Assessment of Environmental Effects of Discharge of Featherston Treated Wastewater to Land

Prepared for

South Wairarapa District Council

Prepared by

Lowe Environmental Impact

February 2017

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Ref:RE-10075SWDC-Featherston_WWTP-Land_AEE_160901v3

Job No.: 10075

Date: February 2017

Revision Status			
Version	Date	Reviewer	What Changed & Why
1	15/01/2016	SWDC	Preliminary client review
2	31/05/2016	Mott MacDonald	Final draft following Staging decisions
2	23/06/2016	Mott MacDonald	Final draft
3	8/02/2017	Hamish Lowe	Final following data set changes and incorporation of client comments
4	15/02/2017	Mott MacDonald	Minor amendments following MM review

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1 EXECUTIVE SUMMARY

South Wairarapa District Council (SWDC) has lodged an application for consent to discharge Featherston Wastewater Treatment Plant (FWWTP) effluent following advanced treatment, to Donald Creek with Greater Wellington Regional Council (GWRC). Following SWDC purchasing land near to the FWWTP, the consent application was placed on hold to enable the development of a discharge programme incorporating land application on this newly acquired land.

The land available has the potential to receive 100 % of the annual wastewater flow from FWWTP, but requires a substantial storage volume to enable 100 % of flows to be discharged sustainably. A land application option has been developed to reduce the storage to an affordable and manageable size while maximising the amount of wastewater that is discharged to land. As a result, a staged approach to the development of a land application scheme has been proposed which eventually sees an average of 90 % of treated FWWTP wastewater discharged to land. This report assesses the effect of discharging treated FWWTP flows to land on the receiving environment.

This report details the:

- Land application regime and impact of the discharge to land of treated wastewater; and
- Impacts of discharges to air from the land discharge of treated wastewater.

The proposed discharge area (Site) is located 1 km to the south of Featherston township. The Site comprises two properties referred to here as Site A (12 ha) and Site B (166 ha). Of the 12 ha of Site A, it is proposed that 8 ha will receive wastewater; and, of the 166 ha available on Site B, it is proposed that 116 ha will receive wastewater following the exclusion of buffers to waterways, property boundaries, dwellings and bores.

The proposed stages as they relate to the land application of treated wastewater can be summarised as follows:

- **Stage 1A** involves minor treatment pond improvements and irrigation to land starts with an area 8 ha of land (Site A) allowing for approximately 3-5% of the average annual wastewater discharge volume and 28% of the average summer discharge volume to be irrigated;
- **Stage 1B** involves expansion of the irrigation area to include a further 70 ha of Site B, allowing for irrigation of approximately 44% of the **current** average annual wastewater discharge volume to land;
- **Stage 2A** involves the infiltration and inflow (I&I) into the pipe sewage reticulation network being reduced by upgrading of the pipe network, resulting in a reduction of approximately 35% of inflow into the system. The area of irrigation is further increased allowing for irrigation of approximately 68% of the **current** average annual waste water discharge; and
- **Stage 2B** involves a large storage pond being constructed to defer flows and to provide additional storage and oxidation of the effluent. The buffering allows for approximately 94% of the **current** average annual wastewater discharge volume to be irrigated. During this stage discharge to Donald Creek occurs infrequently and is predicted to occur 91% of the time when Donald Creek's flow exceeds two times the median flow and 73% of the time when the flow exceeds three times the median flow.

The land application regime has been designed based on the soil properties of the site and uses deficit irrigation for Site A, where irrigation is matched to plant requirements; and deferred irrigation for Site B, where irrigation is ceased during excessively wet periods, to assist with:

- Minimising contamination of groundwater;
- Minimising groundwater mounding and seepage (to groundwater springs);
- Avoid overland flow of wastewater to surface water; and
- Protect soil physical health, to ensure the system is sustainable over the consent period and beyond.

Discharge of wastewater to the Site is the priority for management, and land use will be adopted based on what is most suitable for the irrigation regime. Management flexibility is able to be achieved for the Site because sufficient land is available to avoid excessive hydraulic or nutrient loading. Future land use may include pastoral grazing, fodder crop production, cut and carry pasture or a combination of the three. Irrigation scheduling can allow grazing to occur over the site without animals grazing wet soils.

A total nitrogen application rate not exceeding 300 kg N/ha/y has been evaluated, which represents a productive grazed pastoral system. This nitrogen application figure includes additional nitrogen application (by fertiliser or additional wastewater) to assist the agronomic management of the site. In the event that a higher rate of nitrogen application (in excess of 300 kg N/ha/y) is required, for instance, under high producing cut and carry pasture for off-site feeding, a nutrient management plan would be produced to demonstrate how additional nitrogen can be added without increasing leaching losses i.e. by harvesting of material and feeding outside of the irrigated areas.

Key input and output parameters for the Site are summarised in Table 1.1 below.

Table 1.1: Land Management Units

Parameter	Stage 1A	Stage 1B	Stage 2A	Stage 2B
Storage volume (m^3) – to satisfy 90th percentile flow conditions	None	None	None	186,000
Average annual outflow from FWWTP (m^3)	~830,000	~830,000	~538,000[1]	~538,000[1]
Irrigated Site	Site A	Site B (and potentially Site A)	Site B (and potentially Site A)	Site B (and potentially Site A)
Irrigation Regime	Site A: Deficit	Site A: Deficit Site B: Deferred	Site A: Deficit Site B: Deferred	Site A: Deficit Site B: Deferred
Landform	Alluvial flats	Alluvial flats	Alluvial flats	Alluvial flats
Total area (ha)	12	166-178	166-178	166-178
Irrigated area (ha)	8	70	70-116	116
Irrigated area per discharge event (ha)	8	8	8	8
Irrigation event application (mm/event)	up to 19	up to 55	up to 55	up to 55
Average annual application volume (m^3/y)[2]	32,500	385,000	305,200	510,300
Average annual application depth (mm)	406	480	360	447

Parameter	Stage 1A	Stage 1B	Stage 2A	Stage 2B
Wastewater Nitrogen load (kg N/ha/y)[3]	35	42	42	51
Wastewater Phosphorus load (kg P/ha/y)[3]	7	8	8	10
Farm Management current	Stock grazing	Dairy		
Farm Management proposed	Pasture for removal (cut and carry)	Stock grazing and/or Cropping and/or Pasture for removal (cut and carry)		
Vegetation current	Pasture	Pasture		
Vegetation proposed	Pasture and/or Cropping			

[1] Post I & I reduction
[2] At Stage 2A the total volume discharged to land decreases due to a reduction in the total volume discharged due to I & I reduction.
[3] Following I & I reduction the concentration of N and P in the wastewater will increase, resulting in the same mass loading of nutrients even though the application depth decreases slightly.

The proposed low rate of nutrients discharged to land combined with a new storage pond at the commencement of Stage 2B is intended to minimise impacts on the surface water environment. The use of land discharge will result in the following percent average removal/reduction of the annual wastewater flows from direct surface water discharge compared to current flows, and therefore contaminant load to the surface water environment (Donald Creek) following the commencement of each Stage of developing the land application of wastewater:

- Stage 1A – 3 % removal;
- Stage 1B – 44 % removal;
- Stage 2A – 68 % removal; and
- Stage 2B – 94 % removal.

Overall, the use of land application of wastewater will a substantially reduce the nutrient load entering surface water compared to the current discharge from the Site (currently farmed) and FWWTP following the commencement of Stage 2B.

A summary of the potential risk and actual effects of the proposed activities at the Site is shown in Table 1.2. The actual effects reflect the design and mitigation adopted to avoid identified potential risk.

Table 1.2: Potential Risk and Actual Effects from Wastewater

		Source / Contaminant				
		Sensitivity	Organic matter Nitrogen Phosphorus	Pathogens	Water	Wastewater
Receptor / Pathway /	Soil	Potential risk	Low	Moderate	High	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Groundwater	Potential risk	High	High	Moderate	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Surface water	Potential risk	High	Low	Low	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Habitat	Potential risk	High	Moderate	Moderate	-

	Source / Contaminant				
	Sensitivity	Organic matter Nitrogen Phosphorus	Pathogens	Water	Wastewater
	Actual effect	Less than minor	Less than minor	Less than minor	-
Amenity	Potential risk	-	-	-	High
	Actual effect	-	-	-	Less than minor
Cultural	Potential risk	-	-	-	High
	Actual effect	-	-	-	Less than minor
Archaeological/ Heritage	Potential risk	-	-	-	Moderate
	Actual effect	-	-	-	Less than minor
Air	Potential risk	Moderate	High	Moderate	-
	Actual effect	Less than minor	Less than minor	Less than minor	-

The effects of the proposed land application regime have been assessed based on the potential loading of nutrients, contaminants and water received for an average year. It is concluded that:

- There are no adverse effects to the soil and plant system that are more than minor;
- There is no adverse effect to down-gradient groundwater receptors due to minimisation of leaching;
- Surface water is the main receptor for discharged groundwater and effects to surface water from the Project will result in a significant improvement when compared to the current 100 % direct discharge to surface water;
- Flooding within the Site boundaries will not cause, or exacerbate, any adverse effects for the proposed discharge regime; and
- No adverse odour or air quality effects will occur from land treatment areas.

This Assessment of Environmental Effects concludes that there are no adverse environmental effects from the proposed discharge of treated wastewater to land at the Site that cannot be satisfactorily avoided, remedied or mitigated, such that any adverse effects are low (and significantly better for surface water than the existing 100% direct discharge).

2 INTRODUCTION

2.1 Purpose

The purpose of this report is to provide an assessment of the effects to the environment from two activities related to the Featherston Wastewater Treatment Plant (FWWTP) being:

- Land application regime and impact for the discharge to land of treated wastewater; and
- Impacts of discharges to air from land discharge of treated wastewater.

2.2 Background

South Wairarapa District Council (SWDC) is responsible for the management of Featherston's wastewater. The current system was originally constructed in circa 1975, and it currently consists of two oxidation ponds with UV sterilisation treatment. The treated wastewater is discharged via a surface drain into Donald Creek (also known as Boar Creek) to the east of FWWTP.

SWDC has lodged an application for consent to discharge FWWTP effluent following advanced treatment, to Donald Creek, with the Greater Wellington Regional Council (GWRC) for processing. Following the SWDC purchase of land adjacent to the FWWTP, the consent application was placed on hold to enable the development of a discharge programme incorporating the adjacent land. This land is referred to in this report as Site B. Land already owned by SWDC and located adjacent to the FWWTP between the plant and Longwood West Road is also proposed to be used for the application of treated wastewater, and is referred to as Site A. Together Site A and Site B are referred to as the Site.

Site investigations have been carried out by Lowe Environmental Impact (LEI) in 2014 (Site A) and 2015 (Site B) that assessed the suitability and assimilative capacity of the land, and contributes to the assessment in this report.

2.3 Scope

This report is one of a suite of documents which support the main consent application for the FWWTP wastewater discharge. This report provides an assessment of the environmental effects of the discharge of treated wastewater from the Featherston WWTP plant to land at the Site.

The report covers:

- Section 3 outlines the receiving environment for the discharge;
- Section 4 describes the proposed activity;
- Section 5 describes the effects of the discharge; and
- Section 6 outlines the measures to mitigate adverse effects of the proposed activity.

This report addresses the application to land of FWWTP wastewater. Determination of discharge options, description and evaluation of other system elements, and programme of development are discussed elsewhere.

Detailed design will follow resource consenting, as changes may result during the consenting process.

3 RECEIVING ENVIRONMENT

3.1 General

Section 3 summarises the receiving environment for the discharge and provides detail about the characteristics of the existing environment which may be influenced by the discharge of wastewater.

3.2 Site Location and Description

The Site is located South of Featherston, in the Wairarapa. Figure 3.1 below shows its location.

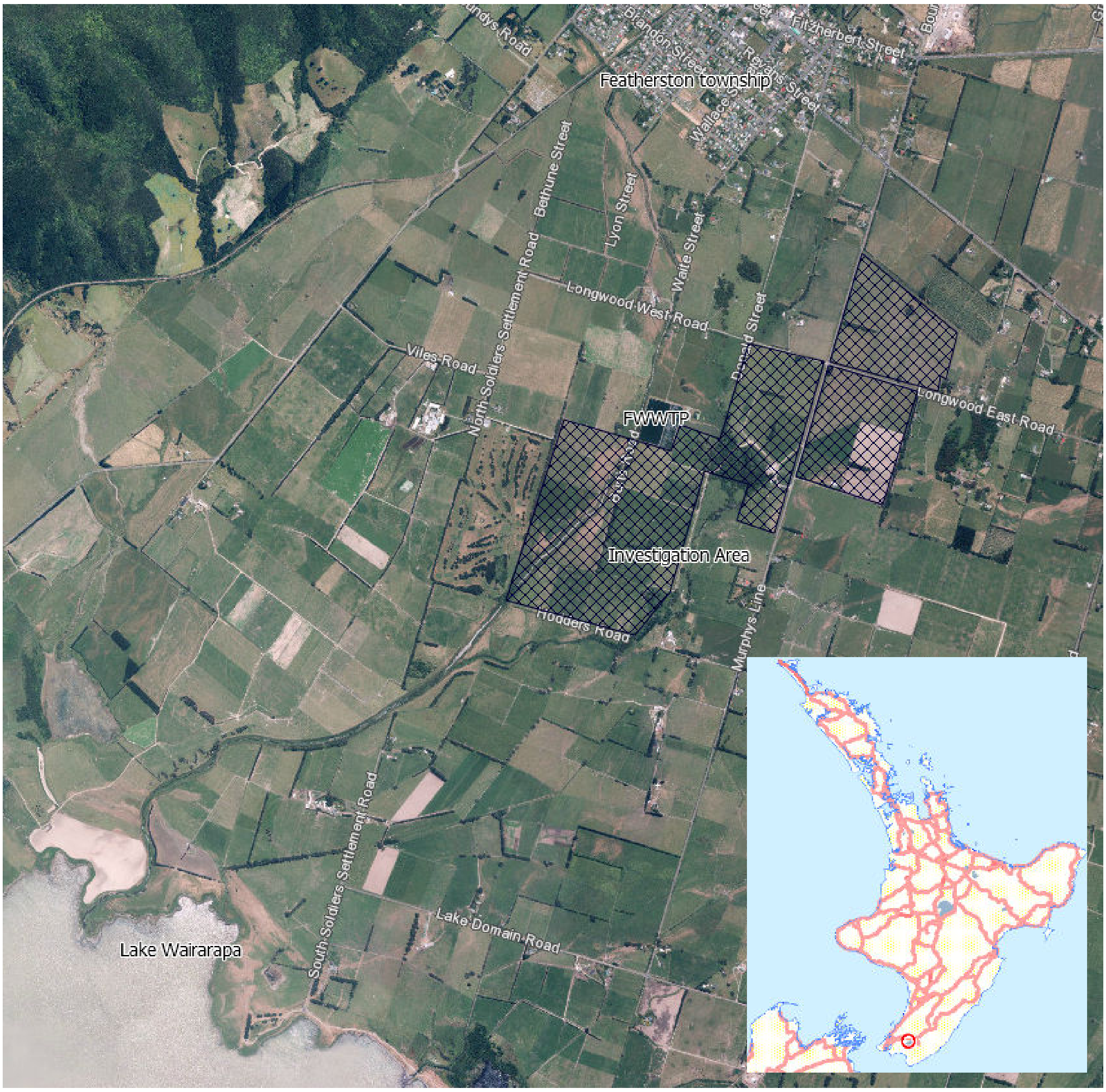

Figure 3.1: Site Location

The Site comprises two properties which are located adjacent to the FWWTP. The property details of this land are given in Table 3.1 below and shown in Figure 3.2. SWDC own both the land where the WWTP is and the Site where the treated wastewater is intended to be discharged. Throughout the report "Site A" is used to describe the land between the FWWTP and Longwood

West Road (12.6 ha more or less), Site B is used to describe the recently purchased land also known as Hodder Farm, and the Site is used to describe both properties together.

