have low nitrate leaching potentials.

4.4 Nutrient effects when deficit irrigation undertaken

The area of land available for land application of wastewater impacts the rate at which wastewater can be applied and therefore the amount of nitrogen being applied per hectare, as highlighted above. If the nitrogen loading is too high, there is a potential for increased nitrate leaching losses.

The method of deferred irrigation improves the efficiency of nitrogen because water volume can be managed so drainage events are limited. Thus, nitrate is predominantly held within the root zone making it available for plant uptake and preventing it from being lost from the system.

On an average year for rainfall with the current flow rates deferred irrigation is possible to achieve, with only 15 ha of land being required. However, on a wet year due to the fixed land application area deferred irrigation is not possible. Therefore, irrigation needs to happen when conditions are not optimal. When irrigation is applied to a soil already at field capacity drainage events result in an increasing risk of nitrate leaching. As highlighted above, due to the nature of the soils at the application site nitrate leaching potentials are moderate to high (expect in the small pockets of gley soil). However, permeability is also considerably high therefore the soil will return to a soil moisture level of below field capacity quicker than a clay base soil type, apart from the gley soil due to the high-water table on this soil type (as highlighted above).

If irrigating to 20ha (ongoing irrigation to the duneland area) the modelled scenario A demonstrates that allowing ongoing irrigation to the duneland area would allow for additional month of deficit irrigation.

4.5 Nutrient effects when mixed irrigation undertaken

To achieve deferred irrigation sufficient land is required as noted above. In additional, the size of buffer storage also impacts whether deferred irrigation is feasible. Water storage is expensive, thus can a mixed irrigation system of deferred irrigation and non-deferred be untaken with having no or minor effects on the amount of nitrate being leached. Below highlights that it is possible for the scenarios explored for Ratana.

Several scenarios have been investigated and the buffer storage required can be significantly reduced if irrigation is applied between September and November under non-deferred conditions and then deferred irrigation between December and March. The same amount of irrigation water is applied annually with irrigation being spread over more months. This means there is no change in annual nitrogen loading. However, the nitrogen loading across the months does change. On the months where deferred irrigation is not occurring the risk of nitrate leaving the root zone does increase due to drainage events taking place. However, as shown in Figure 5-2, irrespective of the month, pasture is always growing to some degree in the Rangitikei region. Growth rates are greatest during the spring months and then decrease until winter when they are at there lowest. Due to the pasture growing to some degree year-round, nitrate is being removed through plant uptake year around. Figure 5-3 highlights that the amount of nitrogen being applied to land each month (apart from January) is significantly less than what pasture requires to sustain average growth. In January nitrogen applied is slightly less than nitrogen required.