Table 3.1: Site Legal Description

Site ID	Legal Description	Owner	Address	Map ref, centre of site:	Area (ha)
Site A - Adjacent Block	LOT 2 DP 342631	SWDC	65 Longwood Rd West, Featherston	-41.134445, 175.324826	12.58
Site B - Hodder Farm	LOTS 17-25 PT LOTS 26 28 DEEDS PLAN 317	SWDC	270 Murphys Line, Featherston	-41.138342, 175.325098	162.61
QEII Covenanted Open Space	LOTS 17-25 PT LOTS 26 28 DEEDS PLAN 317	SWDC	270 Murphys Line, Featherston	-41.139063, 175.328044	3.59
WWTP	PT SEC 258 SECS 330-331 FEATHERSTON SUBURBAN	SWDC	Donald Street, Featherston	-41.136782, 175.323395	7.35

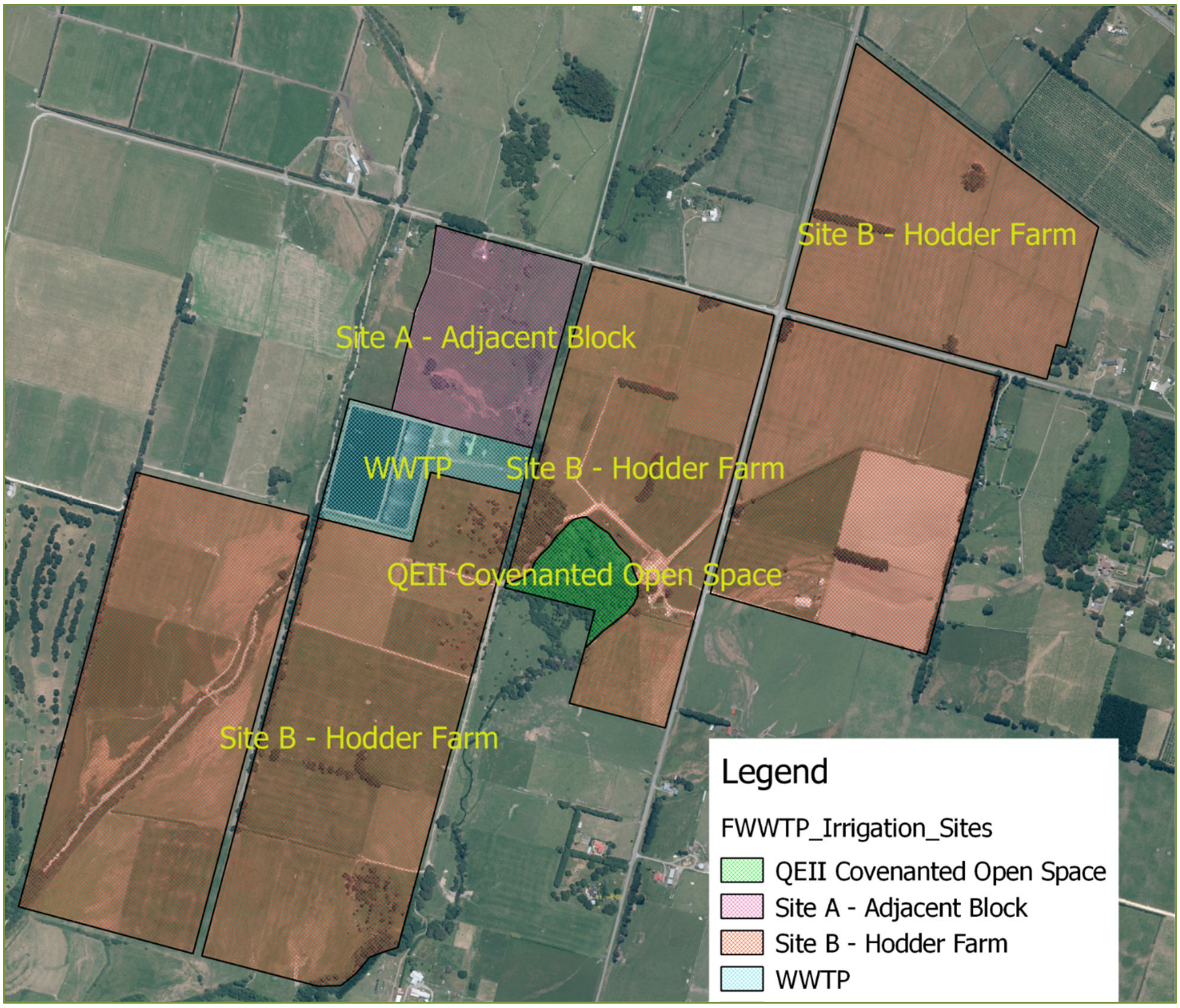

Figure 3.2: Site Layout

The Site is in close proximity to a wide range of activities and landscape features. It is less than 1 km from Featherston township. The Featherston golf course is adjacent and Murphy's Line bisects the property. Abbot's Creek and Donald Creek are significant water courses which pass through the property and Lake Wairarapa is just over 2 km to the south. The two water courses are identified by a variety of names and the ones used in this report are referenced from Land Information New Zealand (LINZ). Otauira Stream has been used to identify Abbot's Creek, in some sources. Donald Creek is sometimes identified as Boar Creek. It is important to recognise references to other names to allow association of activities that occur along this water course. This includes the town water supply (upper reaches) and the discharge from the treatment ponds.

3.3 Land Use of Site and Adjacent Areas

3.3.1 Site Land Use

The existing land use over Site A is grazing of drystock, and Site B is dairy production and arable cropping. The Site is well-suited to carrying stock, particularly as the stony soils help to resist soil compaction and provides relatively good drainage. However, the stony soils create limited ability for cultivation and therefore cropping is restricted to areas with fewer stones. The land characteristics are described in further detail in Section 3.4 and 3.5 below.

Around 70 ha of the farm has been irrigated with small moveable irrigators from two bores supplying 19 L/s and 25 L/s water.

3.3.2 Surrounding Land Use

Properties adjacent to the Site are managed as dairying units with a few lifestyle blocks and the golf course on the western boundary south of the FWWTP. A piggery is located on the far side of the golf course away from the Site. North-west of the Site is Featherston which is 0.75 km from the Site at its closest point.

The foothills of the Tararua Forest Park and Rimutaka Ranges begin 1.8 km west of the Site and Lake Wairarapa is situated 2.1 km to the south. The Tauherenikau River enters Lake Wairarapa 3.5 km south of the Site where a large wetland is situated. This river entrance and wetland is part of the largest wetland area in the North Island known as the Lake Wairarapa Wetlands that includes Lake Wairarapa, Lake Onoke and 900 ha of associated wetlands. It is of international importance for the flora and fauna; and ranked as significant for habitat values (Wildlands, 2013). Detail of this wetland system and its conservation can be found in the Directory of Wetlands in New Zealand (Cromarty & Scott, 1995).

3.4 Topography, Landform and Geology

The site is generally flat to gently sloping with low hummock and swale topography and a fall from the north towards the south (gradient of around 0.004 m/m).

The area around Featherston is located at the western edge of the Wairarapa Basin. The FWWTP and site are located on an alluvial fan created by rivers and streams draining the nearby Tararua Ranges (the Rimutaka Ranges are near but do not drain over the site), and as such the dominant mineralogy of the alluvial sediments is from greywacke. The simple name for this geological unit is Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene). At the site the unit is further delineated into late Pleistocene river deposits being, poorly to moderately sorted gravel with minor sand or silt underlying terraces and includes minor fan gravel. The age is between 14,000 to 24,000 years old. The boundary where the geology changes to Holocene swamp deposits is directly south of the farm boundary (GNS, 2012).

Three kilometres west, at the base of the Tararua Range, is the Wairarapa Fault Line that is active. Risk of earthquakes is similar to elsewhere in the Wellington region.

3.5 Soils

Site investigations have been conducted for Site A (February 2014) and Site B (November 2015), including soil mapping and field testing of soil hydraulic properties. Key information regarding the soils of the site from these investigations is as follows.

3.5.1 Soil Description

For Site A, the dominant soil series was identified as Opaki brown stony loam (Mottled Orthic Brown Soil). Variations in the soil were due to microtopographic changes whereby finer grained soils were present in swales and coarser grained soils were found on hummocks. Lower lying soils were noted to be strongly gleyed below 70 cm, indicating soil saturation is frequent beyond this depth.

For Site B, the identified soil series correspond to Tauherenikau shallow stony silt loam (Typic Firm Brown Soil) and Ahikouka silt loam (Typic Recent Gley Soil).

Observations of the soils at Site A and Site B indicate the benefits and constraints as:

- Presence of gravel over most areas will assist to avoid compaction and will provide some "winter dry" areas;
- Mottling indicates seasonal wetness in lower lying areas of the site which may be exacerbated if winter irrigation occurred to these areas; and
- There was noted variation at depth, including lenses of clay dominated material. This suggests that water movement may be horizontal as well as vertical and so discharge rates should be slow enough to avoid rapid drainage.

3.5.2 Soil Fertility

Soil fertility testing was undertaken for Site B by the previous owner's fertiliser supplier in 2013 and 2014. Results of the testing are given in Table 3.2.

Table 3.2: Soil Fertility Test Results

	pH		Olsen P		SO_4-S		K		Ca	
units	pH units		mg/L		mg/kg		me/100g		me/100g	
Paddock	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
4 5	5.9	5.9	37	32	4	6	0.25	0.24	18.3	17.5
14 15	5.6	5.6	21	20	4	3	0.23	0.26	9.7	9.3
19 24	6	6	36	24	3	4	0.41	0.57	13.1	12.7
30 31	5.8	5.8	24	24	4	3	0.32	0.33	9.6	7.6
43 44	6	6	29	27	4	3	0.45	0.31	11.1	10.3
70 71	5.7	5.7	26	21	3	4	0.30	0.34	11.4	9.1
	Mg		**Na**		**CEC**		**BS**			
units	me/100g		me/100g		me/100g		me/100g			
Paddock	2013	2014	2013	2014	2013	2014	2013	2014		
4 5	1.45	1.25	0.14	0.17	30	29	67	68		
14 15	1.1	1.06	0.11	0.10	21	20	54	53		
19 24	2.36	2.12	0.21	0.22	25	26	64	61		
30 31	1.56	1.36	0.18	0.14	19	17	60	65		
43 44	1.77	1.79	0.19	0.15	21	21	63	61		
70 71	1.50	1.13	0.14	0.11	20	18	66	60		

The test results indicate that Site B has pH, Olsen P and cation exchange capacity (CEC) within the optimum range for pastoral soils. Potassium (K) and sulphate-sulphur (SO_4-S) are low. Calcium (Ca) and Magnesium (Mg) are high and may represent lime dressings applied to the area.

Implications for the use of Site B for wastewater irrigation are:

- The land is not constrained by fertility issues, but should be monitored to determine if supplemental SO_4-S or K needs to be applied to maintain pasture growth;
- Olsen P is not excessive indicating that saturation of P sorption sites is unlikely to occur in the near future; and
- Application of sodium (Na) in wastewater is unlikely to cause the soils exchangeable sodium percentage to exceed trigger values for soil structural health due to current low Na and high Ca and Mg.

3.5.3 Soil Physical Properties

The soil physical properties determine the ability of the soil to transmit air and water, and to resist damage by vehicles or animals. Soil physical properties evaluated for the site are bulk density (Site B only), porosity (Site B only), macroporosity (Site B only), saturated hydraulic conductivity (K_{sat}) and unsaturated hydraulic conductivity (K_{-40mm}).

A summary of testing results is given in Table 3.3.

Table 3.3: Soil Physical Properties

ID	Bulk density (g/cm³)	Porosity (%)	Macroporosity (%)	K_{sat} (mm/h)	K_{-40mm} (mm/h)
Site A	-	-	-	240 ± 120	8 ± 5
Site B	1.23 ± 0.06	53 ± 3	9 ± 1	33 ± 14 to 172 ± 31	8 ± 3 to 14

A design irrigation rate (DIR) based on the hydraulic conductivity of the soil can be established using the recommendations of Crites and Tchobanoglous (1998). A value between 10 and 30 % of the hydraulic conductivity is recommended for use as DIR.

Nominating a rate closer to 10 or to 30 % requires consideration of the test method and of other site considerations. For both areas the use of the K_{-40mm} has been adopted since it represents soil movement in an unsaturated soil and is therefore more conservative. For Site A a further consideration is that to maximise the amount applied the whole area should be available for discharge on every discharge event. This, coupled with Site A being directly adjacent and upgradient to the FWWTP ponds, has led to the use of 10 % for Site A. This corresponds to a **DIR of 19 mm/d for Site A** for the average K_{-40mm}. For Site B the ability to rest each area between irrigation events allows a value of 30 % of the K_{-40mm} to be adopted, resulting in a **DIR of 55 mm/d for Site B**.

3.6 Surface Water

There are two main water courses that cross the Site being, Abbot's Creek (also known as Otauira Stream) and Donald Creek (Boar Creek). These streams converge around 1.5 km south of the site and enter Lake Wairarapa. Donald Creek receives the discharge from the FWWTP. Both waterways originate in the foothills of the Tararua Ranges to the north of Featherston.

3.6.1 Donald Creek

A detailed account of the hydrology of Donald Creek is given in Butcher (2016). Discussion of the upstream hydrology including the influence of the Torohanga Stream is given in that report. Table 3.4 summarises mean monthly flow data.

Table 3.4: Donald Creek –Monthly Flows (L/s) 14/1/2000 to 7/10/2015

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Mean
Minimum	47	45	43	52	86	84	171	207	154	215	122	83	229
Mean	142	137	143	171	261	478	633	715	478	471	241	203	354
Maximum	303	882	474	538	580	978	1,045	1,511	961	1,020	398	535	444

Near the site and FWWTP the creek is considered to have a neutral flow i.e. neither gains or loses flow to groundwater. As Donald Creek turns west towards its confluence with Abbot's Creek it gains water from groundwater. This area of gain is likely to be influenced by groundwater passing from under the Site.

A detailed account of the water quality and ecological health of Donald Creek is given in Main AEE, Section 6.4 (2017a). It is known that Donald Creek shifts from "fair" stream health upstream of the discharge to "poor" stream health downstream of the discharge. This indicates that the creek is impacted to some extent by upstream land use which is then exacerbated by the FWWTP discharge. The following parameters are believed to contribute to the observed effect:

- Biochemical oxygen demand (BOD);
- Total nitrogen (TN);
- Dissolved reactive phosphorus (DRP);
- Total solids (TSS); and
- Water clarity.

3.6.2 Site Drainage and Riparian Management

During the site visits by LEI staff it was noted that Donald Creek, where it passes through the Site, is predominantly fenced on Site B, and not fenced on Site A.

Abbots Creek runs through the Site to the south of the FWWTP. Abbot's Creek is fenced off creating a 20 m riparian buffer each side. There is access into this buffer area but it did not appear animals had entered for some time. A stock race runs along one embankment inside the 20 m buffer. Vegetation in this buffer area includes willow, lupin, gorse and fennel.

A branch of the Longwood Water Race is located through Site B. Significant flows in this water race network in the vicinity of the Site have not been observed and it is likely that the race way will act as a drainage network for the site.

Artificial drainage has been installed in the south eastern corner of the site and covers around 8 ha. Large wet areas exist on paddocks west of Abbot's Creek. All wet areas, drains and streams are identified on Figure 3.3. Irrigation can be applied to these areas, but should only occur at a rate and under conditions that will not cause ponding, or rapid drainage to the artificial drainage network.

Figure 3.3: Water Courses and Wet Areas

3.6.3 Site Flooding

The FWWTP is not located within the flood hazard zone identified by the Wairarapa Combined District Plan. Figure 3.4 presents the extent of a 50 year flood event. Some water from Donald Creek begins to enter the Site on the northern side. This may extend further if a 100 year flood event is experienced.

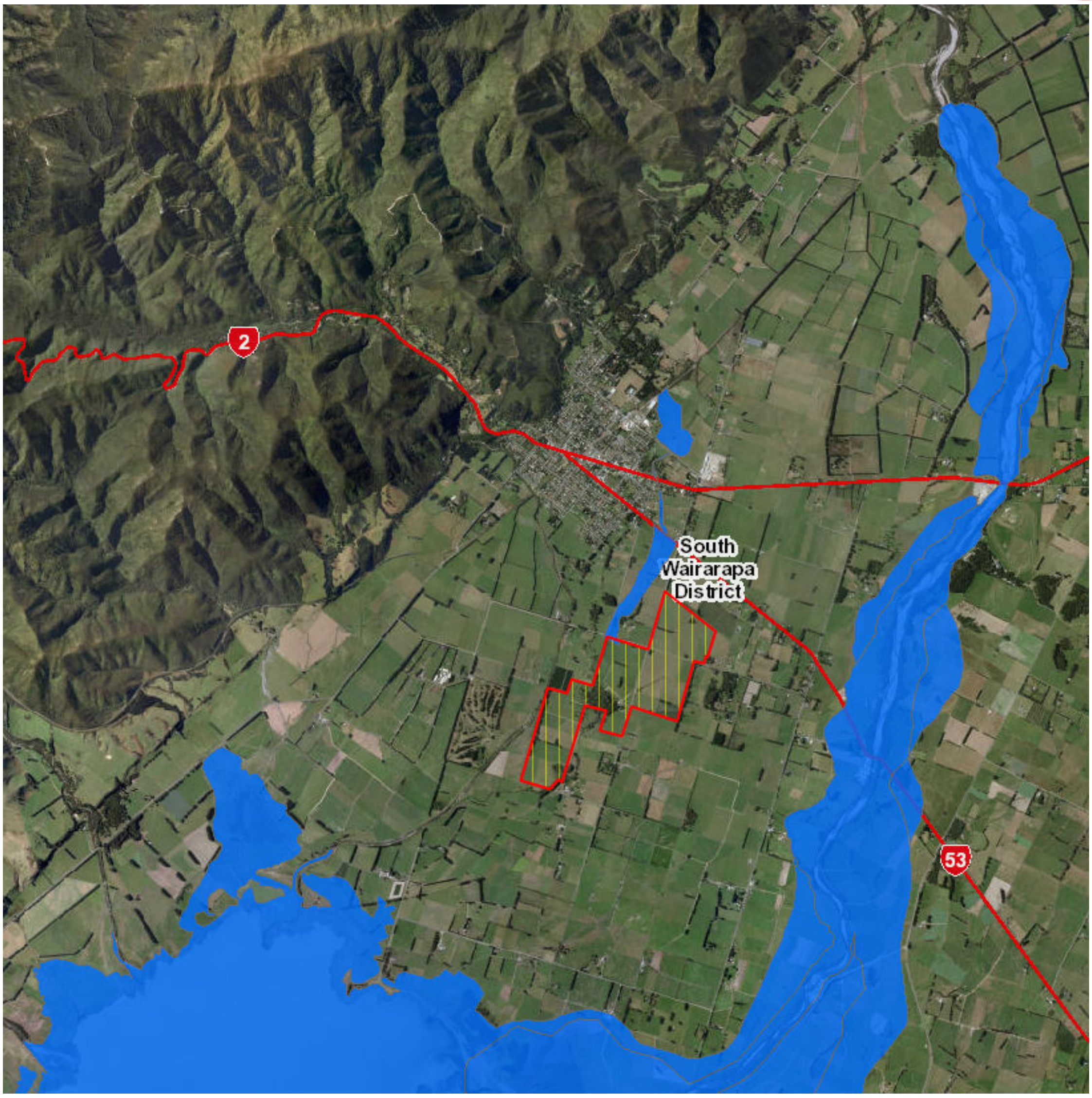

Figure 3.4: Extent of Flooding in a 50 year Event (map developed from Greater Wellington Regional Council)

3.7 Groundwater

The local hydrogeological setting can be summarised as follows:

- GWRC Water Zone: South Featherston;
- Geology: Sand and gravel alluvial fan with high percentage of silts and clays. South of Site sands and gravels intercalate with thick silt and clay sequences;
- Unconfined or semi-confined aquifers: 20 – 30 m deep (Aquifer 1) and 50 – 60 m deep (Aquifer 2);
- Groundwater levels: 1.0 to 3.0 m below ground level;
- Groundwater flow: Aquifer 1 generally southerly from Site;
- Hydraulic gradient: Aquifer 1 is 1:180;
- Transmissivity: Aquifer 1 is 350 m^2/day;
- Recharge: Aquifer 1 mainly from rainfall infiltration and probably leakage from Abbot's Creek (Abbotts Creek).

Greater Wellington Regional Council lists 49 bores within 2 km of the FWWTP (Figure 3.5). Of those bores, 33 draw water from less than 10 m depth, being the zone most likely to be impacted by recharge from the ground-surface, including irrigated water or wastewater. Of the 49 bores, seven are located between the Site and Lake Wairarapa, and are therefore likely to be downgradient of the Site. Of the seven downgradient bores, five are shallower than 10 m. The shallowest is 4 m.

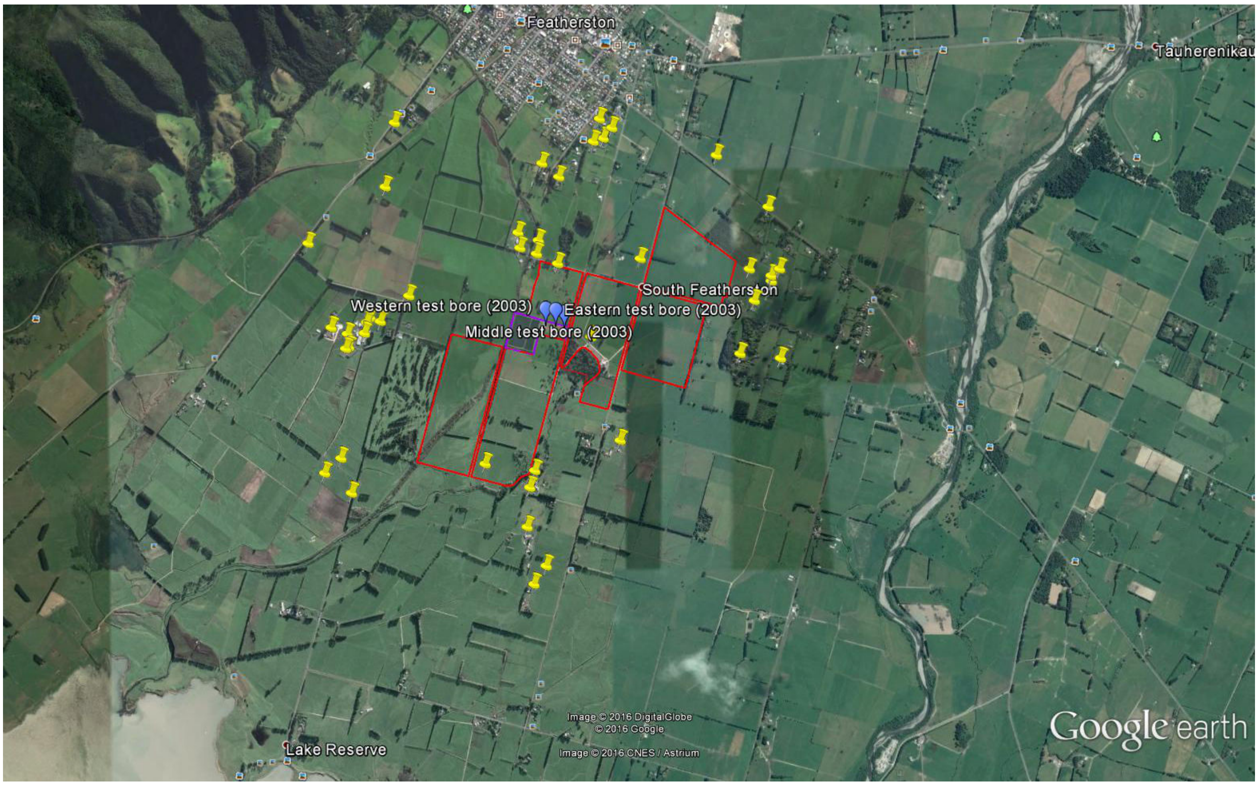

Figure 3.5: GWRC listed bores within 2 km of the FWWTP

Within the proposed land application area of the Site there are three piezometers installed. It is understood that these were installed around 2003 to investigate groundwater in the vicinity of the FWWTP. At the time of LEI's site investigation (November 2015) depth readings and water quality samples were taken from the piezometers. Table 3.5 gives the analysis results. Results from two bores located near to the FWWTP outlet channel, sampled in 2003 were also sourced and are included in Table 3.5. Figure 3.6 shows the locations of the bores (Western, middle and Eastern bores were not observed by LEI staff).

Table 3.5: Groundwater depth and quality near the site

Bore	Total depth	Depth to water	Temp	Conductivity	Chloride	Ammoniacal Nitrogen	Nitrate Nitrogen
	m	m	^{o}C	mS/m @ $25^{o}C$	g/m^3	g/m^3	g/m^3
Western*	4.01	2.86	16	11.1	16.9	<0.005	0.510
Eastern*	3.21	2.17	16	13.6	17.1	<0.005	0.045
LEI 1**	4.40	1.34	11	12.4	17.4	0.034	1.47
LEI 2**	4.54	1.48	11.3	12.1	17.1	0.017	1.24
LEI 3**	4.14	0.88	11.5	12.2	17.3	0.018	1.68

* Sampled by Professional Groundwater and Environmental Services March 2003
** Samples collected by LEI November 2015

Figure 3.6: Bore locations

The water quality results suggest that groundwater quality in the vicinity of the site is not adversely impacted by the current activities. Measured values are far below concentrations in the nearby ponds. The quality of the groundwater is unlikely to prevent any use.

Groundwater depth varies from almost 3 m to less than 1 m from the soil surface. Significant differences between the 2003 depths and 2015 depths are likely to be due to the seasonal variation in groundwater levels rather than due to landform differences since all piezometers are within around 300 m and located on the alluvial plain adjacent to Donald Creek. This fits with observations of mottling at depth in the soils of the site.

3.8 Climate

3.8.1 Rainfall and Evapotranspiration

Daily rainfall data and daily potential evapotranspiration (PET) data is given in Table 3.6 below. The nearest climate station with a complete record that covers up-to-date data over a sufficient time span (1993 to 2014) is the Virtual Climate Station for South Wairarapa (NIWA/28201); 1 km north of the Site. The data from this Station is created from actual data and extrapolated to this location. It takes into account the dramatic variation in climate that occurs across Wairarapa, therefore is the best representation for the Site. This dramatic change in climate is represented in Figure 3.7 that depicts the change in rainfall close to the Rimutaka Ranges where the Site is located. Featherston is located within the mean annual rainfall zone of 1,200 to 1,400 mm.

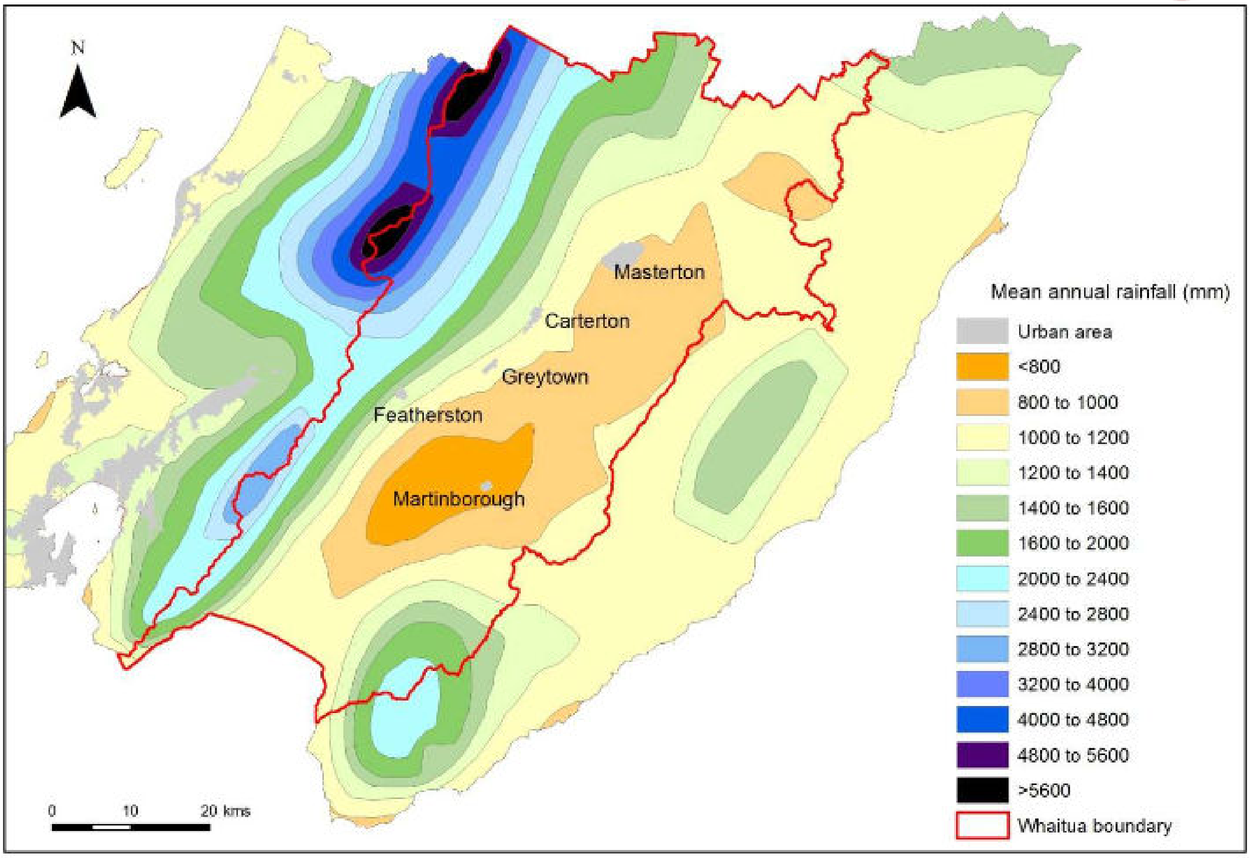

Figure 3.7 Rainfall Variations Across South Wairarapa (Sourced: GWRC 2014)

Table 3.6: Monthly Average Climate Data for South Wairarapa 1993-2014

Month	Average Rainfall Total (mm)	Average PET (mm) (Priestley-Taylor)
January	88	153
February	62	115
March	112	93
April	105	52
May	131	29
June	157	19
July	189	24
August	136	37
September	106	63
October	162	93
November	82	122
December	104	139
Annual	1434	937

3.8.2 Wind

A windrose is shown in Figure 3.8 using data from the Tauherenikau at Alloa climate station. This was sourced through Greater Wellington Regional Council and provides data for the period of September 1999 to March 2013. This was the closest record available with sufficient time span of data and is considered to be representative of conditions at Featherston that are less than 5 km north east of the Site. This wind rose shows that the predominant wind direction is north-northeasterly. These winds are dominantly light <2 m/s. North-west and south-west winds are the next most common directions and they are stronger than the prevailing NNE winds.

There are private residents and public areas around the whole site and properties on the north north east around to the west to west south west will be in the direction of the wind carrying potential odours. This indicates that the predominant wind run over the WWTP and Site is largely away from Featherston township residential area although the northern end of the Site would have winds directed at the township.

80% of the time wind speeds are less than 4 m/s; and 93% of the time, 6 m/s. The overall mean wind speed is 2.1 m/s (7.5 km/h). The frequency of the wind speeds is presented in Figure 3.9.