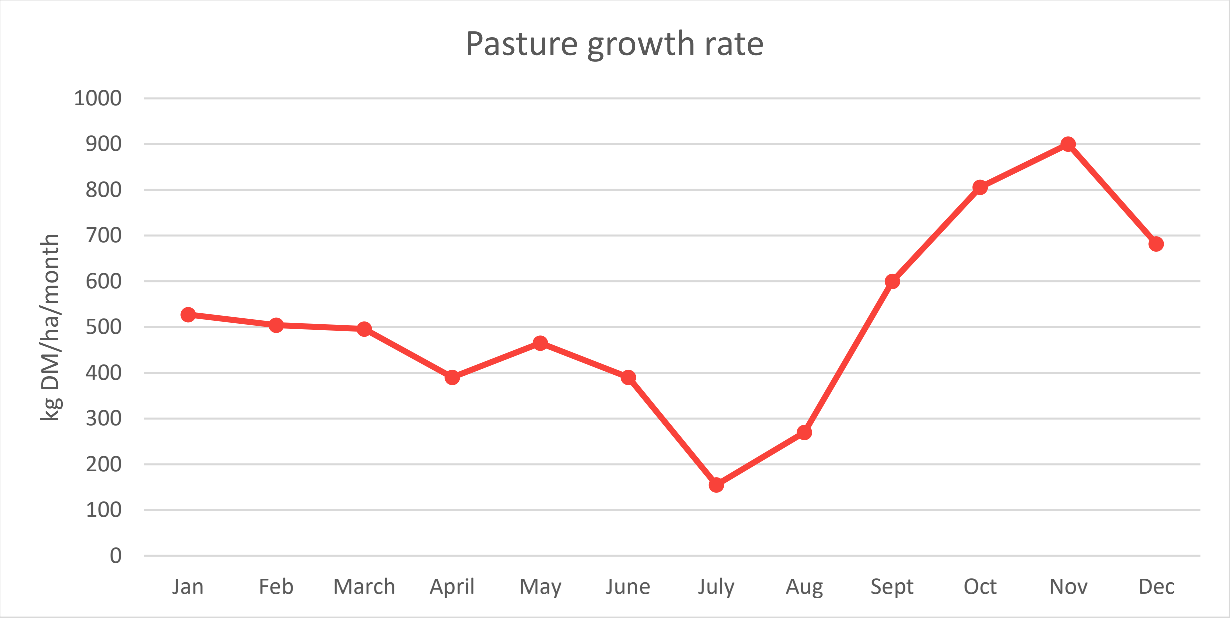

Figure 5-2: Pasture growth rate curve for non-irrigated pasture in the Rangitikei region[1]

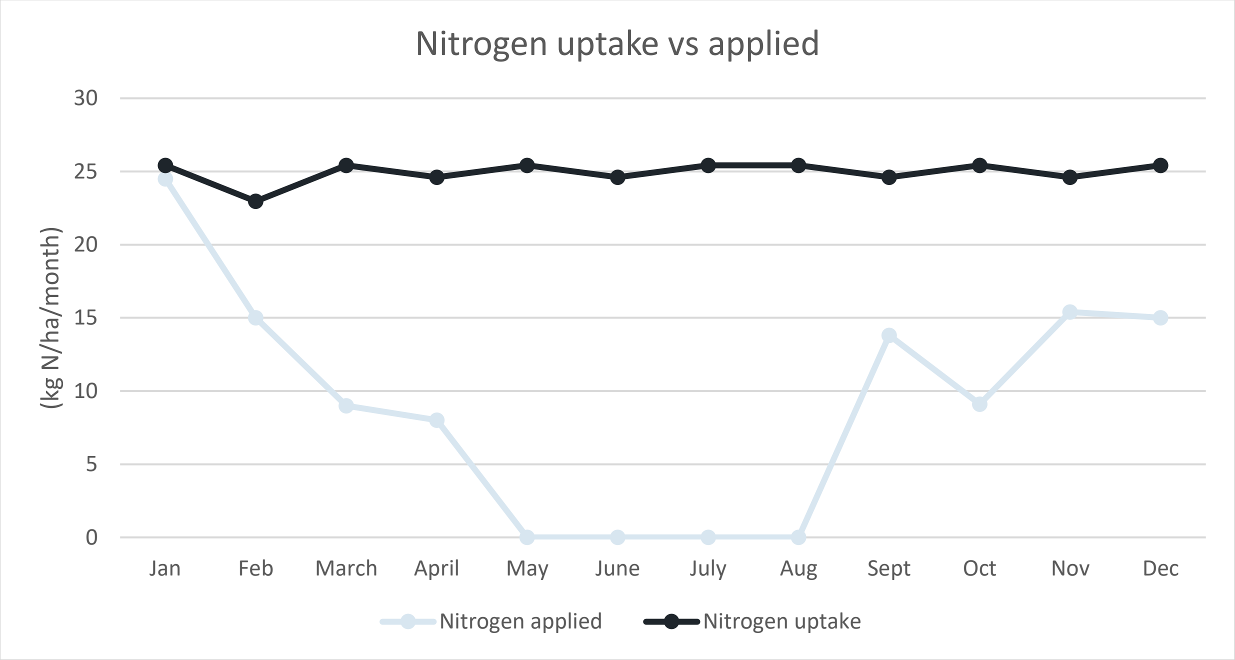

Figure 5-3: Pasture nitrogen uptake compared to nitrogen applied through irrigation[2]

4.6 Discussion – potential effects

Taking full advantage of the available area of 15 ha would result in a nitrogen loading of 56 kg N/ha/yr (Table 4-1) on an average rainfall year under current flow rates. Under these conditions deferred irrigation has been determined to be possible year-round minimising the potential nitrate losses from the root zone with significant buffer storage being required.