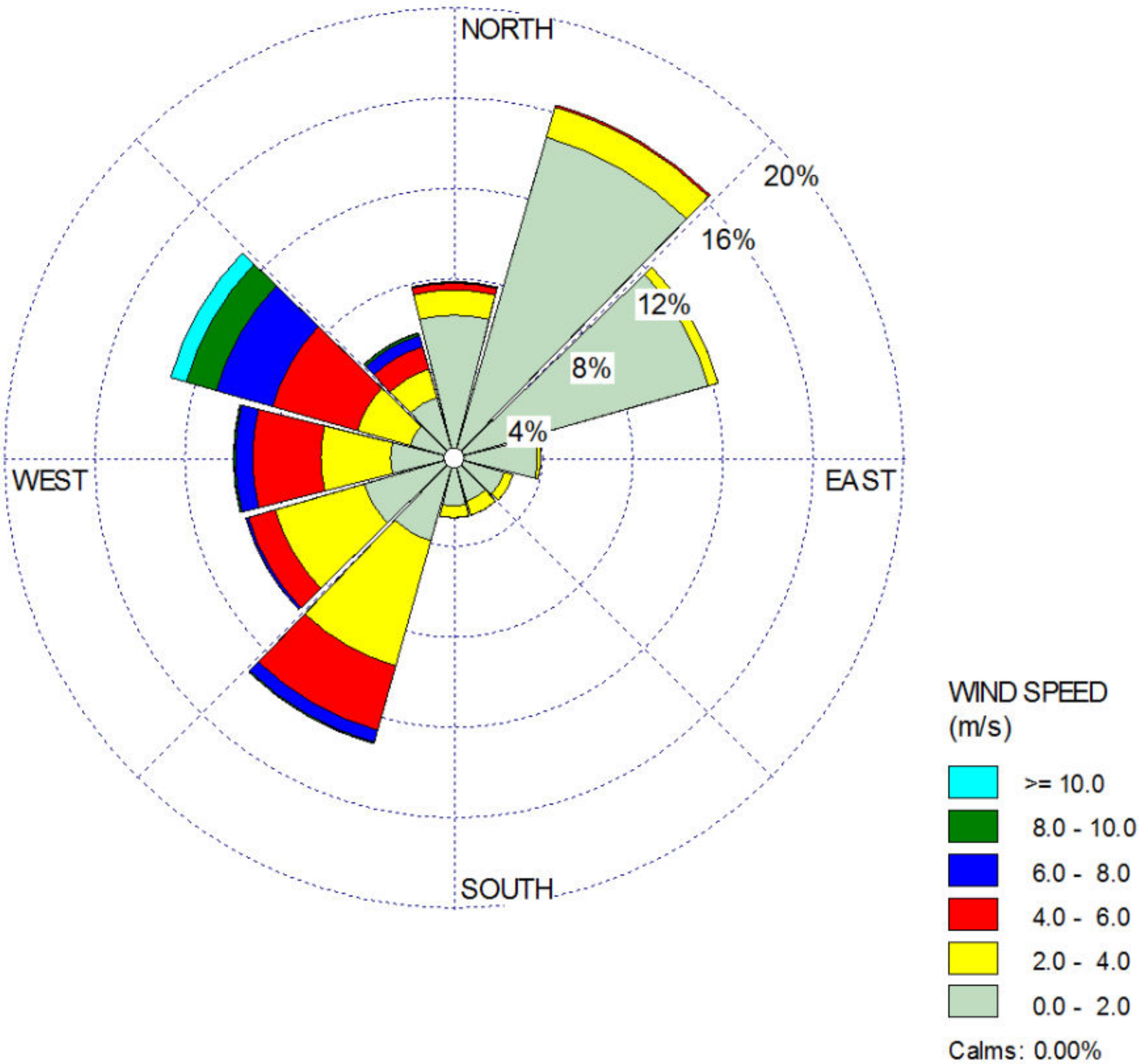

Figure 3.8: Wind Rose for Tauherenikau at Alloa During 1999-2013

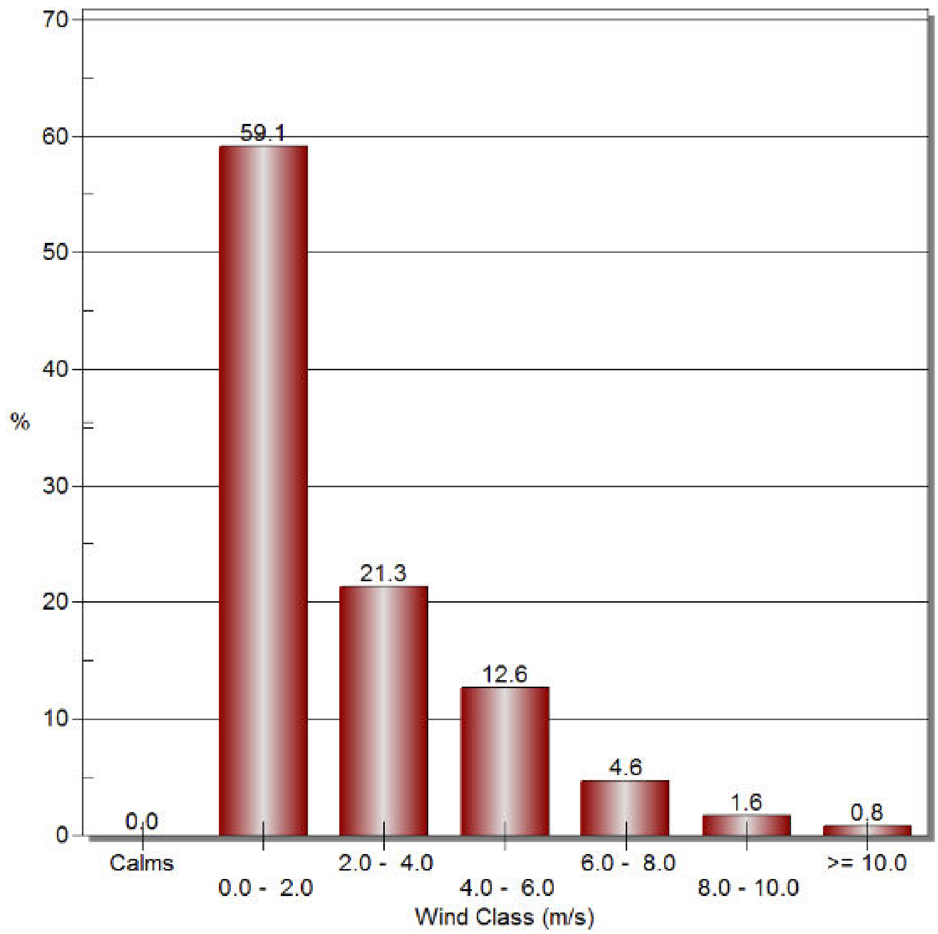

Figure 3.9: Wind Frequency at Tauherenikau at Alloa

3.8.3 Climate Change

A middle of the range prediction of climate change (GWRC 2014) suggests there will be little change in rainfall. By 2090 there may be slightly less rain in winter and spring and more in summer and autumn. This prediction has been attributed to the influence of the hydrological system. However, extreme events may be more common as summarised below:

- Heavy rainfall over the next 50 years changed by a factor of 2. i.e. a 10 year storm occurs every 5 years;
- Drought increase; and
- Severe drought will occur twice as often by 2100.

Table 3.7: Predicted climate change in Masterton by 2090

Season	2090 possible climate changes
All seasons	Frequency of extreme winds 2-3% increase
Spring	0.6 to 2.7°C temperature rise 3% less to 2% more rain
Summer	0.7 to 3.1°C temperature rise 1% more to 8% more rain
Autumn	0.7 to 3.1°C temperature rise No change to 3% more rain
Winter	0.7 to 3.2°C temperature rise 7% less to 1% more rain

Source: http://www.mfe.govt.nz/climate-change/how-climate-change-affects-nz/how-might-climate-change-affect-my-region/wellington

The Ministry for the Environment provides statistical predictions for 2090 for Masterton as presented in Table 3.7. With reference to Figure 3.5, Masterton has significantly less rainfall compared to Featherston, however changes are predicted as percentages and may be assumed to be similar. Temperatures are expected to be around a 2°C rise.

3.9 Site Buffers

Buffers around sensitive receptors have been proposed as:

- Boundary – 25 m;
- Dwellings – 150 m;
- Waterways – 20 m either side; and
- Bores – 50 m.

4 DESCRIPTION OF THE ACTIVITY

4.1 General

The activity that needs to be considered as part of the land based application of wastewater from the FWWTP is the discharge of wastewater to land via irrigation and air quality considerations. SWDC has collected a range of data which has been supplied to LEI and forms the basis for the land application regime proposed. A detailed evaluation of the other elements of the FWWTP scheme are given elsewhere and summarised in the Main Consent Application.

This section provides a summary of the key parameters relied upon to determine the effects of the land discharge.

4.2 Treated Wastewater Collection and Treatment

FWWTP was originally constructed in circa 1975. A detailed discussion of the wastewater treatment system is given elsewhere (Chapter 2, Main Consent Application). In summary, wastewater from Featherston is primarily domestic with an estimated maximum dry weather flow of 5 % from commercial and industrial sources. The wastewater is reticulated to a two pond system at the FWWTP where it undergoes passive oxidative treatment. Based on current wastewater flows there is an average retention time of 45 days which can reduce to as low as 10 days at peak flows in wet weather. Under the existing resource consent, following UV disinfection treatment the wastewater is discharged via an open channel to Donald Creek which flows via Abbot's Creek to Lake Wairarapa.

The treatment system has a combined volume of 47,400 m^3. This is calculated from the surface area of 38,900 m^2 and the nominal depth of 1.2 m (Chapter 2, Main Consent Application). The treatment volume is considered to be sufficient for the treatment of future flows (note, this does not include storage requirements).

4.3 Discharge Characteristics

Key parameters of importance for the assessment of the effects of the discharge to land are summarised in Table 4.1. The FWWTP outflow rate is summarised from data collected from March 2005 to May 2016. FWWTP wastewater quality data is summarised from February 2009 to May 2016, with the exception of *E.coli* data which has been collected from December 2011 onwards.

Table 4.1: Featherston WWTP Treated Wastewater Characteristics

Parameter	n	25th percentile	Mean	Median	95th Percentile	Proposed for consent[1]
Outflow (m^3/d)	3,809	1,133	2,270	1,907	5,272	-
BOD_5 (g O_2/m^3)	39	10.9	18.3	17.0	31.8	35
TSS (g/m^3)	40	9.8	32.0	25.0	73.9	100
TN (g/m^3)	39	7.3	8.6	8.4	12.1	15/25
NH_4-N (g/m^3)	39	2.6	4.9	4.4	9.7	12/18
SIN (g/m^3)	39	4.1	5.8	5.6	11.1	-
DRP (g/m^3)	39	0.7	1.3	1.2	2.8	4/6
TP (g/m^3)	39	1.0	1.7	1.5	3.8	5.0/6.5

Parameter	n	25th percentile	Mean	Median	95th Percentile	Proposed for consent[1]
pH	291	7.2	7.6	7.5	NR	6.0-9.5
E. coli (cfu/100 mL)	18	8	56	18	NR	100

[1] proposed consent values. Values are based on an exceedance in more than 3 out of every 12 consecutive monthly test results. Where two figures are listed, the first is the consent concentration prior to I/I reduction and the second is post-I/I reduction works.

The wastewater from the FWWTP has low concentrations of parameters compared to typical well performing oxidation ponds which is most likely attributed to the high I & I contribution. The annual average daily flow at 2,270 m^3/d is over 400 % above the average flow expected from a New Zealand population the size of Featherston. The distribution of flows throughout the year is influenced by stormwater inflow and groundwater infiltration that are estimated to comprise 74 % of the inflow. This also results in higher flows occurring during the winter months and lowest flows typically occurring in late summer.

The target for I & I reduction works as proposed for Stage 1B is to reduce average daily flow volumes entering the FWWTP by 35 %. This will decrease the volume available for irrigation but will not substantially alter the nutrient loads from the wastewater. The treated wastewater composition is well suited to application onto land.

Predicted discharge volumes were supplied by Mott MacDonald and repeated here in Table 4.2. The FWWTP outflow volumes are summarised from data collected from 2009 to 2016. FWWTP inflow volumes of wastewater vary from outflow due to pond buffering, evaporation, rainfall and pond leakage (although pond leakage is minimal at FWWTP as described in Chapter 2, Main Consent Application).

Table 4.2: Outflow from FWWTP

	FWWTP Outflow	
All Year	**Mean (m^3/d)**	**95%ile (m^3/d)**
Current	2,270	5,272
Post I & I reduction	1,476	3,426

4.4 Proposed Activity and Staging

The activities for which resource consent is being applied for are described in detail in Section 4 of the Main Consent Application document. A summary of the activities and proposed stages which impacts the assessment of effects due to land application is as follows:

- **Stage 1A** involves minor treatment pond improvements and irrigation to land starts with an area 8 ha of land (Site A) allowing for approximately 3-5 % of the average annual wastewater discharge volume and 28 % of the average summer discharge volume to be irrigated;
- **Stage 1B** involves expansion of the irrigation area to include a further 70 ha of Site B, allowing for irrigation of approximately 44% of the **current** average annual wastewater discharge volume to land;
- **Stage 2A** involves the infiltration and inflow (I&I) into the pipe sewage reticulation network being reduced by upgrading of the pipe network, resulting in a reduction of approximately 35% of inflow into the system. The area of irrigation is further increased allowing for irrigation of approximately 68% of the **current** average annual waste water discharge; and

- **Stage 2B** involves a large storage pond being constructed to defer flows and to provide additional storage and oxidation of the effluent. The buffering allows for approximately 94% of the **current** average annual wastewater discharge volume to be irrigated. During this stage discharge to Donald Creek occurs infrequently and is predicted to occur 91% when Donald Creek's flow exceeds two times the median flow and 73% of the time when the flow exceeds three times the median flow.

An evaluation of treated wastewater flows to be discharged to land at each stage has been made on the basis of the historical record of wastewater flows and climatic conditions. A summary of the discharge regime for each stage is given in the following sections.

4.5 Determination of Design Irrigation Rate

A site investigation and field testing of Site A in 2014 indicated that the land of Site A is suitable for irrigation with wastewater. An appropriate irrigation application depth has been determined from field testing of soil unsaturated hydraulic conductivity ($K_{-40\ mm}$). The $K_{-40\ mm}$ as determined from field testing is 3 to 8 mm/h and the lowest result of 3 mm/h corresponds to a design irrigation application depth of 19 mm/d using the method of Crites and Tchobanoglous (1998) (Section 3.5.3).

Prior to SWDC's purchase of Site B a desktop assessment of land suitability was undertaken by LEI to assist SWDC to determine if the available land would be suitable for land treatment of FWWTP wastewater. The assessment determined that the land was likely to be suited to irrigation with wastewater.

In early November 2015 LEI conducted a detailed site investigation of Site B with key parameters summarised in Section 3.5 above. An appropriate irrigation application depth has been determined from field testing of soil unsaturated hydraulic conductivity ($K_{-40\ mm}$). The most conservative $K_{-40\ mm}$ as determined in the Site Investigation report (LEI, 2015) is 8 mm/h which corresponds to a design irrigation application depth of 57.6 mm/d using the method of Crites and Tchobanoglous (1998). For practical irrigation purposes this value has been rounded to 55 mm/d.

Using the design irrigation application depth of 19 mm/d for Site A and 55 mm/d for Site B will restrict irrigation water movement through the soil to matrix flow, thereby maximising the travel time in the soil and contact with soil particles. This is intended to maximise sorption, filtration and plant removal of applied nutrients and pathogens. Maximising soil treatment is further enhanced using an irrigation rate not exceeding the lowest K_{-40mm} of 3 mm/h for Site A and 8 mm/h for Site B. This will also avoid ponding and run-off.

The design irrigation depths and rates discussed here are the maxima for the Site however, there is potential to reduce the per event application rate to fit in with land management requirements and to optimise the discharged volumes. This is discussed further below.

4.6 Determination of Discharge Regime

In order to determine the proportion of wastewater that can be applied to a land area, and the amount of storage required, a water balance approach has been used to develop a land application regime. This section summarises the methodology used to build the regime.

4.6.1 Water Balance Principle

There are a number of processes to be considered when applying treated wastewater to land. The use of a water balance enables these processes to be quantified and then considered together. This report is based on an empirical water and nutrient budget for a land discharge system. In the case of the stages presented here, actual data (typically daily) is used and so the outputs represent how the system would have operated for the period of the dataset.

4.6.2 Water Balance Key Inputs

Specific input data used includes:

- **Daily wastewater outflow volume:** This was the shortest data set available and therefore is the limiting parameter in terms of the length of time represented by the scenarios. Gaps in data sets were populated with estimates based on previous outflow and current inflow data. Data was available for the period 18 March 2005 to 30 May 2016. Following I & I reduction a reduced volume of 35 % for every day of record has been assumed;
- **Mean wastewater quality:** While the wastewater quality is known to vary, nutrient data is considered in the context of yearly loads and so mean values for total N and total P are considered to be appropriate for the water balance. Values are summarised in Table 4.1;
- **Daily rainfall data** (for additions to the pond surface and for scheduling irrigation): From the nearest climate station with a complete daily data set. In this case the NIWA Virtual Climate Station (VCS) Network was used which has a point 1.2 km to the north of the FWWTP (available to 10/4/2014), additional data was soured from the Martinborough Ews (to 30/5/2016);
- **Daily Priestly-Taylor Potential Evapotranspiration** (for losses from the land application area): From the nearest climate station with a complete daily data set. In this case the VCS and Martinborough Ews as for rainfall; and
- **Daily open-pan evaporation** (for losses from the storage pond surface): From the nearest climate station with a complete daily data set, also from the VCS and Martinborough Ews as for rainfal.

4.6.3 Variable Inputs to Water Balance

There are many variables for the system which, when manipulated individually, can produce multitudinous outcomes. Predominantly the variables represent possible day-to-day management decisions such as:

- Irrigation event application depth;
- Area available for irrigation on any day;
- Irrigation limits based on month (% of maximum);
- Irrigation return period;
- Limit to application volume based on amount of rainfall received over preceding days;
- Soil moisture content trigger to start irrigation;
- Soil permeability and available water holding capacity;
- Inclusion of surface water or rapid infiltration discharge limited by nutrient or hydraulic load;
- Pond dimensions; and
- Minimum volume to be retained in storage.

In order to work with a manageable number of scenarios some decisions have been made as to which variables to fix. These decisions are based on an understanding of the assimilative capacity of the local environment and a need to discharge as much of Featherston's wastewater to land as possible in a sustainable manner, without having a detrimental impact on the land.

Details of the parameters adopted are discussed in Sections 4.7 to 4.10 below.

4.6.4 Processing of Data

The water balance considers the system as a series of separate reservoirs and then as interacting systems. The process can be summarised as follows:

- Determine what volume of wastewater is available for discharge (stored volume and inflow);
- Determine if the soil moisture status criteria are met. This a function of the rainfall and/or irrigation received previously, the evapotranspiration for that day and drainage that may have occurred;
- If sufficient wastewater is available and soil moisture status allows, apply wastewater to land area at the prescribed irrigation rate;
- If insufficient wastewater is available from inflow or in storage then no discharge occurs and inflows are directed to storage;
- If there is not sufficient capacity in the soil to receive wastewater (high soil moisture), direct FWWTP outflows to alternative discharge (Stages 1A, 1B and 2A) or storage (Stage 2B); and
- If storage is full and soil moisture will not allow discharge to land, direct outflows to alternative discharge.

Where multiple land areas are defined i.e. where they have different criteria to allow discharge to occur, or if there are alternative discharges such as surface water or rapid infiltration then the water balance progressively assesses and discharges the wastewater to each management unit sequentially. The order is determined by the priority for each unit – in the case of FWWTP the land application units are the priority before storage or alternative discharge.

4.6.5 Outputs

The water balance produces a daily record of discharges to each of the management units. From this data a summary of the discharge regimes can be produced, including:

- Average annual discharge volume to land and to an alternative discharge which may be to Donald Creek;
- Average annual land application depth;
- Days of discharge, both the number of days that discharge could occur (due to soil moisture conditions) and the number of days that the discharge did occur (due mostly to stored volume available);
- Nitrogen (N) and phosphorus (P) load received by the land application area; and
- The maximum storage volume needed to operate a full time land treatment system.

These outputs are given below for the Stages described earlier.

4.7 Stage 1A – Discharge to 8 ha (current flows)

Following the commencement of Stage 1A, it is proposed that irrigation will be applied to the land identified as Site A. Of the 12.6 ha site, **8 ha was deemed irrigable** following the exclusion of boundary and waterway buffers. Investigations have determined that a rate of **up to 19 mm/d** of wastewater from the FWWTP could be assimilated by the soils of the site.

The soil is likely to be able to remove all solids and assimilate all BOD applied from the FWWTP wastewater. There are limits to the efficiency of removal of nutrients based on the rate at which wastewater travels through the soil. The proposed rate of 19 mm/d is designed to maximise the time that the wastewater remains in the surface (biologically active) zone of the soil, and will avoid ponding and overland or preferential flow. The proposed regime intended to be sustainable for the lifetime of the land application scheme.

To maximise the removal of nutrients from wastewater, decision criteria are recommended to determine on any day whether application to land can occur, as follows:

- **Deficit-standard:** Represents a regime similar to fresh water irrigation that is common in the district. A small amount of nutrient leaching can be expected, but the amount leached is expected to be equivalent to or less than occurs under the surrounding (predominantly dairy) land use. A deficit system has been adopted for Site A since no rotation around the block is proposed (no resting period). The criteria to discharge are:
    - **Soil moisture status:** Irrigation will not cause the soil moisture to exceed field capacity;
    - **Application rate control:** Vary the application depth to "top-up" a deficit whenever it occurs;
    - **Wind speed and direction:** Irrigation may occur if wind speed is less than 12 m/s, or 4 m/s in the direction of any dwelling within 300 m of the irrigated area;
    - **Previous rainfall:** Irrigation may occur if less than 50 mm rain has fallen in the preceding 3 days; and
    - **Crop condition / harvest schedule / animal rotation:** Harvest or grazing should not occur within 48 h of irrigation ceasing, and irrigation should not be commenced within 24 h of completion of harvest or removal of stock.

All described criteria for the adopted regime should be met before irrigation is allowed to occur. As a result of these criteria, discharge will not occur on every day. For an average year, the regime management outcomes are given in Table 4.3. The regime outcomes assume that no I & I reduction to wastewater flows occurs, no storage is available to withhold irrigation and the remaining wastewater to be discharged goes to Donald Creek.

Table 4.3: Stage 1A – Irrigation Management Outcomes

Regime	Average Year
Annual application depth	406 mm
Maximum application rate per event	19 mm/d
Average volume per year	32,500 m^3
Average volume per event (%average daily WW flow)	420 m^3/d (19 %)
N mass loading (summer flows)	35 kg N/ha/y
P mass loading (summer flows)	7 kg P/ha/y

* For period 2005-2016

During a dry year the discharge to land is in the order of 6 % (35,900 m^3) of that years annual wastewater flows. For a wet year this reduces to 3 % even though the total discharged is higher (37,000 m^3). The lowest annual discharge of the period of record was 24,000 m^3 which is likely to indicate a wet summer. The annual application depth is similar to what would be typical for a clean water deficit irrigation scheme in the district. The use of a variable daily application depth is proposed to maximise deficit discharge.

4.7.1 Stage 1A Land Management

The land management proposed for Stage 1A is as follows:

- Pasture managed in a 4 - 6 week rotation over the irrigation period, comprised of 3 - 5 weeks of irrigation and then 1 week for harvest (or grazing by stock); and
- Over the winter, non-irrigated period it is recommended that land is lightly grazed to maintain pasture quality.

The ability to irrigate is not limited by the land use and so the land management adopted will depend on the availability of resources i.e. is the farmer able to get stock on and off in a timely manner, or is a contractor available to cut, bale, wrap and shift the harvested crop when needed. Cut and carry pasture will remove more nutrients from the site than grazing. A well-managed cut and carry system can remove more than 400 kg N/ha/y, while grazing will return some of that nitrogen as excreta resulting in a net removal of nitrogen from the site of around 90-140 kg N/ha/y. The amount of nitrogen applied to the soil from the wastewater as indicated in Table 4.3 does not require the "nutrient stripping" abilities of cut and carry management however, the advantage of cut and carry over grazing in this situation is the avoidance of spot application of nutrients as (in particular) urine, and flexibility of irrigation i.e. no need to plan around stock movements.

4.8 Stage 1B – Discharge to around 70 ha (current flows)

Following the commencement of Stage 1B it is proposed that irrigation will be applied to part of the land identified as Site B which has an established network of irrigation pipes. Application to Site A can still occur as part of the irrigation rotation. Around **70 ha of Site B is to be irrigated** at Stage 1B. Site investigation and field testing has determined that a rate of **up to 55 mm/d** of wastewater from FWWTP could be assimilated by the soils of the site where a sufficient soil moisture deficit exists. The maximum daily application depth of 55 mm/d has been determined to be suitable based on:

- The profile available water to 60 cm soil depth which is 115 mm to 160 mm (varies by soil type) over the area;
- The soil hydraulic conductivity as described in Section 3.5.3 above; and
- Allowing that the rate of application does not exceed 3 - 5 mm/h to avoid rapid drainage occurring from the soil.

As with the Stage 1A discharge, the soil is likely to be able to remove all solids and assimilate all BOD applied from the FWWTP wastewater. However, the proposed discharge regime will result in a larger depth of drainage from the site due to the adoption of application criteria which allows a discharge beyond the soil field capacity (see below). Details of the drainage amounts are given in Section 4.12 below.

Some nutrient loss is expected from the site and management of the irrigation and land as described in Section 4.8.1 below will be designed to avoid excessive loss. The proposed regime is intended to be sustainable for the lifetime of the land application scheme.

To maximise the removal of nutrients from wastewater, the following decision criteria are recommended to determine on any day whether application to land can occur:

- **Deferred, non-deficit:** Represents a regime which maximises the volume of discharge to land while protecting the land from damage by over-watering, and avoiding excessive leaching to groundwater or surface water. A portion of the applied nitrogen will be transported to groundwater and surface water by leaching, but it will enter surface water as a diffuse discharge and at a substantially lower mass loading than would occur due to direct discharge from the FWWTP. Deferred irrigation is suited to Site B because the large available area enables a return period for irrigation. The criteria to discharge are:

- **Soil moisture status:** Irrigation will not cause the soil to exceed field capacity by more than 3 mm per event;
- **Application rate control:** Vary the discharge rate to match the soil moisture criteria;
- **Depth to groundwater:** Irrigation should not occur when the groundwater table is less than 1 m from the soil surface;
- **Wind speed and direction:** Irrigation may occur if wind speed is less than 12 m/s, or 4 m/s in the direction of any dwelling within 300 m of the irrigated area;
- **Previous rainfall:** Irrigation may occur if less than 2 mm rain has fallen in the 24 hours prior to commencement of irrigation; and
- **Crop condition / harvest schedule / animal rotation:** Harvest or grazing should not occur within 48 h of irrigation ceasing, and irrigation should not be commenced within 24 h of completion of harvest or removal of stock.

All described criteria for the adopted regime should be met before irrigation is allowed to occur. As a result of these criteria, discharge will not occur on every day. For an average year, the regime management outcomes are given in Table 4.4. The regime outcomes assume that no I & I reduction to wastewater flows occurs, no storage is available to withhold irrigation and the remaining wastewater to be discharged goes to Donald Creek.

Table 4.4: Stage 1B – Irrigation Management Outcomes

Regime	Average Year
Annual application depth (mm)	480
Maximum application rate per event	55 mm/d
Average volume per year	385,000 m^3
Average volume per event (%average daily WW flow)	1,420 m^3/d (63 %)
N mass loading (summer flows)	42 kg N/ha/y
P mass loading (summer flows)	8 kg P/ha/y

During a dry year the discharge to land for this regime is in the order of 58 % (350,900 m^3) of that years annual wastewater flows. For a wet year this reduces to 34 % even though the total discharged is higher (380,000 m^3). The annual application depth is slightly higher than occurs during Stage 1A due to the use of a, more permissive, deferred irrigation regime. While there is potential for a greater volume to be discharged to land, the amount of wastewater available to discharge on any day is controlled by the outflow from the FWWTP in the absence of additional storage of treated wastewater i.e. while there may be capacity for the land to receive up to 4,520 m^3 (as controlled by the rotation of irrigation blocks) on a day when irrigation can occur, the outflow available from the FWWTP is likely to be less than this on days that irrigation to land is suitable.

4.8.1 Stage 1B Land Management

The irrigation management proposed is as follows:

- Establishment of 8-9 ha irrigation blocks within the 70 ha irrigation area;
- Within irrigation blocks a 3 day minimum return for irrigation; and
- For irrigation blocks an approximate 8 day rotation with a total of up to 55 mm applied over 8 days.

This allows flexibility to tailor the irrigation to the soil moisture status and to plan around rainfall events. For instance, within an 8-9 ha irrigation block a total of 55 mm over 8 days could be applied as one application of 55 mm where a significant deficit exists in the soil, or it might be applied sequentially to parts of the block over an eight day period for instance, it may be that 15-20 mm is applied every three days up to a maximum total of 55 mm in an eight day period.

The establishment of multiple blocks will assist with stock or harvest management.

As with Stage 1A the pasture management is as follows:

- Pasture managed in a 4-6 week rotation over the irrigation period, comprised of 3-5 weeks of irrigation and then 1 week for harvest or grazing by stock; and
- Over the winter, non-irrigated period it is recommended that land is lightly grazed to maintain pasture quality.

As with Stage 1A the nutrient loading proposed, and volume of water applied does not restrict the type of land use adopted for the site. Pastoral grazing or "cut and carry" with additional fertiliser will be considered depending on the resources available, and assessed best rate of economic return. Both options can be managed without compromising the environmental sustainability of the land application of treated wastewater.

4.9 Stage 2A – Discharge to around 70 ha (I & I reduced flows)

Following the commencement of Stage 2A continued discharge to 70 ha of Site B is proposed with the potential to expand the irrigation to up to 116 ha of Site B if there is sufficient wastewater to enable it. The proposed discharge and management regime is the same as adopted for Stage 1B. As with Stage 1B Site A can be used as needed.

Wastewater irrigation under Stage 2A varies from Stage 1B in that the impact of I & I reduction works on wastewater flows are realised at this stage, reducing the outflows from the FWWTP. The nutrient concentration of the discharge is expected to increase as a direct result of the I & I reductions. No storage is available to withhold irrigation and the remaining wastewater to be discharged goes to Donald Creek. For an average year, the regime management outcomes are given in Table 4.5.

Table 4.5: Stage 2A – Irrigation Management Outcomes

Regime	Average Year
Annual application depth (mm)	390
Maximum application rate per event	55 mm/d
Average volume per year	305,200 m^3
Average volume per event (%average daily WW flow)	1,220 m^3/d (83 %)
N mass loading (summer flows)	42 kg N/ha/y
P mass loading (summer flows)	8 kg P/ha/y

Nutrient loading increases fractionally from Stage 1B as a result of I & I reductions at Stage 2A but is still below a standard agronomic loading and so is not limiting to the land management. The total volume irrigated at Stage 2A decreases from Stage 1B however, it represents a higher proportion of the outflows from FWWTP as a result of I & I reductions. As for the previous stage, the absence of storage limits the amount discharged to land.

4.9.1 Stage 2A Land Management

The irrigation management proposed for Stage 2A is the same as occurs at Stage 1B.