Under the future flow rates the amount of water to irrigated to land and the amount of nitrogen present has been predicted to increase. (Table 4-1). Using the maximum area available the nitrogen loading would increase to 103 kg N/ha/yr (Table 4-1). Thus increasing the risk of nitrate being lost from the root zone. However, a loading increase of 47 kg N/ha/yr would not lead to a dramatic increase in nitrate losses. This is because a nitrate loading of 103 kg N/ha spread across

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[1] https://beeflambnz.com/sites/default/files/factsheets/pdfs/RB14-Pasture-quality-Q-Graze.pdf
[2] McLaren and Cameron 1996

several months is still a low input of nitrogen into the system. Irrigation will be applied little and often allowing for nitrate to be up taken by plants before it is lost from the root zone and therefore impacting ground water the majority of the year when there is a mix irrigation approach.

If irrigating to 20 ha the loading rate would be lower, as demonstrated by Table 4-1. This would have the effect of further reducing potential nitrate losses – this would be a result of both the additional month of deferred irrigation (under a median year) and reduced loading rate.

Under future flows however, it is not possible to practice deferred irrigation during an average year. Irrigation will be required during the spring months when soil moisture levels are not at deficit levels. Although the nitrogen loading would remain the same, potential nitrate losses during these months would increase as more leaching would be happening. However, as highlighted above the effect of this would be minor due to the spring months being during the active plant growth periods – therefore greater plant uptake of nitrate. In addition, regardless of whether deferred irrigation is in practice extra measures have been factored into the irrigation design to minimise nitrate losses. The key measure being no irrigation between the months of May to August when evapotranspiration and plant uptake for nitrate is low.

Although the dominant soil type present is free draining the potential risk of nitrogen lost from the root zone is low. If the irrigation design and the practice of deferred irrigation is not achieved the risk of nitrogen loss will have a minor increase. This risk will also increase if the nitrogen concentration in the wastewater increases. In saying that, due to nitrogen loading rates being low significant changes would need to occur before the risk level would increase to a point that would cause concern.

5 Plant selection

At a high level, two crop types (pasture and trees) have been considered to be grown at the potential discharge site. These two vegetation types are considered at a high level from a site management perspective. Trees and pasture may be grown in conjunction with each other. Certain areas of the site may be more suitable for establishing a stand of trees, and other areas may be better suited for pasture.

Crop selection can influence the uptake and cycling of nutrients, and the irrigation system used.

The following criteria have been considered:

- setback distances from wetlands and dunes
- wind drift and odour
- rooting depth
- canopy formation
- accessibility for irrigation system
- potential as a resource
- ability to harvest regularly

5.1.1 Trees

Trees can easily be established at the discharge site, including on the steeper areas, and laid out so that they are setback from sensitive ecological areas. The trees will need to be laid out allowing access tracks so that mowers, vehicles, and workers can easily access the irrigation system and all parts of the block for weed control, harvesting and irrigation maintenance.

An irrigation system will need to be precise and targeted at the root zone around each tree, and this can be achieved through micro-sprinklers or dripline. Dripline is preferred, as this system does not generate any aerosols (therefore there is no wind drift, it can be laid along the ground under the trees, and it is simpler to maintain with less instances of blockages than a micro-sprinkler system. Dripline is also favourable to install along contours and can be laid within a specific setback distance from sensitive ecological areas.

Tree species may provide a source of firewood or timber production. Additionally, some species such as tagasaste and acacia could provide fodder for livestock in a drought year.

A number of tree species may be considered, such as (but not limited to):

- mānuka
- kānuka
- tagasaste
- acacia
- poplar
- eucalypts

When considering which species of tree to plant, it is recommended to select a tree that can be harvested (coppiced or pruned) regularly on a cyclical basis, to maintain trees in an active growth phase and maximise nutrient uptake and removal.