4.10 Stage 2B Discharge to up to 116 ha

Stage 2B occurs following the construction of storage for treated wastewater to enable the wastewater to be held until conditions are suitable to discharge it to land. It also includes expansion of the irrigated land area to 116 ha of Site B if this has not already been implemented during Stage 2A. The conditions to discharge are the same as proposed for Stages 1B and 2A. The storage to be constructed will hold the 90th percentile storage requirement, with volumes beyond the 90th percentile discharged to Donald Creek or some other alternative discharge system.

The discharge volumes and nutrient loads assume a 35 % reduction in flows has been achieved by I & I reduction works. For an average year, the regime management outcomes are given in Table 4.6.

Table 4.6: Stage 2B- Irrigation Management Outcomes

Regime	Average Year
Annual application depth (mm)	447
Maximum application rate per event	55 mm/d
Average volume per year	510,300 m^3
Average volume per event (%average daily WW flow)	4,440 m^3/d (301 %[1])
N mass loading (summer flows)	51 kg N/ha/y
P mass loading (summer flows)	10 kg P/ha/y

[1] The average volume per event is greater than the average daily flow from the WWTP as the irrigation draws down on the volume stored over the winter months when irrigation is infrequent or ceased.

4.10.1 Stage 2B Land Management

The irrigation management proposed for Stage 2B is the same as occurs at Stages 1B and 2A.

4.10.2 Storage of Treated Wastewater

At Stage 2B, it is proposed that dedicated storage will be provided for the treated wastewater. The storage will be actively managed to ensure that there is capacity available during periods when no discharge to land can occur due to high soil moisture or rainfall.

The provision of storage has a number of advantages for the scheme which include:

- Ensuring the discharge to land is sustainable by directing wastewater to storage during wet periods when discharge to land might cause land damage;
- Minimising the need to discharge wastewater directly to surface water; and
- Enabling the discharge to land to occur when maximum productive benefit can be achieved i.e. by storing wastewater during wet winter months when highest flows enter the WWTP, it is able to be used during the summer (water short) months when inflow to the WWTP are unable to meet the plant requirements for water.

The amount of storage required is determined from the water balance and is based on daily data as described in Section 4.6. Figure 4.1 shows how the volume of wastewater in storage varies over time. The data assumes that a 35 % reduction in I & I is achieved and shows how the scheme would have operated over the period 2005-2014. Peaks occur during the winter wet months when there are high inflows to the WWTP.

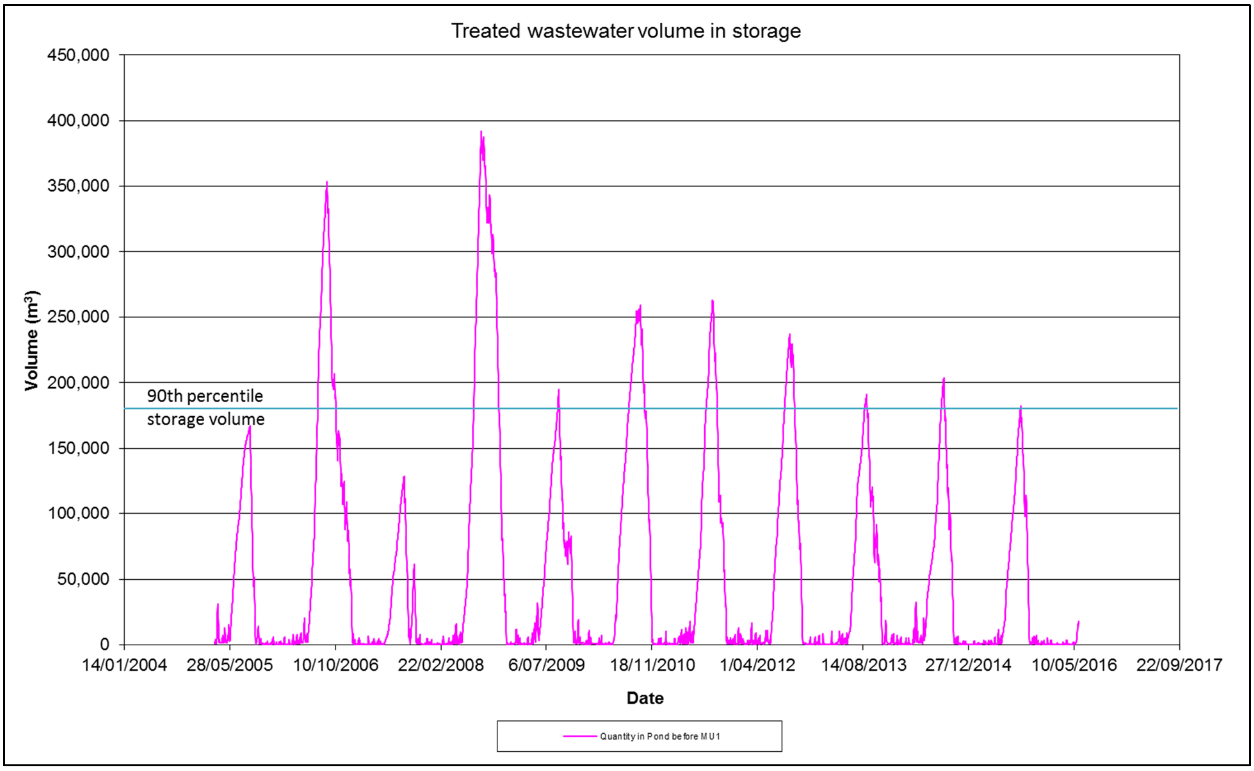

Figure 4.1: Daily treated wastewater in storage for Stage 2B

The maximum storage volume needed varies from year to year as a result of wastewater inflow and climatic variations. Figure 4.1 shows that if the maximum storage was provided (395,000 m^3), the pond would be substantially underutilised for 9 out of 11 years of record. It is proposed to construct storage for the 90th percentile stored volume (186,000 m^3) rather than for the maximum volume. The volume required to hold the 90th percentile stored volume is 40 % of the maximum volume required. The adoption of the 90th percentile storage volume will avoid the construction of infrastructure that is redundant for long periods of time, will take less land and will help manage costs of the scheme. As a result, some contingency discharge to other environments, most likely Donald Creek, will occur. This is described in the Main Consent Application.

4.11 Land Treatment Design Parameters

The land management characteristics used for the conceptual design are summarised in Table 4.7.

Table 4.7: Land Discharge and Management Summary

Parameter	Stage 1A	Stage 1B	Stage 2A	Stage 2B
Storage volume (m^3) – to satisfy 90th percentile flow conditions	None	None	None	186,000
Average annual outflow from FWWTP (m^3)	~830,000	~830,000	~538,000[1]	~538,000[1]
Irrigated Site	Site A	Site B (and potentially Site A)	Site B (and potentially Site A)	Site B (and potentially Site A)
Irrigation Regime	Site A: Deficit	Site A: Deficit Site B: Deferred	Site A: Deficit Site B: Deferred	Site A: Deficit Site B: Deferred
Landform	Alluvial flats	Alluvial flats	Alluvial flats	Alluvial flats
Total area (ha)	12	166-178	166-178	166-178
Irrigated area (ha)	8	70	70-116	116
Irrigated area per discharge event (ha)	8	8	8	8
Irrigation event application (mm/event)	up to 19	up to 55	up to 55	up to 55
Average annual application volume (m^3/y)[2]	32,500	385,000	305,200	510,300
Average annual application depth (mm)	406	480	360	447
Wastewater Nitrogen load (kg N/ha/y)[3]	35	42	42	51
Wastewater Phosphorus load (kg P/ha/y)[3]	7	8	8	10
Farm Management current	Stock grazing	Dairy		
Farm Management proposed	Pasture for removal (cut and carry)	Stock grazing and/or Cropping and/or Pasture for removal (cut and carry)		
Vegetation current	Pasture	Pasture		
Vegetation proposed	Pasture and/or Cropping			

For Stage 2A, I & I improvements will have reduced the available volume of wastewater and elevated its nutrient concentrations, while the lack of storage prevents irrigation of an annual application depth matching the other Stages. For Stage 2B, when the highest volume of wastewater is applied to the largest area, the irrigation application of 55 mm per event indicates the wastewater can be fully utilised with 10 passes per year on average. An average of 186 days each year meet the criteria for the application of wastewater. This means that more frequent applications of less than 55 mm per event could occur.

4.12 Drainage Water Impacts of Stage 2B

The drainage losses from the site are considered here as they relate to Stage 2B since this stage represents the largest volume and nutrient loads discharged to land and therefore the worst case for effects assessment.

The adoption of a deferred, non-deficit irrigation regime for Site B will avoid excessive drainage from the site, however there will be more drainage than would occur if there was no irrigation, or if a deficit irrigation (such as occurs currently over 70 ha of Site B) regime was used. The impact on the annual drainage volume from the site is given in Table 4.8. These drainage volumes assume that any water passing below 600 mm is considered drained, and that current irrigation on 70 ha of Site B is at 380 mm/y as a deficit regime. Both these figures are considered conservative to ensure that the effects due to drainage are not underestimated

Table 4.8: Annual Drainage from Sites A and B

ID	Area (ha)	Current		Stage 2B	
		Drainage depth (mm)	Volume (m^3)	Drainage depth (mm)	Volume (m^3)
Site A irrigated	8	705	56,453	899	71,920
Site A buffer non-irrigated	4	705	28,226	705	28,200
Site B current irrigated	70	899	629,210	1,180	826,000
Site B current non-irrigated and future expanded irrigated	46	705	324,602	1,180	542,800
Site B non-irrigated	50	705	352,500	705	352,500
Total	178	NA	1,390,991	NA	1,821,420
Increase in annual drainage		430,429 m^3 or 31 %			

Over the entire site, the drainage will increase by an estimated 31 % following the commencement of Stage 2B in an average year. For the preceding stages the change in drainage volume from the site is:

- Stage 1A – Reduction by 9 % if clean water irrigation to the currently irrigated areas of Site B cease to be irrigated;
- Stage 1B – Increase by 15 %; and
- Stage 2A – Increase by 14 %.

The increased drainage for the irrigated areas represents a depth of 450 mm/y.

4.13 Nutrient Impacts of Stage 2B

The nutrient losses from the site are considered here as they relate to Stage 2B since this stage represents the largest volume and nutrient loads discharged to land and therefore the worst case for effects assessment.

4.13.1 Nitrogen Losses

The nitrogen losses via leaching have been evaluated using a monthly nitrogen balance for the current land use and for Stage 2B. Tables 4.9 and 4.10 give nitrogen leaching estimates for the site. The nitrogen leaching estimates assume that supplementation of nitrogen from wastewater will be needed i.e. the nitrogen loading includes both wastewater nitrogen and fertiliser application.

Table 4.9: Nitrogen Leaching Losses From Stage 2B

ID	Area (ha)	Management	N Loading (kg N/ha/y)	N Leached	
				(kg N/ha/y)	(kg N/y)
Site A	8	Cut & Carry	295	14.5	116
Site B	116	Grazed Pasture	301	36.6	4,251
Non-irrigated	54	Grazed Pasture	90	14.1	763
Totals	**178**				**5,130**
Averages			**237**	**28.8**	

The leached nitrogen is equivalent to 12 % of the applied nitrogen from all sources. Based on the Stage 2B discharge to land being 90 % of the treated wastewater produced by Featherston, and assuming that all leached nitrogen eventually enters the surface water environment, then the land application results in a substantial reduction of wastewater nitrogen currently discharged to surface water (quantified in Mott Macdonald, 2017b). There is likely to be additional attenuation of nitrogen in the groundwater environment prior to reaching surface water and so the reduction in nitrogen reaching surface water is expected to be greater than that described here.

A further consideration is the change in management of the farm (Site A and B combined) from dairy pasture to wastewater irrigated land. Table 4.10 shows the impact on leaching losses from the site. Leaching losses predicted under the existing land management are based on conservative leaching values expected for the land management (dairying and livestock grazing) currently practiced.

Table 4.10: Leaching Losses from Existing Land-use and at Stage 2B

Stage 2B Leaching Estimate			
Landuse	**Area (ha)**	**N Leached (kg N/ha/y)**	**Total N Leached (kg N/y)**
Site A, Site B and non-irrigated	178	14.1 to 36.6	5,130
Total Post-development	**178**		**5,130**

Existing Management Leaching Estimate			
Landuse	**Area (ha)**	**N Leached (kg N/ha/y)**	**Total N Leached (kg N/y)**
Run-off (Site A)	12	12	144
Dairy Farm	166	28	4,648
Total Pre-development	**178**		**4,792**

Post-development - Pre-development *(Percent change in nitrogen leaching load from site)*	**7%**

Nitrogen leaching losses are predicted to increase by 7 % compared to the existing land use and farm management. It should be noted that, while there is a net increase in nitrogen leached from the Site, there is actually a significant reduction in the nitrogen entering the water catchment due to the removal of direct discharge of wastewater to surface water.

4.13.2 Phosphorus Losses

The primary mechanism for phosphorus loss is via overland flow, which will be avoided on the Site by the maintenance of suitable buffers from waterways. Plant requirements for phosphorus is in the order of 130-160 kg P/ha/y if cut and carry pasture is grown, or 52-64 kg P/ha/y if grazed pasture is maintained on the Site. For all Stages the annual phosphorus loading will be removed from the Site through plant uptake.

The soils of the Site (both Site A and Site B) have low to medium phosphorus retention (19-35 %). The soil' s capacity for sorbing phosphorus is likely to be 500-900 mg/kg of soil. This equates to 2,400-4,320 kg/ha of P storage for 0.4 m of soil depth. The low rate of phosphorus application will result in plant uptake, with soil sorption likely to be negligible. As such, the site life for phosphorus is unlimited under the proposed application regime.

5 ASSESSMENT OF EFFECTS

5.1 General

This section provides an assessment of the effects of the discharge of treated wastewater to land as described in Section 4 against the receiving environment as described in Section 3.

5.2 Summary of Effects

Environmental risks arising from discharges depend on three major factors, as follows:

- Source and type of contaminant;
- Migration pathways; and
- Receptors.

If one of these factors is absent, then the potential risk is greatly reduced.

The activity that may produce actual or potential effects on the environment that needs to be considered relates to the discharge to land of treated wastewater.

The treated wastewater to be irrigated onto the Site will have the following properties of potential environmental concern:

- Organic material, expressed as carbonaceous biochemical oxygen demand ($CBOD_5$);
- Nitrogen (N as ammoniacal nitrogen (NH_4-N) and nitrite/nitrate nitrogen (NO_x-N));
- Total phosphorus (TP);
- Pathogens; and
- Water.

Actual or potential effects upon the environment are considered as:

- Effects of the discharge on the soil;
- Effects of the discharge on groundwater quality;
- Effects of the discharge on surface water quality;
- Effects of the discharge on habitats;
- Effects of the discharge on amenity, community, cultural and heritage values; and
- Effects of the discharge on air quality.

There will be no effects that are not capable of satisfactory avoidance, remediation or mitigation. The individual effects concluded from the assessments completed are all no more than minor. This conclusion is detailed in the following sections. A risk summary of the potential and actual effects from the FWWTP wastewater is given in Table 5.1.

Table 5.1: Potential Risk and Actual Effects from Wastewater

		Source / Contaminant				
		Sensitivity	Organic matter Nitrogen Phosphorus	Pathogens	Water	Wastewater
Receptor / Pathway / Vector	Soil	Potential risk	Low	Moderate	High	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Groundwater	Potential risk	High	High	Moderate	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Surface water	Potential risk	High	Low	Low	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Habitat	Potential risk	High	Moderate	Moderate	-
		Actual effect	Less than minor	Less than minor	Less than minor	-
	Amenity	Potential risk	-	-	-	High
		Actual effect	-	-	-	Less than minor
	Cultural	Potential risk	-	-	-	High
		Actual effect	-	-	-	Less than minor
	Archaeological/ Heritage	Potential risk	-	-	-	Moderate
		Actual effect	-	-	-	Less than minor
	Air	Potential risk	Moderate	High	Moderate	-
		Actual effect	Less than minor	Less than minor	Less than minor	-

5.3 Receiving Environment

The initial environment to receive the discharge of treated wastewater is the soil and plant system of the Site. If the treated wastewater is not retained or renovated in the soil it may travel to shallow groundwater, or by overland flow to local surface water at rates that could potentially generate adverse effects (albeit smaller effects than the current discharge directly into Donald Creek).