Food cropping trees would need further consideration in terms of food safety requirements.

5.1.2 Pasture

Irrigation systems for pasture (e.g., travelling irrigator, fixed sprinklers, moveable pods) will create aerosols resulting in wind drift and odour, especially as there is no canopy to mitigate this. Careful timing of irrigation (i.e., during low wind conditions) and a larger setback distance from wetlands and dunes may be needed in order to prevent drift into these systems. However, a pasture system does allow for easy access to the irrigation system, to move components, and when maintenance is required.

Pasture grown under a “cut and carry” system could provide feed for local farms. Steeper areas of the site will be unsuitable to operate a harvester in and therefore the harvestable area is likely to be limited. Grazed pasture should not be considered due to the additional nutrient loading from livestock.

5.1.3 Summary

Both trees and pasture could be suitable land uses for the proposed discharge site. When considering these from a site management perspective, trees compare favourably in terms of wind drift mitigation. As pasture does not form a canopy, this land use will not mitigate wind drift as well as trees and possibly allows rainfall to more easily infiltrate through the soil, however access to the site for maintenance of the irrigation system is simpler.

These plant types may be established in conjunction with each other on the site. Different areas of the site may be more suitable for different plant types or mixed plantings. Plant species and planting layouts across the site will need further consideration during detailed design.

6 High level feasibility irrigation design

6.1 Appropriate type of irrigation

The key attributes of an effective irrigation system are:

- It can be effectively installed.
- It is as simple to operate and maintain as practicable, in particular it has.
  - the ability to effectively flush the system remotely

- the ability to monitor performance (pressure and flow) and identify faults (blockages or breaks)
- a minimal need to be inspected physically or need unplanned maintenance.

Under-tree irrigation systems have been considered here as it is understood that a range of vegetation types may be considered for the site. The types of possible systems and how well they achieve under-tree irrigation is restricted in type because in order to maintain the required uniformity the throw of individual sprinklers will be limited. The types of under-tree irrigation to be considered for the site are highlighted in Table 6-1.

Table 6-1: Under-tree irrigation system options to be considered for the proposed discharge site.

	Dripline	Small Impact Sprinklers	Micro Sprinkler
Installation	Relatively simple to install.	Relatively complex to install.	Relatively complex to install.
Planned Maintenance	-Flushing of dripline required. Preferably automatic. When designed properly simple to achieve. -Management of undergrowth, i.e. mowing/ weed eating required. -Physical inspection of system. Can be in conjunction with undergrowth management.	-Flushing of dripline required. Preferably automatic. When designed properly simple to achieve. - Management of undergrowth, i.e. mowing/ weed eating required. -Physical inspection of system. Can be in conjunction with undergrowth management.	-Flushing of dripline required. Preferably automatic. When designed properly simple to achieve. -Management of undergrowth, i.e. mowing/ weed eating required. -Physical inspection of system. Can be in conjunction with undergrowth management.
Monitoring	It is essential to monitor rainfall, evapotranspiration (ET), soil moisture, flow, and pressure across the system. This is to ensure irrigation is correctly scheduled and any faults (blockages and pipe breaks).	It is essential to monitor rainfall, ET, soil moisture, flow, and pressure across the system. This is to ensure irrigation is correctly scheduled and any faults (blockages and pipe breaks).	It is essential to monitor rainfall, ET, soil moisture, flow, and pressure across the system. This is to ensure irrigation is correctly scheduled and any faults (blockages and pipe breaks).
Unplanned Maintenance	Because dripline has very few elements and fittings, there is least chance of unplanned maintenance and is the simplest to fix.	Because impact sprinkler systems have multiple elements and fittings, there is the real chance of unplanned maintenance and is relatively complex to fix.	Because micro sprinkler systems have the most elements and fittings, there is the most chance of unplanned maintenance and is the most complex to fix.

The philosophy behind this is described as follows:

- In order to maximise the land area available, the irrigation system needs to be able to operate as to close as possible to the critical boundaries (neighbouring properties, and wetlands).
- In order to ensure those areas on the boundaries are not affected by the operation of the system, the area being irrigated at the boundary needs to be able to be operated separately to most of the system to allow to irrigate more carefully.
- This is achieved by setting up separate irrigation management zones which can be controlled separately:
    - a wetland zone (20m setback from wetlands),

- an edge zone (20m setback from neighbouring properties), and
- the remaining irrigable area (excludes duneland and storage area).