5.4 Sensitivity of the Receiving Environment

The land application areas themselves are not sensitive to wastewater irrigation, and the application of treated wastewater can be managed to ensure it will not adversely affect farming operations.

The main receiving environment of potential concern is Donald Creek. Any discharge from the Site to the creek would be via drainage to groundwater which eventually reaches the creek. Donald Creek is already subject to significant nutrient inputs not related to the Project or the Site. If treated wastewater reaches the creek, it will do so having passed through the plants, soil, and groundwater resulting in removal of contaminants. While leaching will be minimised by diligent design and management, it is expected that some contaminant leaching will still occur. However, the proposed discharge to land and its potential leaching through the soils is a big improvement on water quality compared to the effect of the current 100 % direct discharge to Donald Creek.

5.5 Effects of the Discharges on Soil and Plants

The treated wastewater will be applied at a rate equivalent to a maximum application depth per application event of 55 mm. The impact of the discharge on the soil and plant system relates to the potential for a reduction in soil quality which would reduce the future land use options for the Site, and potential for loss of productivity leading to poor plant growth on the Site. These are discussed below with regard to the contaminants of concern identified in Section 5.2 above.

5.5.1 Effect of Water on Soil Structure

Soil structure refers to the size and distribution of soil particles and void spaces (pores) in the soil. It is important since it controls the rate at which water can be infiltrated into and drained from the soil, and the amount of water that can be retained in the soil. In addition, the distribution of pores influences the aeration of the soil. If the soil structure is degraded, drainage and root passage becomes impeded which leads to increased risks for ponding, a loss of productivity and reduction in soil quality.

Irrigation has the potential to initiate soil structural degradation if not sustainably managed. If soil is allowed to remain at a high soil moisture content or saturation for a prolonged period damage to soil structure may occur by:

- Pugging due to animal traffic on wet soils (if stock included);
- Mechanical damage by cultivation or vehicle traffic on wet soils; and
- Chemical and biological damage to structure by treated wastewater constituents or microbial action in anoxic conditions due to saturated conditions.

The methods to avoid adverse effects due to water on the soil over the Site are:

- The selection of a site whose soils are dominated by gravelly subsoils;
- Application rates per event which are 3 to 6 times less than the soil unsaturated hydraulic conductivity when applications are at the maximum proposed 55 mm per event;
- A return time of at least 8 days to enable wetting and drying cycles to occur;
- Exclusion of stock for at least 2 days from the last irrigation event; and
- Withholding of irrigation when rainfall, flooding or other prolonged wetness occurs.

The depth of treated wastewater to be applied in any event has been designed to meet industry best practice for wastewater irrigation and is based on the actual measured hydraulic properties of the soil on the Site. Application to land is to be halted during periods of wet weather to ensure that the additive effect of treated wastewater plus rainfall does not cause prolonged soil wetness or excessive drainage. It is considered that the effect of the hydraulic component of treated wastewater application on the soil will be no more than minor.

5.5.2 Effect of Cations on Soil Structure

Typically, the risk of cations on soil structure refers to the ratio of sodium to other cations in the soil. Sodium has not been tested in the F WWTP discharge, however a typical value would be in the order of 100 g/m^3 for municipal wastewater. This is low compared to industrial wastes.

The clay component may disperse if sodium accumulates in the soil causing soil structure to weaken. The effects of sodium on soil structure are considered to be negligible for the Site because:

- Sodium content of FWWTP wastewater is relatively low; and

- Natural rainfall at the site is sufficiently high to flush accumulated sodium from the soil profile.

The effect of wastewater derived cations on the soil of the site is considered to be less than minor.

5.5.3 Effect of Organic Material on Soil and Plants

Potential adverse effects of organic material, measured as $CBOD_5$, on soil and plants of the site include the generation of anaerobic conditions in the soil as oxygen is consumed. If this is not properly managed this could cause production of surface bioslimes with the associated problems of:

- Soil pore blockage, leading to reduced soil infiltration capacity;
- Plant die off;
- Degraded visual appearance;
- Production of odour; and
- Degradation of soil structure.

Over time the addition of organic carbon and nutrients associated with the wastewater application will increase the organic carbon in the topsoil. This results in an increase in the soil quality and production from these areas.

A healthy soil environment can assimilate up to 600 kg BOD/ha/d (NZLTC, 2000). The proposed consent conditions include a 90th percentile BOD of the wastewater of 35 g/m^3. The equivalent loading of BOD to be applied by the system is:

- 19.2 kg BOD/ha/application event (at 55 mm/event). This equates to 192 kg BOD/ha/y for an average year at a 90th percentile BOD.

These rates are well within the capacity of a healthy soil, so the effects of BOD on soil and plants within the proposed application area are expected to be less than minor.

5.5.4 Effect of Nitrogen on Soil and Plants

Potential adverse effects of high nitrogen loading on soil and plants may include:

- Oversupply of nitrogen in excess of plant requirements, leading to leaching to groundwater and drainage to surface water; and
- Plant damage due to high ammonia.

Much of the N will be removed by soil microbe use, plant uptake, short-term soil storage and gaseous losses (volatilisation and denitrification). A level of ammonia volatilisation has been shown to occur as a result of the spraying action during irrigation. This can result in the removal of 2 to 5 % and up to 15 % of total N (Myers et al, 1999) depending on its chemical form, ambient conditions and irrigation operation.

The proposed depth of application of treated wastewater is up to 55 mm/event throughout the year, for an annual volume of up to 5,210 m^3/ha/y, depending on the management regime. The land treatment area is 116 ha in size and is predominantly covered with pasture. In future a range of crops could be grown. Following the commencement of Stage 2B the proposed loading of N to the site from wastewater is on average 51 kg N/ha/y for an average year. The pasture is capable of removing 186 - 437 kg N/ha/y from the effluent as explained in Barton et.al (2005). Despite the low nitrogen loading rate, limited leaching may still occur due to the function of natural systems (inhomogeneity, rainfall extremes, etc.). However, the proposed conservative rates will enable a level of confidence that leaching will not be more due to wastewater irrigation, and typically will be less, than occurs under the surrounding land use that receives fertiliser application. As a result, the effects are expected to be less than minor on the soil.

There may be a need for targeted fertilisation to manage pasture or crop production, and it is proposed that up to 300 kg N/ha/y from all sources may be applied. This results in up to 249 kg N/ha/y applied from additional sources in an average year. It should be noted that the application of this mass of nitrogen is not a requirement, instead it is assessed to determine the effects of this rate (300 kg N/ha/y), to allow SWDC flexibility to manage the site as a productive unit. If there is a need for additional nitrogen due to the production of a crop with a high nitrogen requirement, then a nutrient management plan demonstrating how the nitrogen application is matched to plant requirements will be prepared.

As described in Section 4.13.1, with the inclusion of nitrogen from other sources, up to 300 kg N/ha/y the estimated nitrogen leaching from the Site increases by 7 % from the current land use. This is the equivalent of 1.9 kg N/ha/y which is expected to cause a negligible change to the groundwater nitrogen concentration.

A nitrogen application rate of 300 kg N/ha/y is not unusual for a well producing dairy farm where there is regular removal of actively growing crops. The current land use is dairy farming, and so the proposed nitrogen loading is in keeping with the existing land use, especially if there is to be a regular cropping programme. The supplementary nutrients will be applied in accordance with best practice (Fertiliser Association, 2013) to minimise losses. The effects of this additional nitrogen will be positive for the soil and plant system by allowing maximum growth. The impact of this greater loading, whether it be more wastewater or synthetic fertiliser will result in adverse effects that are less than minor for soil and plants. The implication for water ways is discussed in Sections 5.6.3 and 5.7.2.

5.5.5 Effect of Phosphorus on Soil and Plants

The treated wastewater contains phosphorus, which is an essential nutrient for plant growth and microbial activity. The risk from P is predominantly due to the effects if it reaches surface water, causing nuisance growths in streams and rivers.

The proposed phosphorus loading to the Site at Stage 2B is on average 10 kg P/ha/y. This rate is low for a productive system. At the proposed rate of application, it is expected that soil fertility and plant production will benefit from the irrigation of the treated wastewater. Soil transformation and plant uptake of the applied P is expected to match (and exceed) the rate of application. The impact on ground and surface water is discussed in subsequent sections. Because all the applied phosphorus is able to be utilised by plants, a site life for phosphorus is unlimited.

As for nitrogen, there may be a need for supplementary phosphorus fertilisation for the site. Application of phosphatic fertilisers can be well controlled using soil tests to predict the plant requirement and to identify if excess phosphorus is present in the soil. Adverse effects on soil and plants due to phosphorus from treated wastewater application are considered to be less than minor. The implication for water ways is discussed in Sections 5.6.4 and 5.7.3.

5.5.6 Effect of Pathogens on Soil and Plants

Treated wastewater has the potential to contain pathogens, as indicated by *E. coli* levels. The risk from pathogens in the soil occurs when they enter the food chain. Effects due to pathogens reaching surface or groundwater are assessed in Sections 5.6.5 and 5.7.4. In the case of FWWTP wastewater, UV treatment significantly reduces the *E.coli* levels and is the primary means for reducing risk from discharges of pathogens.

On the Site, the main mechanisms that operate within the soil matrix to ensure pathogen removal are filtration, adsorption and natural attrition. It is understood that 92 - 99.9 % of applied microbes are removed in the top 10 mm of the soil (Crane and Moore, 1984; Gunn, 1997). As shown by Aislabie *et al.* (2001) and MAF (2006) well drained soils with predominantly matrix flow and less bypass flow are very efficient removers of microbial contaminants even at application rates 2 to 5 times higher than the proposed 55 mm/event. Adoption of an application rate below the soil unsaturated hydraulic conductivity results in matrix flow thorough the soil. Matrix flow ensures maximum contact between the soil particles and bacteria, enabling adsorption and/or filtration processes to limit bacterial movement.

The greatest risk is potentially not with the soil but with stock ingesting the pathogens that have been applied. This is a farm management and animal health issue which is to be managed using stand-down periods following irrigation events. It is expected that the effect of pathogens from irrigation of treated wastewater on soil and plants will be less than minor, and the potential effects on animal health will be avoided.

5.6 Effects of the Discharges on Groundwater

Contaminants applied to the land surface by irrigation have the potential to enter groundwater. On the land treatment sites the discharge will be applied at the surface of the soil and there is the potential for treated wastewater or treated wastewater derived contaminants to leach into shallow groundwater. Contaminants in groundwater may have an effect if the groundwater is abstracted for use or if groundwater enters surface water and that surface water is used.

As indicated in Section 3, there are 7 groundwater abstractions close to the FWWTP which are downgradient from the Site. Within a 2 km boundary from the Site that includes west to the Tauherenikau River and South to Lake Wairarapa there are an additional 14 potential groundwater takes and 4 surface water takes according to GWRC.

Effects on groundwater can be significantly mitigated by adopting an appropriate irrigation regime that avoids field capacity being excessively exceeded following irrigation and the adoption of an instantaneous application rate that avoids preferential or bypass flow through large soil pores and cracks. Testing of the soil properties on the Site has been undertaken (LEI, 2014 and 2015) to develop an application rate to minimise the potential for preferential flow and loss of applied contaminants directly to groundwater.

The following discussion on the effects on groundwater also refers to a groundwater report for the Southern Featherston area that was completed in late 2006 (Tidswell, 2008). This assessment sampled nitrate, nitrite, DRP, faecal coliforms, and *E.coli*.

Overall the effects of the Project on groundwater are less than minor.

5.6.1 Effect of Water from Wastewater on Groundwater

Water applied as wastewater at the soil surface has the potential to affect groundwater by causing localised mounding of the groundwater surface. Mounding occurs if drainage from the irrigation areas reaches groundwater at a rate in excess of the ability for groundwater to move away from the site. Mounding has the potential to cause adverse effects if:

- The groundwater mound causes the direction of groundwater to change, thereby changing the groundwater properties of adjacent land users;

- A raised groundwater table reduces the aerated zone of the soil and therefore the ability to treat some applied contaminants;
- The mounding reduces the rooting zone of overlying soil; and
- The mounding causes the development of seeps or springs in low lying areas.

The primary means for avoiding effects due to mounding for the site is to apply wastewater at a frequency and rate which does not cause mounding to occur. This is achieved by applying wastewater to all sites at a rate that doesn't exceed the unsaturated hydraulic conductivity of the soil. This will avoid rapid gravitational drainage to groundwater in all conditions except the onset of high rainfall events following irrigation. The maximum application depth of 19 mm/d applied at a rate not exceeding 3 mm/h for Site A and 55 mm/d applied at a rate not exceeding 8 mm/h for Site B does not exceed the average unsaturated hydraulic conductivity for the site, which will assist to avoid excessive drainage due to irrigation events.

Investigations into the direction of groundwater flow under the site indicate that shallow groundwater flows south towards Lake Wairarapa. As a result there is potential that water applied at the northern end of the property may impact the groundwater at the southern end of the property.

The effects of water from wastewater irrigation on groundwater are expected to be minor, and able to be mitigated by the way the conceptual design can adopt different discharge regimes to avoid wet areas and accommodate different land management requirements.

Neighbouring properties are protected by drains which occur commonly in the area. Overall the effects of water from wastewater irrigation on groundwater height and movement is expected to be no more than minor.

5.6.2 Effect of Organic Material on Groundwater

Organic material (as BOD) in groundwater becomes a problem when the water reaches the surface, either through a bore for some productive use or as it reaches surface water such as Donald Creek or Lake Wairarapa. High BOD causes a reduction in dissolved oxygen, leading to anaerobic conditions. Anaerobic conditions in groundwater may result in an unpleasant taste or odour, and when groundwater enters surface water may contribute to mortality of river flora and fauna, and growth of undesirable flora and fauna.

BOD from treated wastewater irrigation will be effectively intercepted in the soil and metabolised by the soil bacteria as the wastewater percolates through the soil. BOD entering groundwater from wastewater irrigation will be negligible, and the effect of BOD on groundwater will be less than minor.

5.6.3 Effect of Nitrogen on Groundwater

As described above, it is considered that potential adverse effects of nitrogen on groundwater in this situation would become apparent when groundwater enters surface water, or when it is abstracted from a bore for use. The agronomic nitrogen application rate, predominantly applied during summer, ensures that a substantial proportion of applied nitrogen will be taken up by plants, sequestered by soil, or volatilised/denitrified.

An assessment of groundwater quality in the South Featherston report (Tidswell, 2008) found no bores with nitrate levels above the drinking water standards. Some bores did have elevated concentrations, particularly in shallow bores and were likely to be due to farming which is common in the area.

Where additional nitrogen is applied to meet plant requirements there is an increased risk of nitrogen being transported to groundwater. The amount lost to groundwater can be minimised by adopting best practice for nutrient application (Fertiliser Association, 2013). The supply of nutrients and water at a rate to meet plant needs will enable a level of confidence that leaching will not be more than occurs under the surrounding land use that receives fertiliser application and animal excreta.

The irrigation application rate set at or below the unsaturated hydraulic conductivity of the soil, plus nutrient uptake by plants and volatilisation of nitrogen is expected to result in effects from wastewater nitrogen on groundwater that are no more than minor.

The estimated change in nitrogen leaching due to conversion from dairy farming with clean water irrigation, to wastewater irrigation under mixed grazing and cropping have been evaluated as described in Section 4.13. It should be noted that this doesn't include details of the current discharge from the FWWTP since this is a direct discharge to surface water.