6.2 Monitoring requirements

Crucial to ensuring the irrigation system performs is the ability to monitor key performance indicators to enable:

- Accurate irrigation scheduling.
- Accurate identification of critical failures (what and where) to allow the system to stopped, repaired and made operational in in reasonable time.

The extent of required monitoring covers.

- Soil moisture sensors in the field to monitor soil moisture. The number of sensors is to be determined. Time is required to install and calibrate these in the field.
- A weather station to monitor rainfall and evapotranspiration.
- Flow and pressure meters on the irrigation pipeline.

7 Risks and potential mitigation

7.1 Reduced deficit irrigation

- May occur during wetter years, if wastewater flows increase beyond predicted volumes, reduced irrigable area due to increased buffer zones.

- Mitigation would include careful irrigation scheduling through appropriate soil moisture monitoring, maintenance of wastewater network, maximise area of irrigable land and ongoing monitoring of wastewater quality and groundwater quality.

Risk of increased nitrate leaching, considered a low risk due to modest predicted nitrogen concentrations and mild climate meaning good growing conditions (relative to other sites) year round.

7.2 Surface runoff

May occur if application rates exceed infiltration capacity of soil, increased risk as slope increases.

Mitigation would include appropriate detailed design of irrigation system, irrigator choice and management of application rates taking into account slope class.

Risk is considered low.

7.3 Equipment failure

May occur if equipment is not well maintained and operated.

Mitigations:

- Undertake planned maintenance and inspections, detailed in management plans including frequency of when checks would occur.

- Undertake real time monitoring of primarily flow and pressure to identify early faults.

Risk is considered low.

7.4 Spray drift

Has the potential to occur in either high wind situations with some irrigator types.

Mitigations

- Use dripline irrigation in higher risk areas

Risk is considered low.

Appendix - Water balance: 1-in-5 wet year

This memo is additional to the August 2021 report "Ratana Wastewater Treatment Plant Preliminary Water Balance". The same climate data sites and WWTP outflows have been used for this analysis, and this has been carried out for Site 2 only.

A water balance was calculated using the 1-in-5 monthly high rainfall (P_5) and low evapotranspiration (PE_5) data i.e. for a "1-in-5 wet year" (Table 0-1). A PRAW of 62mm was applied in line with the PRAW class which covered most of the site (Table 0-2, Figure 0-1).

Table 0-1. P_5 rainfall and PE_5 evapotranspiration data used for the Ratana WWTP water balance.

Month	P_5 rainfall (mm)	PE_5 evapotranspiration (mm)
January	64	130
February	72	102
March	76	83
April	100	49
May	113	30
June	120	20
July	113	23
August	107	36
September	100	57
October	109	84
November	97	104
December	110	122
Total	1183	840

The 1-in-5 wet year scenario annual soil moisture surplus and deficit, assuming a PRAW of 62mm, would be 401 and 60mm, respectively (Table 0-2, Figure 0-1). In this wet year climate scenario, soils are in deficit in the months of January and February, and to a lesser extent in March.

Table 0-2. Water balance for the Ratana WWTP disposal site, based on 1-in-5 high rainfall (P) and low evapotranspiration (PET) and a PRAW of 62mm.

Water balance for soils with 62mm storage capacity													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
P	64	72	76	100	113	120	113	107	100	109	97	110	1181
PE	130	102	83	49	30	20	23	36	57	84	104	122	840
P - PE	-66	-30	-7	51	83	100	90	71	43	25	-7	-12	
ΔST	-43	0	0	51	11	0	0	0	0	0	-7	-12	
ST	0	0	0	51	62	62	62	62	62	62	55	43	
AE	107	72	76	49	30	20	23	36	57	84	104	122	
D	23	30	7	0	0	0	0	0	0	0	0	0	60
S	0	0	0	0	72	100	90	71	43	25	0	0	401

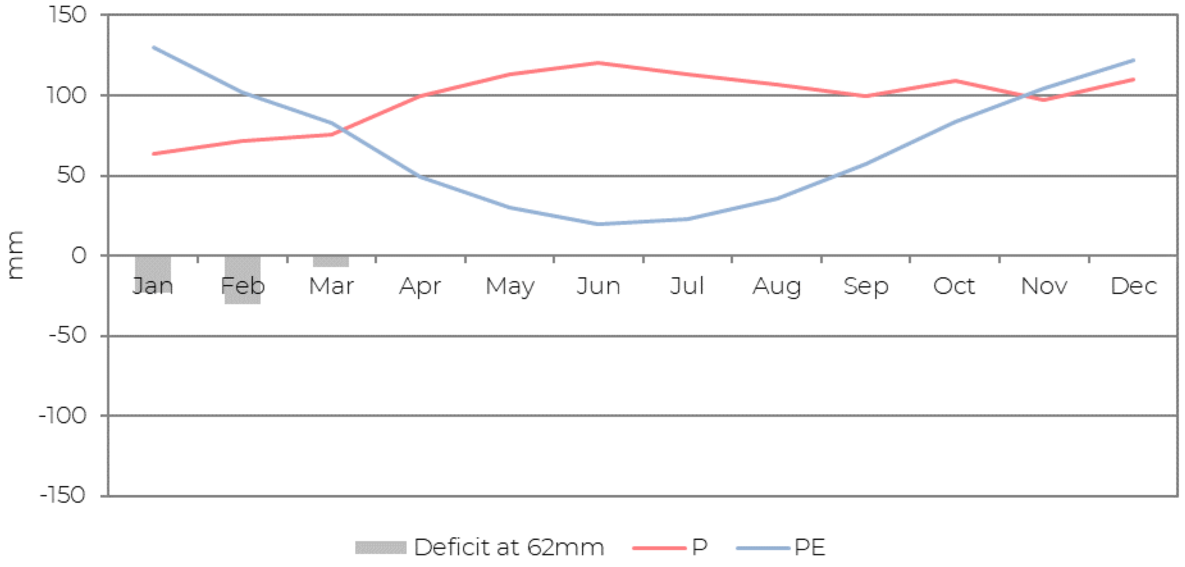

Figure 0-1. Rainfall (P), potential evapotranspiration (PE) and deficit curves for the Ratana WWTP disposal site assuming a PRAW of 62mm during a 1-in-5 wet year climate scenario.

7.5 Annual irrigation and storage potential

The assessed water balances provide the total deficit and surplus over a 1-in-5 wet year at the Ratana WWTP potential disposal site. Soil moisture deficits only occur over 3 summer months (January to March), allowing for the irrigation of treated wastewater over a shorter period than could be feasible during a median year.

Wastewater from the treatment plant would need to be stored between April and December when the soils are at capacity or when there is a surplus of soil moisture. However, the minimal soil moisture deficits over January to March also means wastewater may need to be stored at these times too.

By assessing the water budget, the land required to irrigate the accumulated annual surplus of wastewater and the volume of storage required over the winter months have been derived (Table 0-3). It is noted that the area of land provided is the effective area for deficit irrigation. In the winter months when there is a surplus of soil moisture, all wastewater will be required to be stored within the WWTP. The shoulder month of March has been included due to the limited capacity of the soils at this time.

Table 0-3. Area of land required to discharge annual accumulated surplus of wastewater and volume of storage required using deficit irrigation, under a 1-in-5 wet year scenario at the Ratana WWTP potential disposal site.

	Current flows	Future flows
Area of land required (ha):	~68.3	~88.3
Volume of storage required (m^3)	~41,000	~53,000

As area of the proposed discharge site is significantly less than the area of land required to achieve deficit irrigation during a wet year (under both current and future flow scenarios), there will need to be months where non-deficit irrigation is applied. Although soils are in deficit at times over January to March, non-deficit irrigation is likely to be needed over the months of November to March in order to dispose of the volume of wastewater. Over the winter months no irrigation is to be applied (as is the case for a median year).