The change in the nitrogen lost to groundwater represents an increase of 7 % over the current land use even though when considered with discharge to surface water there is an overall large reduction in nitrogen load.

As previously described, the increase in nitrogen leached to groundwater is equivalent to around 1.9 kg N/ha/y when a total of 300 kg N/ha/y is applied. A detailed evaluation of the flow and mixing of groundwater under the site has not been undertaken, however using the groundwater parameters given in Section 3.7, and assuming a conservative mixing depth of the top 0.5 m of the groundwater, this would result in an increase of groundwater N in the order of 0.003 g/$m^{3.}$ This is near the detection limit for nitrogen analysis. As a result, the effect to groundwater users in a down-gradient position is expected to be no more than currently experienced. The effects due to the discharge of the nitrogen from groundwater to surface water are addressed in Section 5.7.2 below.

5.6.4 Effect of Phosphorus on Groundwater

Potential adverse effects from phosphorus occur when groundwater enters surface water, under which conditions it can contribute to eutrophication. This is discussed further in Section 5.7.3 below.

The mechanisms to avoid phosphorus entering groundwater are sorption to soil, incorporation into soil organic matter and plant uptake. Soils of the Site have low to medium phosphorus retention capacity meaning that soil sorption is not the primary (though still important) mechanism relied on to capture phosphorus applied in wastewater. Plant uptake and removal is the main mechanism for avoiding phosphorus loss from the soil. A grazed, irrigated pasture can be expected to remove 52-64 kg P/ha/y (Williams and Haynes, 1990), while this increases to 130-160 kg P/ha/y under cut and carry management (Morton *et al.*, 2001).

A phosphorus loading rate from wastewater following the commencement of Stage 2B for an average year will be 10 kg P/ha/y, which is likely to be entirely utilised by the plant matter. Supplementary phosphorus may be needed across the site to optimise plant growth. Under this circumstance, adverse effects to groundwater from phosphorus can be avoided by applying phosphorus at a rate which does not cause the soils Olsen P to exceed the recommended range for sedimentary soils of 20 – 30 mg P/L of soil.

Existing groundwater quality as described by Tidswell's (2008) assessment indicates low phosphorus concentrations in the groundwater at < 0.1mg/L in all bores except one. The method of applying phosphorus in irrigation water results in low mass loading occurring frequently. This will further assist to avoid loss of phosphorus in drainage water since phosphorus is applied at a rate and frequency better able to be used by the growing plants.

The amount of phosphorus entering groundwater is expected to be negligible and adverse effects due to phosphorus entering groundwater are expected to be negligible.

5.6.5 Effect of Pathogens on Groundwater

Potential adverse effects from pathogen contamination of groundwater arise from the risk to human and animal health. As described in Section 5.5.6 above, UV treatment of applied wastewater will minimise pathogen loads to the site, and the remaining pathogens will mostly perish within 10 mm of the soil surface. It is expected that the effect of pathogens from the discharge on groundwater will be negligible.

5.7 Effects of the Discharge on Surface Water Quality

Donald Creek is the surface water receiving environment for the applied treated wastewater. Treated wastewater derived contaminants have the potential to enter Donald Creek and Abbot's Creek via either surface run-off or groundwater drainage. The proposed land application system is designed to ensure that no treated wastewater enters surface water by direct run-off. Groundwater is expected to be the main source of wastewater derived contaminants to surface water. This represents a significant change for the WWTP which has traditionally 100 % discharged directly to surface water (Donald Creek).

It should be noted that this report provides an assessment of the effects to surface water associated with the land treatment of wastewater. The effects due to the direct discharge at each stage are assessed by Main AEE, Section 6.4 (2017a).

The proposed low rate of discharge to land combined with a new storage pond at the commencement of Stage 2B is intended to minimise impacts on the surface water environment from the land discharge area. Further, the use of land discharge will result in the following % removal of the current annual wastewater flows from direct surface water discharge and therefore contaminant load to the surface water environment (Donald Creek) following the commencement of each Stage of developing the land application of wastewater.:

- Stage 1A – 3 % removal;
- Stage 1B – 44 % removal;
- Stage 2A – 68 % removal; and
- Stage 2B – 94 % removal.

5.7.1 Effect of Organic Material on Surface Water

The potential adverse effect of organic material (as BOD) on surface waters is a reduction in the dissolved oxygen content of the water. This leads to stress on the ecosystem and mortality of river flora and fauna. Reducing conditions may occur in the sediment of the bed of a waterway, leading to release of nutrients into the water. Currently, with the direct discharge to surface water, BOD has been identified as adversely affecting the receiving waters in particular due to its role in the development of sewage fungus.

As described in Section 5.5.3 above, the soil of the site has ample capacity to assimilate the applied organic material. The irrigation system involves the application of treated wastewater to the surface to travel through the soil column. Applied organic material entering surface waters from groundwater will be negligible due to filtration and transformation. The potential for run-off of organic material from the site to surface water will be mitigated by avoiding the application to saturated soils near to surface water bodies and the maintenance of vegetated 20 m exclusion zones (buffers) from surface water ways.

The Project will have a highly positive effect on surface water BOD levels, significantly reducing the measurable effects of the current direct discharge on surface water.

5.7.2 Effect of Nitrogen on Surface Water

Potential adverse effects of nitrogen on surface waters may include:

- Excessive growth of nuisance aquatic plants;
- Reduction in dissolved oxygen;
- Alteration of river flow due to blockage by macrophytes;
- Change in biodiversity; and
- Reduction in recreational amenity.

The nitrogen applied to the application area is expected to be assimilated by the soil and growing plants. Leaching of nitrogen will still occur and nitrogen entering surface waters from the catchment via groundwater is described in Section 5.6.3 above. The inclusion of a vegetated 20 m buffer from water ways will assist with reducing the transport of nitrogen to surface water. Overall the use of land application of wastewater will have a positive effect on surface water nitrogen levels providing a substantial decrease (Mott Macdonald, 2017b) in the amount of nitrogen discharged to surface water from the Site and FWWTP due to the removal of the direct surface water discharge following the commencement of Stage 2B. The impact of this reduction is discussed by Main AEE, Section 6.4 (2017a).

5.7.3 Effect of Phosphorus on Surface Water

Potential adverse effects of phosphorus on surface waters are similar to those described for nitrogen above. At the proposed application rates plant uptake will account for most applied phosphorus with soil sorption accounting for a minor portion.

Run-off of phosphorus, being the main mechanism for transport to surface water, will be avoided by the inclusion of a vegetated 20 m buffer from water ways. Accordingly, it is anticipated that phosphorus entering surface waters from the land application system will be minor.

The Project will have a highly positive effect on surface water phosphorus levels as a direct result of reducing the average direct discharge volumes to surface water by 3 % at Stage 1A and 90 % following the commencement of Stage 2B. The impact of this reduction is discussed by Main AEE, Section 6.4 (2017a).

5.7.4 Effect of Pathogens on Surface Water

Pathogens may enter surface water from groundwater or flood flows. The sections above describe the mechanisms to avoid pathogen transport to surface water. If pathogens do enter surface water from the site it will be at a level which is not measurable in the receiving water (Donald Creek), and discharged at a time when levels in the river are elevated due to inputs from the upstream catchment.

Most applied pathogens are attenuated within 10 mm of the soil surface, so they are not expected to enter groundwater, much less surface water. The UV treatment process prior to land discharge also largely addresses pathogen concerns. It is expected that the effect of pathogens from the discharge to land on surface water will be less than minor.

5.8 Effects of the Discharge on Air Quality

The use of spray irrigation has the potential to influence air quality. The nearest receptors are several dwellings adjacent and within a close proximity to the Site, particularly on the northern end. Featherston township is located north west of the irrigation area with the closest distance between Site and a township dwelling being 750 m, and residential dwellings are considered to be sensitive receptors for air quality effects.

The eastern boundary of the Site is shared with the Featherston golf course that will have users sensitive to any air quality effects.

5.8.1 Aerosols and Spray Drift

The land treatment system has the potential to impact on air quality through production of aerosols generated by the spray irrigators. In order to minimize the production of aerosols and minimise spray drift, for irrigation within 125 m of the property boundary, the system pressure and nozzle size will be selected to produce droplets predominantly greater than 200 µm in size, which do not travel far and typically do not form aerosols. As existing infrastructure located greater than 125 m from the property boundary is progressively replaced the new irrigators will also be selected to produce droplets predominantly greater than 200 µm.

Some proportion of smaller droplets, which have the potential to become aerosolised, will still be produced and so the following methods for reducing spray drift effects are to be used:

- **Minimise travel distance:** Use of irrigators with large droplet sizes;
- **Buffers:** Maintenance of separation distances between irrigation and any receptors. There will be a minimum separation distance of 25 m from the irrigated area to any property boundary, 20 m separation from water ways or other sensitive environment, and 150 m separation to any existing dwelling; and
- **Wind speed cut-off:** Ceasing irrigation when the average wind speed reaches 4 m/s in the direction of dwellings within 300 m of the irrigation wetted radius, and ceasing irrigation when the average wind speed is greater than 12 m/s (occurring approximately 1 % of the time) in any direction.

As described in Section 3.8.2, the predominant wind direction is NNE with the next most common directions being NW and SW. The prevailing winds across the site are not in the direction of the township, except for the northernmost part of the Site whereby conditions under which the Site could not be irrigated occur around 6 % of the time. The irrigation can be managed to mitigate adverse effects due to irrigation of wastewater and as a result the likelihood of adverse effects due to spray irrigation is negligible.

5.8.2 Odour

Odours associated with treated wastewater irrigation are in keeping with activities and generated odours that occur in the rural surrounds. Treated municipal wastewater is low strength in comparison with a dairy shed effluent discharge which is common in the area, and occurs under the current land use of the Site.

The wastewater irrigated is in an aerobic state and typically has minor odour at the location of the discharge, and is expected to be undetectable at or beyond the property boundary. Buffer distances from property boundaries and dwellings as described in 5.8.1 above, will assist to avoid detectable odour at the property boundary.

Should there be an issue with odour, it is likely to be a result of treated wastewater having gone anaerobic in the irrigation lines during a long period between irrigation events. Should this be the case, a flushing volume of clean water will be pumped through the irrigation lines.

5.9 Summary of Effects of the Discharge

The proposed loading rate of the wastewater discharge to land will enable soil remediation and plant uptake of applied contaminants including:

- Filtration and incorporation of any suspended solids;
- Assimilation of organic material;
- Plant uptake, microbe use, and soil occlusion of nitrogen and phosphorus, and gaseous loss of nitrogen;
- Cation adsorption; and
- Filtration and attrition of pathogens.

The amounts of wastewater-applied nutrients that are likely to enter surface or groundwater are low, and their effects are expected to be less than minor.

Overall there is a significant net reduction in wastewater derived contaminants discharged to Donald Creek due to the proposed activity compared with the current 100 % direct discharge to this water way. Significant positive effects are achieved as a result of this change to a land discharge system.

There will be no effects that are not capable of satisfactory avoidance, remediation or mitigation. The individual effects concluded from the assessments completed are all no more than minor.

6 MITIGATION OF ENVIRONMENAL EFFECTS

There are a range of measures that are proposed throughout this report, which are used to mitigate or avoid adverse effects from the proposed discharge to land activity. This section summarises the mitigation measures proposed to ensure that the effects assessed can be adhered to.

6.1 Effects on Soil

The methods that have been adopted to avoid adverse effects to soils of the Site are:

- The selection of a site whose soils are dominated by gravelly subsoils;
- Application rates per event which are 3 to 6 times less than the soil unsaturated hydraulic conductivity when applications are at the maximum proposed 55 mm per event;
- A return time of at least 8 days to enable wetting and drying cycles to occur;
- Exclusion of stock for at least 2 days from the last irrigation event;
- Withholding of irrigation when rainfall, flooding or other prolonged wetness occurs;
- Stock will be rotated on a frequent basis to avoid soil damage and maintain adequate pasture cover.

6.2 Effects on Groundwater

Methods to avoid or mitigate adverse effects of the land discharge to groundwater include:

- Apply wastewater at a frequency and rate which:
    - minimises the risk of mounding, and maximises evapotranspirative loss;
    - maximises retention of nutrients in the unsaturated zone of the soil; and
    - maximises opportunities for filtration, attrition and predation of pathogens.

  This is achieved by applying wastewater to all sites at a rate that doesn't exceed the unsaturated hydraulic conductivity of the soil;
- Limiting the annual mass loading of nitrogen to 300 kg N/ha/y;
- Requiring removal of an equivalent mass of nitrogen as harvested material to be removed from Site for mass loadings above 300 kg N/ha/y.

6.3 Effects on Surface Water

The primary means for mitigating any adverse effect to surface water from the FWWTP is the progressive reduction in direct discharge to water (Donald Creek), and the implementation of adequate buffer distances from all open water including drains. Additional measures to mitigate any effect due to discharge from groundwater of wastewater derived contaminants to surface water are:

- Areas likely to have a connection to surface water will be fenced to exclude stock;
- During Stages 1A, 1B and 2A, the application of wastewater to land will be prioritised over the discharge to water i.e. if it is possible to discharge to land it will occur; and
- Following the commencement of Stage 2B, where a contingency discharge to surface water is required to manage storage, the discharge will target flows in Donald Creek greater than three times the median flow, with some discharge occurring at flows above two times the median flow (detailed in the Main AEE, Mott MacDonald, 2017a).

6.4 Effects on Air Quality

The mitigation methods to avoid adverse effects to air quality due to discharges from the irrigation of wastewater are:

- Treatment of wastewater to reduce *e.coli* levels to a median of 100 cfu/100 mL;
- Adoption of separation distances, being:
    - 25 m from property boundaries;
    - 150m from the nearest residential buildings, public place and amenity area where people congregate, or education facility;
    - 50m separation distance from the sites of cultural significance known to exist at the time of developing the concept design;
    - 50 m from rare habitats, threatened habitats or at-risk habitats; and
    - 20m from surface water including Donald Creek, Abbots Creek and all internal drains.
- The irrigation Site is located in a down-wind position from the township based on the predominant wind directions;
- The selection of an irrigation system (system pressure and nozzle size) to produce droplets greater than 200 µm in size to limit spray drift; and
- Automatic shut-down of irrigation when wind speed reaches an average of 4 m/s in the direction of dwellings within 300 m of the irrigation wetted radius, and shut-down of irrigation when wind speed reaches an average of 12 m/s in any direction.

7 CONCLUSIONS

The discharge of treated wastewater from FWWTP directly to surface water is understood to be having an adverse effect on the water quality and habitat values of Donald Creek. SWDC has purchased land to enable the development of a land application scheme for wastewater for FWWTP. The establishment of land treatment will result in a reduction in wastewater discharged to Donald Creek at each stage of the upgrade. Upon commencement of Stage 2B, 90 % removal of the current discharge of treated wastewater to Donald Creek will be achieved.

The assessment of effects has determined that the proposed loading rate of the wastewater discharge to land will enable soil remediation and plant uptake of applied contaminants including:

- Filtration and incorporation of any suspended solids;
- Assimilation of organic material;
- Plant uptake, microbe use, and soil occlusion of nitrogen and phosphorus, and gaseous loss of nitrogen;
- Cation adsorption; and
- Filtration and attrition of pathogens.

The assessment leads to the conclusion that the amounts of wastewater-applied nutrients that are likely to enter surface or groundwater are low, and their effects are expected to be less than minor. Overall there is a significant net reduction in wastewater derived contaminants discharged to Donald Creek due to the proposed activity compared with the current 100 % direct discharge to this water way. Significant positive effects are achieved as a result of this change to a land discharge system.

There will be no effects that are not capable of satisfactory avoidance, remediation or mitigation. The individual effects concluded from the assessments completed are all no more than minor. A risk summary of the potential and actual effects from the FWWTP wastewater is given in Table 6.1.

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